Triumph at SATURN

Part One

JPL and the Space Age

1
00:00:09,241 --> 00:00:12,512
- [Narrator] Ask someone to
draw a picture of a planet,

2
00:00:12,512 --> 00:00:14,647
and odds are it
will be this one.

3
00:00:16,749 --> 00:00:19,551
It is the sixth planet
out from the sun

4
00:00:19,551 --> 00:00:22,188
and the second-largest
in our solar system.

5
00:00:23,556 --> 00:00:26,225
It is, of course, Saturn,

6
00:00:26,225 --> 00:00:29,829
a world encircled not
only in majestic rings

7
00:00:29,829 --> 00:00:32,431
but in an array of moons
that have been likened

8
00:00:32,431 --> 00:00:34,601
to a solar system in miniature.

9
00:00:37,870 --> 00:00:41,374
(rocket boosters roaring)

10
00:00:43,276 --> 00:00:47,179
In 1997, an international
mission was launched to Saturn

11
00:00:47,179 --> 00:00:49,782
that would, for the first time,

12
00:00:49,782 --> 00:00:53,652
attempt to place an orbiting
spacecraft around the planet

13
00:00:53,652 --> 00:00:57,957
and land a probe on a moon
in the outer solar system.

14
00:00:59,959 --> 00:01:02,161
But this was a
mission that had to

15
00:01:02,161 --> 00:01:04,130
fight its way to the launch pad.

16
00:01:05,632 --> 00:01:06,899
- [Lew] We're going
to have to operate

17
00:01:06,899 --> 00:01:08,567
under a very strict
fund ceiling,

18
00:01:08,567 --> 00:01:11,270
one that is imposed by Congress.

19
00:01:11,270 --> 00:01:13,973
- [Casini] This will
require doing business

20
00:01:13,973 --> 00:01:17,510
in a drastically different
way than we've done before.

21
00:01:17,510 --> 00:01:21,381
- [Bob] It took a lotta
time, a lotta negotiating,

22

00:01:21,381 --> 00:01:24,284
a lot of compromises
to make that work.

23
00:01:24,284 --> 00:01:27,186
- [Julie] The first time I
saw the spacecraft together

24
00:01:27,186 --> 00:01:29,722
when we stacked without
the blankets, we were just,

25
00:01:29,722 --> 00:01:32,425
we were without words
standing out there.

26
00:01:32,425 --> 00:01:34,226
- [Narrator] The
journey to Saturn

27
00:01:34,226 --> 00:01:36,596
would take seven long years,

28
00:01:36,596 --> 00:01:41,134
but the success, or failure,
of being captured into orbit

29
00:01:41,134 --> 00:01:45,872
depended on what would happen
during just three hours.

30
00:01:47,172 --> 00:01:49,141
- [Charles] The
engine better fire,

31
00:01:49,141 --> 00:01:51,711
otherwise we'll
end with a flyby.

32
00:01:51,711 --> 00:01:52,545

- Copy.

33
00:01:52,545 --> 00:01:53,980
DCS Fault Protection.

34
00:01:53,980 --> 00:01:56,048
- [Linda] I think
as a ring scientist,

35
00:01:56,048 --> 00:01:58,318
my greatest concern
was really crossing

36
00:01:58,318 --> 00:02:00,520
through that gap in
the F and G rings.

37
00:02:00,520 --> 00:02:04,356
It would only have taken
one marble sized particle

38
00:02:04,356 --> 00:02:06,792
in the wrong place
in the spacecraft

39
00:02:06,792 --> 00:02:09,329
to perhaps have
ended the mission.

40
00:02:09,329 --> 00:02:11,964
- [Man] So I would lie in
bed at night and think about

41
00:02:11,964 --> 00:02:14,166
what other tests should we do?

42
00:02:14,166 --> 00:02:16,735
What other question
should I be asking?

43
00:02:16,735 --> 00:02:19,672
What should we be poking out
here that we haven't done yet?

44
00:02:20,973 --> 00:02:23,376
- [Julie] We chased
everything that could go wrong

45
00:02:23,376 --> 00:02:24,677
down the rabbit hole.

46
00:02:24,677 --> 00:02:26,946
We went down every path
of, if this goes wrong,

47
00:02:29,782 --> 00:02:28,147
what do we do?

48
00:02:29,782 --> 00:02:31,417
- [Earl] And this was
one of those moments

49
00:02:31,417 --> 00:02:33,452
where you're either in orbit

50
00:02:33,452 --> 00:02:35,555
or you're a billion
dollar flyby.

51
00:02:35,555 --> 00:02:37,656
- [Todd] Closest approach
is just a little over

52
00:02:37,656 --> 00:02:39,092
two minutes away.

53
00:02:39,092 --> 00:02:42,728
Predicted temps today,
-226 degrees Fahrenheit,

54
00:02:42,728 --> 00:02:45,031
winds of 1100 miles per hour.

55
00:02:45,031 --> 00:02:47,800
Hurricanes the
size of the Earth.

56
00:02:47,800 --> 00:02:50,236
Cassini would do well to
batten down the hatches.

57
00:03:14,593 --> 00:03:16,662
- [Narrator] Saturn
was once but a single

58
00:03:16,662 --> 00:03:19,098
bright point of light
in the night sky,

59
00:03:20,633 --> 00:03:24,170
but in 1610 Galileo peered
through his telescope

60
00:03:24,170 --> 00:03:26,072
and saw something else.

61
00:03:27,706 --> 00:03:29,408
On either side of the planet,

62
00:03:29,408 --> 00:03:31,644
he thought there might be moons.

63
00:03:34,847 --> 00:03:37,884
Two years later,
Galileo looked again.

64
00:03:39,752 --> 00:03:43,389
To his astonishment, the

two objects had disappeared.

65
00:03:46,592 --> 00:03:49,895
Another two years
passed and Galileo again

66
00:03:49,895 --> 00:03:51,931
trained his telescope on Saturn.

67
00:03:54,033 --> 00:03:56,669
The puzzling bulges
had returned.

68
00:03:58,704 --> 00:04:01,741
This drawing shows
how close Galileo came

69
00:04:01,741 --> 00:04:02,909
to solving the riddle,

70
00:04:04,510 --> 00:04:08,548
but he went to his grave
without ever knowing the answer.

71
00:04:10,649 --> 00:04:13,786
A half century would pass
before the Dutch scientist

72
00:04:13,786 --> 00:04:17,790
Christiaan Huygens realized
the bulges were rings.

73
00:04:19,658 --> 00:04:23,162
As for their appearing
and disappearing,

74
00:04:24,497 --> 00:04:27,666
when the rings are
viewed from Earth edge on,

75
00:04:27,666 --> 00:04:29,269
they all but disappear.

76
00:04:32,604 --> 00:04:36,776
As time passed, Saturn
came into closer focus,

77
00:04:38,610 --> 00:04:42,881
and in 1979, NASA's
Pioneer 11 spacecraft

78
00:04:42,881 --> 00:04:45,584
gave the world the
first closeup look

79
00:04:45,584 --> 00:04:48,187
at the planet and its rings.

80
00:04:50,623 --> 00:04:54,727
- We received several
pictures yesterday afternoon

81
00:04:54,727 --> 00:04:58,731
and evening, and we'd like to
run through some of those now.

82
00:04:58,731 --> 00:05:01,133
This is the one
that came in here

83
00:05:01,133 --> 00:05:03,636
at about three o'clock
yesterday afternoon.

84
00:05:03,636 --> 00:05:06,773
This is by far the most
spectacular picture

85
00:05:06,773 --> 00:05:08,007

that we have so far.

86
00:05:09,274 --> 00:05:10,810
This is raw data.

87
00:05:10,810 --> 00:05:12,912
It has not been
processed in any way.

88
00:05:14,314 --> 00:05:17,683
We can see the big banded
planet and, of course,

89
00:05:17,683 --> 00:05:20,853
the ring system is very
prominent in this picture.

90
00:05:20,853 --> 00:05:25,057
Also prominent is Saturn's
largest moon, Titan,

91
00:05:25,057 --> 00:05:26,659
in the upper right-hand corner.

92
00:05:30,396 --> 00:05:33,566
- [Narrator] The two Voyager
flybys soon followed,

93
00:05:35,334 --> 00:05:39,439
offering even more captivating
views and discoveries.

94
00:05:41,173 --> 00:05:43,876
What these missions
found left scientists

95
00:05:43,876 --> 00:05:47,680
clamoring to go again,
and not just to pass by,

96
00:05:47,680 --> 00:05:49,349
but to stay.

97
00:05:50,616 --> 00:05:53,652
A blueprint and even
some spare parts

98
00:05:53,652 --> 00:05:56,689
for just such an
adventure already existed.

99
00:05:57,623 --> 00:05:59,525
NASA's Galileo mission,

100
00:05:59,525 --> 00:06:02,861
that sent an orbiter
and a probe to Jupiter.

101
00:06:02,861 --> 00:06:05,765
Advocates in Europe
and the United States

102
00:06:05,765 --> 00:06:09,135
argued for a similar
mission destined for Saturn,

103
00:06:09,135 --> 00:06:12,238
one composed of an
international consortium.

104
00:06:14,039 --> 00:06:16,709
How such a project with
all its complexities

105
00:06:16,709 --> 00:06:19,511
could be done, no
one really knew.

106
00:06:19,511 --> 00:06:24,049

Sorting out roles,
responsibilities, and
especially funding,

107
00:06:24,049 --> 00:06:26,552
took the better
part of a decade.

108
00:06:28,187 --> 00:06:32,090
The European Space Agency
offered to build the probe,

109
00:06:32,090 --> 00:06:36,361
named Huygens, to land
on Saturn's moon Titan.

110
00:06:36,361 --> 00:06:39,432
The Italian Space Agency
would build the main antenna

111
00:06:39,432 --> 00:06:41,100
and communication system.

112
00:06:42,268 --> 00:06:45,671
The spacecraft thrusters
and the main engines

113
00:06:45,671 --> 00:06:48,941
would be provided by US
commercial space companies.

114
00:06:51,009 --> 00:06:54,913
And NASA's Jet Propulsion
Laboratory signed on

115
00:06:54,913 --> 00:06:56,882
to build and fly the spacecraft,

116
00:06:56,882 --> 00:06:59,551
to be named in honor

of the 17th century

117
00:06:59,551 --> 00:07:02,722
astronomer Giovanni Cassini.

118
00:07:04,823 --> 00:07:08,561
JPL would also provide overall
management of the mission.

119
00:07:09,728 --> 00:07:13,232
In total, 19 countries
would provide hardware,

120
00:07:13,232 --> 00:07:17,036
while scientists would
come from 26 nations.

121
00:07:17,036 --> 00:07:18,270
- Good morning.

122
00:07:18,270 --> 00:07:20,172
I wanna welcome
all of you to JPL,

123
00:07:20,172 --> 00:07:21,874
and at the beginning of
what is gonna be clearly

124
00:07:21,874 --> 00:07:23,909
a very exciting mission.

125
00:07:23,909 --> 00:07:26,078
I know that a lot
of you have a...

126
00:07:26,078 --> 00:07:27,646
- [Narrator] This is
the first gathering

127

00:07:27,646 --> 00:07:30,949
of Cassini Huygens
scientists and engineers,

128
00:07:30,949 --> 00:07:34,753
their goal to transform
this complex partnership

129
00:07:34,753 --> 00:07:37,489
into a functioning team.

130
00:07:37,489 --> 00:07:40,559
- Our Congress has had some
agony over the program.

131
00:07:40,559 --> 00:07:43,428
For a time it looked
as though only Cassini

132
00:07:43,428 --> 00:07:45,397
would be approved.

133
00:07:45,397 --> 00:07:48,400
- [Narrator] There are
layers of unease in the room.

134
00:07:48,400 --> 00:07:50,236
The Europeans want to
know that they'll be

135
00:07:50,236 --> 00:07:52,771
treated as equal partners.

136
00:07:52,771 --> 00:07:56,709
And there are also concerns
about US reliability,

137
00:07:56,709 --> 00:07:59,144
given that NASA has
recently dropped out

138
00:07:59,144 --> 00:08:00,612
of another partnership.

139
00:08:00,612 --> 00:08:01,880
- We're going to have to operate

140
00:08:01,880 --> 00:08:03,515
under a very strict
fund ceiling,

141
00:08:03,515 --> 00:08:08,153
one that is imposed by Congress
and an unyielding schedule.

142
00:08:08,153 --> 00:08:09,721
And we all have
great challenges-

143
00:08:09,721 --> 00:08:11,290
- [Narrator] NASA
has already warned

144
00:08:11,290 --> 00:08:12,858
that the mission
will be canceled

145
00:08:12,858 --> 00:08:15,361
if the project strays
over its budget.

146
00:08:16,762 --> 00:08:20,366
All eyes are on Cassini's
first program manager,

147
00:08:20,366 --> 00:08:24,035
John Casani, who has already
spoken of eliminating

148

00:08:24,035 --> 00:08:26,339
some of the science instruments.

149
00:08:26,339 --> 00:08:29,342
- Seriously like to
welcome everybody.

150
00:08:29,342 --> 00:08:30,575
Nice to be here.

151
00:08:30,575 --> 00:08:32,945
A lot of old friends,
a lot of new faces,

152
00:08:32,945 --> 00:08:34,947
which I hope we'll be
friends before we're through

153
00:08:34,947 --> 00:08:36,682
with this process.

154
00:08:36,682 --> 00:08:39,051
But those of you
who don't know me,

155
00:08:39,051 --> 00:08:44,056
will find out a lot in
the next couple of years.

156
00:08:45,390 --> 00:08:48,927
This will require doing
business in a fairly drastically

157
00:08:48,927 --> 00:08:51,463
different way than
we've done before.

158
00:08:51,463 --> 00:08:53,198
We are all gonna
have to strive for,

159
00:08:53,198 --> 00:08:56,668
as we go through this process,
is a continual search,

160
00:08:56,668 --> 00:08:59,338
as my old friend Gentry
Lee used to like to say,

161
00:08:59,338 --> 00:09:01,073
for the least
unacceptable solution.

162
00:09:01,073 --> 00:09:03,242
There are gonna have
to be compromises.

163
00:09:03,242 --> 00:09:05,044
We wanna work with you.

164
00:09:05,044 --> 00:09:08,313
- [Narrator] This was not what
scientists had hoped to hear.

165
00:09:08,313 --> 00:09:11,216
- I think this is a
very severe degrade

166
00:09:11,216 --> 00:09:12,918
in the capabilities
of this mission.

167
00:09:12,918 --> 00:09:14,853
- What we did was we
did all of these things

168
00:09:14,853 --> 00:09:17,523
to finally get down to
something that we could afford.

169
00:09:17,523 --> 00:09:19,792
- That sounds to me like
a very unwise thing to do.

170
00:09:19,792 --> 00:09:22,628
I mean, the essence of this
mission is to get data back.

171
00:09:24,063 --> 00:09:25,998
- [Narrator] The friction
between what scientists want

172
00:09:25,998 --> 00:09:29,101
and what engineers
can do will be a theme

173
00:09:29,101 --> 00:09:31,537
running throughout the
lifetime of the mission.

174
00:09:32,671 --> 00:09:35,307
So, we'll be deciding
which of Cassini's

175
00:09:35,307 --> 00:09:38,810
12 different science
instruments will have priority

176
00:09:38,810 --> 00:09:40,413
at any given time.

177
00:09:41,614 --> 00:09:44,583
First up to plead
his case is the head

178
00:09:44,583 --> 00:09:48,688
of the science radar
team, Charles Elachi.

179

00:09:48,688 --> 00:09:49,922
- Good morning.

180
00:09:49,922 --> 00:09:51,657
I understand from Dennis
that the first speaker

181
00:09:51,657 --> 00:09:53,159
gets everything he asks for.

182
00:09:57,329 --> 00:09:59,865
There is a good thing and a
bad thing about the radar.

183
00:09:59,865 --> 00:10:03,068
The good thing is that
for every Saturn orbit,

184
00:10:03,068 --> 00:10:05,137
we need to operate
only for one hour.

185
00:10:05,137 --> 00:10:07,707
You can have all the rest
of the time, but one hour.

186
00:10:08,907 --> 00:10:10,409
The bad thing is that
when we turn it on,

187
00:10:10,409 --> 00:10:12,244
the lights on the
spacecraft will dim,

188
00:10:12,244 --> 00:10:14,279
you know, it'll go down.

189
00:10:14,279 --> 00:10:16,615
- [Narrator] Representing
the needs of the imaging team

190
00:10:16,615 --> 00:10:19,151
is its leader, Carolyn Porco.

191
00:10:19,151 --> 00:10:20,786
- Rates which are
lower than that.

192
00:10:20,786 --> 00:10:22,454
After all, we know
what it will take

193
00:10:22,454 --> 00:10:24,756
to image the objects at Saturn,

194
00:10:24,756 --> 00:10:26,225
that we know are there.

195
00:10:26,225 --> 00:10:29,628
My question is, what is it
that's there that we don't know

196
00:10:29,628 --> 00:10:32,498
and we want to have a
very stable platform

197
00:10:32,498 --> 00:10:34,499
and be able to do
long exposures.

198
00:10:34,499 --> 00:10:36,168
These are issues
that ring scientists

199
00:10:36,168 --> 00:10:37,670
stay up late at
night worrying about.

200
00:10:37,670 --> 00:10:39,204

- We are running a
bit behind schedule

201
00:10:39,204 --> 00:10:40,706
so we shall skip
the coffee break,

202
00:10:40,706 --> 00:10:43,875
but there is still coffee
for those who can't survive.

203
00:10:43,875 --> 00:10:45,377
- [Narrator] One after another,

204
00:10:45,377 --> 00:10:48,180
the science teams take to the
podium to make their pitches

205
00:10:48,180 --> 00:10:51,617
and at times to express
their displeasure.

206
00:10:53,118 --> 00:10:56,455
- Okay, this is one
of the smaller teams,

207
00:10:56,455 --> 00:10:59,391
and I suppose one of
the smaller instruments,

208
00:10:59,391 --> 00:11:03,161
although perhaps not as small
as the project might like.

209
00:11:03,161 --> 00:11:07,232
I'm afraid I have to
say that we have to have

210
00:11:07,232 --> 00:11:09,568
an instrument that performs best

211
00:11:09,568 --> 00:11:12,304
within the planetary
environment.

212
00:11:12,304 --> 00:11:15,040
So life is not as
simple as perhaps

213
00:11:15,040 --> 00:11:16,876
some people have seen it.

214
00:11:18,109 --> 00:11:20,713
- The other challenge
that we've had here

215
00:11:20,713 --> 00:11:23,916
is a recognition over the
past few months that the...

216
00:11:23,916 --> 00:11:26,318
- [Narrator] Hoping to
resolve these conflicts,

217
00:11:26,318 --> 00:11:28,854
Casani offers up
an unexpected plan

218
00:11:28,854 --> 00:11:32,191
to put the scientists
more in control.

219
00:11:32,191 --> 00:11:36,628
- We need to incentivize
you to do the best job

220
00:11:36,628 --> 00:11:39,865
of making the best estimates
of what it's gonna cost

221
00:11:39,865 --> 00:11:41,267
at the time of confirmation.

222
00:11:42,434 --> 00:11:43,869
- [Narrator] Instead of
having decisions made

223
00:11:43,869 --> 00:11:45,337
from the top down,

224
00:11:45,337 --> 00:11:48,641
Casani proposes establishing
a trading system.

225
00:11:48,641 --> 00:11:52,311
Each science team will be given
a defined amount of money,

226
00:11:52,311 --> 00:11:55,180
mass, power and data rates.

227
00:11:55,180 --> 00:11:57,649
If later they need
more of anything,

228
00:11:57,649 --> 00:11:59,885
they will have to work
with the other teams

229
00:11:59,885 --> 00:12:01,720
to solve their problem.

230
00:12:01,720 --> 00:12:05,925
The scientists agree to this
unusual bartering system.

231
00:12:05,925 --> 00:12:08,527
It is the first major
step in building

232
00:12:08,527 --> 00:12:11,030
a functioning
international team.

233
00:12:11,030 --> 00:12:12,797
- Any questions?

234
00:12:12,797 --> 00:12:14,400
All right, Dennis, thank you.

235
00:12:36,722 --> 00:12:38,657
- [Narrator] By
the fall of 1997,

236
00:12:38,657 --> 00:12:40,992
what had once been
just blueprints

237
00:12:40,992 --> 00:12:43,295
are now real pieces of hardware.

238
00:12:45,130 --> 00:12:47,332
For over the last six years,

239
00:12:47,332 --> 00:12:50,636
the mission has managed
to survive being canceled,

240
00:12:50,636 --> 00:12:52,638
something another
NASA spacecraft

241
00:12:52,638 --> 00:12:55,574
meant to rendezvous with
a comet and an asteroid,

242
00:12:55,574 --> 00:12:57,209
was unable to do.

243
00:12:59,378 --> 00:13:02,447
This was part of a new
NASA strategy to cut back

244
00:13:02,447 --> 00:13:04,749
on large and
expensive spacecraft.

245
00:13:04,749 --> 00:13:08,754
And there was no
disguising Cassini's size.

246
00:13:08,754 --> 00:13:10,355
It remains, to this day,

247
00:13:10,355 --> 00:13:14,493
the largest US interplanetary
spacecraft ever built.

248
00:13:14,493 --> 00:13:17,730
Standing three stories
tall, when fully loaded,

249
00:13:17,730 --> 00:13:20,966
it will weigh 12 and a
half thousand pounds.

250
00:13:22,868 --> 00:13:25,137
- The first time I saw
the spacecraft together,

251
00:13:25,137 --> 00:13:27,138
when we stacked
without the blankets,

252
00:13:27,138 --> 00:13:30,609
I must have stood in the
visitor gallery for 30 minutes.

253
00:13:30,609 --> 00:13:34,747
And it's... I don't
know how to describe it.

254
00:13:34,747 --> 00:13:36,815
It's not yours
anymore, you know.

255
00:13:36,815 --> 00:13:40,119
Even though I had been
intimate with each piece

256
00:13:40,119 --> 00:13:42,221
and part of that spacecraft
and put it together

257
00:13:42,221 --> 00:13:44,823
wire by wire and
in part by part,

258
00:13:44,823 --> 00:13:48,993
to watch it come together as
a whole entity was incredible.

259
00:13:48,993 --> 00:13:51,030
We were without words
standing out there.

260
00:13:53,498 --> 00:13:55,533
- Every now and then
we'll be working in here

261
00:13:55,533 --> 00:13:58,070
and you'll think, wow,
this is going to Saturn

262
00:13:58,070 --> 00:14:01,540
and this probe is
gonna land on Titan.

263
00:14:01,540 --> 00:14:03,976
And this is going
somewhere where we've never

264
00:14:03,976 --> 00:14:07,146
seen things before and you
get goosebumps from it.

265
00:14:08,446 --> 00:14:10,415
- [Narrator] The spacecraft
has been designed

266
00:14:10,415 --> 00:14:12,718
with redundancy as a priority.

267
00:14:12,718 --> 00:14:16,187
Each critical system
has an identical backup.

268
00:14:16,187 --> 00:14:19,858
And its advanced software
will allow the spacecraft

269
00:14:19,858 --> 00:14:22,161
at times to fly on its own,

270
00:14:22,161 --> 00:14:25,397
and even self-repair
computer glitches.

271
00:14:29,001 --> 00:14:34,006
In Cassini's interior are
some 22,000 wire connections

272
00:14:35,174 --> 00:14:37,243
and more than seven
miles of cabling.

273
00:14:38,409 --> 00:14:41,380

- I'm technically an
engineering assistant,

274
00:14:41,380 --> 00:14:44,883
and what I do is cabling
for the spacecraft

275
00:14:44,883 --> 00:14:46,785
and I've been doing
it for 20 years.

276
00:14:49,855 --> 00:14:53,759
One of the really positive
points about our mechanical team

277
00:14:53,759 --> 00:14:57,996
is that they never say no.

278
00:14:57,996 --> 00:14:59,964
They never seem to tire.

279
00:14:59,964 --> 00:15:01,767
They're always up.

280
00:15:01,767 --> 00:15:05,037
(chuckles) I don't think we
could ask for a better team.

281
00:15:13,378 --> 00:15:15,314
- [Narrator] One of
the last assembly tasks

282
00:15:15,314 --> 00:15:19,718
is to cover this bare
spacecraft with blankets.

283
00:15:22,721 --> 00:15:25,990
Using machines more often
used for fine tailoring

284
00:15:25,990 --> 00:15:27,959
than engineering,

285
00:15:27,959 --> 00:15:31,029
this reflective material is
cut to protect the spacecraft

286
00:15:31,029 --> 00:15:34,967
early in the mission, when
it flies toward the sun.

287
00:15:37,669 --> 00:15:40,238
This black fabric
will do the opposite,

288
00:15:40,238 --> 00:15:43,609
absorbing and retaining
heat out at Saturn,

289
00:15:43,609 --> 00:15:47,212
where sunlight is only 1%
the strength found at Earth.

290
00:15:48,380 --> 00:15:50,415
The layers will also
provide shielding

291
00:15:50,415 --> 00:15:52,217
from micro meteoroids,

292
00:15:52,217 --> 00:15:55,320
tiny particles of
dust that could damage

293
00:15:55,320 --> 00:15:57,389
the spacecraft's electronics.

294
00:16:01,259 --> 00:16:02,761
This is tedious work,

295
00:16:02,761 --> 00:16:06,030
cutting, stitching
and fitting hundreds

296
00:16:06,030 --> 00:16:08,534
of individually measured pieces.

297
00:16:09,635 --> 00:16:12,337
It is a job made
even more challenging

298
00:16:12,337 --> 00:16:14,706
knowing that this
intricate space quilt,

299
00:16:14,706 --> 00:16:17,576
like all of Cassini's
major components,

300
00:16:17,576 --> 00:16:20,646
will have to be unmounted
for shipping to Florida,

301
00:16:20,646 --> 00:16:23,782
where everything will
be reassembled again.

302
00:16:25,617 --> 00:16:27,119
- We have had less
problem with this

303
00:16:27,119 --> 00:16:30,288
than I can remember having
on any other spacecraft.

304
00:16:30,288 --> 00:16:31,824
It's almost scary.

305

00:16:31,824 --> 00:16:33,692
It's just beautiful.

306
00:16:33,692 --> 00:16:34,960
No problems.

307
00:16:34,960 --> 00:16:36,729
No major problems anyway.

308
00:16:41,599 --> 00:16:44,269
- [Narrator] While transforming
Cassini from a blueprint

309
00:16:44,269 --> 00:16:47,639
into a real spacecraft had
gone exceptionally well,

310
00:16:47,639 --> 00:16:51,143
getting to the final
design had been torturous.

311
00:16:54,145 --> 00:16:57,316
Facing budget cuts,
the project was forced

312
00:16:57,316 --> 00:17:00,719
to make another least
unacceptable decision.

313
00:17:01,920 --> 00:17:04,556
Instead of dropping
science instruments,

314
00:17:04,556 --> 00:17:08,126
the spacecraft itself was
scaled back by eliminating

315
00:17:08,126 --> 00:17:09,762
the scan platform,

316
00:17:09,762 --> 00:17:13,065
a kind of turntable
required by some instruments

317
00:17:13,065 --> 00:17:14,666
needing motion.

318
00:17:14,666 --> 00:17:17,202
Without the platform,
the entire spacecraft

319
00:17:17,202 --> 00:17:19,838
will have to rotate
to aim at targets,

320
00:17:19,838 --> 00:17:23,509
resulting also in
less observation time.

321
00:17:23,509 --> 00:17:27,179
But all of the science
instruments have survived.

322
00:17:39,524 --> 00:17:41,693
Operations are now
almost complete

323
00:17:41,693 --> 00:17:44,296
for the launch of
Cassini Huygens.

324
00:17:44,296 --> 00:17:46,665
Already on the launch
pad is the Air Force's

325
00:17:46,665 --> 00:17:49,368
heavy lifting Titan 4B

326
00:17:54,606 --> 00:17:57,176

Cassini and the probe
have been reassembled.

327
00:17:58,309 --> 00:18:00,612
One of the last
procedures involves

328
00:18:00,612 --> 00:18:03,916
loading onto the spacecraft
its power supply,

329
00:18:03,916 --> 00:18:06,751
72 pounds of
plutonium encased in

330
00:18:06,751 --> 00:18:11,089
what are called radio isotope
thermoelectric generators,

331
00:18:11,089 --> 00:18:15,027
or mercifully called
for short RTGs.

332
00:18:19,197 --> 00:18:22,668
RTGs have been used
on previous missions,

333
00:18:24,035 --> 00:18:27,072
but recent nuclear
power plant accidents

334
00:18:27,072 --> 00:18:29,942
and the loss of the
Space Shuttle Challenger

335
00:18:29,942 --> 00:18:32,544
have heightened public
fears of a launch accident

336
00:18:32,544 --> 00:18:34,446

spreading nuclear debris.

337
00:18:38,850 --> 00:18:41,152
Hoping to stop the launch,

338
00:18:41,152 --> 00:18:44,856
anti-nuclear groups
file lawsuits, petition
the White House,

339
00:18:44,856 --> 00:18:48,494
and hold demonstrations at
the Kennedy Space Center.

340
00:18:49,995 --> 00:18:52,964
- Since this is the last public
forum to ensure the public

341
00:18:52,964 --> 00:18:54,999
that everything is
going to be all right,

342
00:18:54,999 --> 00:18:56,501
could you do that one last time

343
00:18:56,501 --> 00:18:58,669
and use your best
argument to persuade,

344
00:18:58,669 --> 00:19:00,605
perhaps, some of your opponents?

345
00:19:00,605 --> 00:19:02,975
- RTGs were designed
for accident conditions.

346
00:19:02,975 --> 00:19:04,309
We've designed them,
we've tested them,

347
00:19:04,309 --> 00:19:06,210
we've analyzed for
it, we've gone through

348
00:19:06,210 --> 00:19:08,079
a very lengthy review process.

349
00:19:08,079 --> 00:19:11,049
And in fact, these
are very safe to use.

350
00:19:11,049 --> 00:19:12,416
There's not a risk
to the public,

351
00:19:12,416 --> 00:19:14,186
even if there is an accident.

352
00:19:14,186 --> 00:19:16,988
- Would you all confirm
your faith in this mission

353
00:19:16,988 --> 00:19:21,592
by telling us how many
family members, kids,

354
00:19:21,592 --> 00:19:26,231
and grandkids you have here
watching this launch with you?

355
00:19:26,231 --> 00:19:29,400
- Well, I have 30 members
of my family here right now,

356
00:19:29,400 --> 00:19:31,636
including my two granddaughters.

357
00:19:31,636 --> 00:19:33,105
There's more on the way.

358
00:19:34,072 --> 00:19:36,041
(crowd laughing)

359
00:19:36,041 --> 00:19:38,243
I don't know if I have more
grandchildren on the way,

360
00:19:38,243 --> 00:19:41,446
but I have more
family on the way.

361
00:19:41,446 --> 00:19:45,783
The reality is there's no
technology on the horizon

362
00:19:45,783 --> 00:19:49,120
that has the promise
to be available

363
00:19:49,120 --> 00:19:51,723
in the foreseeable future at all

364
00:19:51,723 --> 00:19:54,793
that could be used
for feigning power

365
00:19:54,793 --> 00:19:56,361
way in outer space,

366
00:19:56,361 --> 00:19:59,297
where there is effectively
very little sunlight.

367
00:19:59,297 --> 00:20:03,968
At Saturn, we've got a 1% of
what we have here on Earth.

368
00:20:03,968 --> 00:20:05,503

We know Cassini is safe.

369
00:20:05,503 --> 00:20:10,475
The generator is designed to
be robust in the environments.

370
00:20:11,376 --> 00:20:14,112
We do not rely on success.

371
00:20:14,112 --> 00:20:17,415
We make it compatible
with the environments

372
00:20:17,415 --> 00:20:20,285
that might be generated
and it's safe.

373
00:20:20,285 --> 00:20:22,888
I invited everyone I
love to the launch.

374
00:20:22,888 --> 00:20:24,122
- [Man] Will there
be information

375
00:20:24,122 --> 00:20:25,557
on the success of
this launch too?

376
00:20:25,557 --> 00:20:26,625
- Absolutley.

377
00:20:27,993 --> 00:20:30,195
You can find us with a bottle
of champagne some place.

378
00:20:35,600 --> 00:20:38,436
- [Man] FLC, we have
325 and 326 complete.

379
00:20:38,436 --> 00:20:39,338
Roger.

380
00:20:42,741 --> 00:20:46,911
- [Man] EA and LCC
327 and 328 on time.

381
00:20:46,911 --> 00:20:48,546
Roger.

382
00:20:48,546 --> 00:20:50,482
- [Woman] LCC, roger.

383
00:20:50,482 --> 00:20:51,816
- [Man] The Air Force
launch controller

384
00:20:51,816 --> 00:20:53,117
has given a clear to launch.

385
00:20:53,117 --> 00:20:55,186
We've got to go from the range

386
00:20:55,186 --> 00:20:58,089
to proceed with the countdown.

387
00:20:58,089 --> 00:21:00,158
- [Woman] Launch
sequence started.

388
00:21:01,159 --> 00:21:02,160
- [Man] T minus 10,

389
00:21:03,461 --> 00:21:04,929
nine,

390
00:21:04,929 --> 00:21:05,763
eight,

391
00:21:05,763 --> 00:21:06,865
seven,

392
00:21:06,865 --> 00:21:08,099
six,

393
00:21:08,099 --> 00:21:09,200
five,

394
00:21:09,200 --> 00:21:10,101
four,

395
00:21:10,101 --> 00:21:11,102
three,

396
00:21:11,102 --> 00:21:12,270
two,

397
00:21:12,270 --> 00:21:13,571
one,

398
00:21:13,571 --> 00:21:15,807
and liftoff of the
Cassini spacecraft

399
00:21:15,807 --> 00:21:18,343
on a billion mile
trek to Saturn.

400
00:21:19,411 --> 00:21:21,012
(cheering)

401
00:21:21,012 --> 00:21:22,914
Pitch program is in.

402
00:21:22,914 --> 00:21:26,518
(man talking indistinctly)

403
00:21:28,553 --> 00:21:30,455
- [Man] We have
cleared the tower

404
00:21:30,455 --> 00:21:33,325
and the Cassini spacecraft
is on its way to Saturn.

405
00:21:34,493 --> 00:21:35,761
T+20 seconds.

406
00:21:35,761 --> 00:21:37,095
All systems are go.

407
00:21:43,635 --> 00:21:46,705
Standing by for solid
rocket booster separation.

408
00:21:52,110 --> 00:21:55,580
And the solid rocket boosters
have been jettisoned.

409
00:21:55,580 --> 00:21:58,950
- [Man] Item 149 and 150.

410
00:21:58,950 --> 00:22:00,118
- [Man] All systems go.

411
00:22:15,567 --> 00:22:18,403
- [Man] All CAS core
stations, ops engineer,

412
00:22:18,403 --> 00:22:20,605
launch vehicle reports
payload fairing jettisoned.

413
00:22:34,119 --> 00:22:37,689
- This launch was, for all

practical purposes, perfect.

414
00:22:39,090 --> 00:22:41,259
It was just right on target.

415
00:22:41,259 --> 00:22:44,328
And the navigation
corrections that we normally,

416
00:22:44,328 --> 00:22:45,964
routinely expect to have to make

417
00:22:45,964 --> 00:22:49,234
for these kinds of
launches was very small.

418
00:22:49,234 --> 00:22:51,236
It was an exceptionally
good launch.

419
00:22:54,839 --> 00:22:57,475
- [Narrator] But the
launch, as good as it was,

420
00:22:57,475 --> 00:23:01,413
was not powerful enough to send
Cassini directly to Saturn.

421
00:23:06,151 --> 00:23:09,186
To get there, mission
designers had long before

422
00:23:09,186 --> 00:23:12,223
devised a flight path,
using mother nature

423
00:23:12,223 --> 00:23:16,527
to gain extra boosts of
speed by flying by planets,

424
00:23:16,527 --> 00:23:19,598
what are called gravity assists.

425
00:23:19,598 --> 00:23:23,368
Cassini's route required two
inward swing bys at Venus,

426
00:23:23,368 --> 00:23:26,805
next back to Earth,
then outward to Jupiter,

427
00:23:27,973 --> 00:23:30,975
and finally on to Saturn.

428
00:23:30,975 --> 00:23:34,245
In all, a journey of
over 2 billion miles,

429
00:23:34,245 --> 00:23:36,982
lasting nearly seven years.

430
00:23:43,455 --> 00:23:45,757
During the first
Venus encounter,

431
00:23:45,757 --> 00:23:49,594
Cassini grazed just above
the planet's surface,

432
00:23:49,594 --> 00:23:53,832
gaining an extra 16,000
miles per hour of speed.

433
00:23:58,069 --> 00:24:01,106
- The Cassini spacecraft
has now been in space,

434
00:24:01,106 --> 00:24:03,974
in flight, for a little

over eight months.

435
00:24:03,974 --> 00:24:06,244
And the performance of
the spacecraft has been

436
00:24:06,244 --> 00:24:08,146
essentially flawless.

437
00:24:08,146 --> 00:24:11,282
Typically on spacecraft like
this, of this complexity,

438
00:24:11,282 --> 00:24:15,153
there are issues, complications
of one sort or another,

439
00:24:15,153 --> 00:24:18,423
that we have to work with
some of our ground-based

440
00:24:18,423 --> 00:24:19,925
command capability.

441
00:24:19,925 --> 00:24:23,060
For the Cassini spacecraft,
this just hasn't happened.

442
00:24:23,060 --> 00:24:24,963
It's a remarkable spacecraft.

443
00:24:27,332 --> 00:24:28,833
- [Narrator] True enough,

444
00:24:28,833 --> 00:24:32,604
but Cassini is not yet a
fully complete spacecraft.

445
00:24:35,240 --> 00:24:38,609

- We had enough flight
software on board at launch

446
00:24:38,609 --> 00:24:41,812
to be able to fly the
spacecraft, operate
it, navigate it,

447
00:24:41,812 --> 00:24:44,616
and not a whole
lot more than that.

448
00:24:45,784 --> 00:24:48,252
- When we launched,
we had seven years

449
00:24:48,252 --> 00:24:50,589
to get to Saturn and we actually

450
00:24:50,589 --> 00:24:55,594
completely changed out the
computer system twice in flight.

451
00:24:56,728 --> 00:24:58,930
We would take the
old computer software

452
00:24:58,930 --> 00:25:02,533
and then load up the new
software in the backup computer,

453
00:25:02,533 --> 00:25:04,402
watch it for a while,
make sure it was stable.

454
00:25:04,402 --> 00:25:06,905
And then we would swap
and make the backup

455
00:25:06,905 --> 00:25:07,872

the prime computer.

456
00:25:07,872 --> 00:25:10,007
Make sure it was stable.

457
00:25:10,007 --> 00:25:12,444
- [Narrator] As engineers
worked on completing

458
00:25:12,444 --> 00:25:15,746
Cassini's software,
scientists started lobbying

459
00:25:15,746 --> 00:25:17,282
to begin using their instruments

460
00:25:17,282 --> 00:25:20,285
far ahead of the
agreed upon schedule.

461
00:25:21,953 --> 00:25:23,555
- The cartoon.

462
00:25:23,555 --> 00:25:24,922
You gotta see the cartoon.

463
00:25:24,922 --> 00:25:26,424
You gotta see the whole thing.

464
00:25:26,424 --> 00:25:29,961
So the idle spacecraft is
the devil's playground.

465
00:25:30,995 --> 00:25:32,263
For the first three years,

466
00:25:32,263 --> 00:25:34,265
we weren't supposed
to do anything.

467
00:25:34,265 --> 00:25:36,567
We were supposed to fly a rock.

468
00:25:36,567 --> 00:25:39,771
And we were just
gonna go take this,

469
00:25:39,771 --> 00:25:43,074
take the spacecraft,
correct it engineering wise,

470
00:25:43,074 --> 00:25:45,777
fly it by Venus, a
couple of times by Earth,

471
00:25:45,777 --> 00:25:48,145
and we really weren't
gonna do much science.

472
00:25:48,145 --> 00:25:50,181
And here were the
scientists saying,

473
00:25:50,181 --> 00:25:51,916
"You've got this
great spacecraft,

474
00:25:51,916 --> 00:25:54,752
everything's working on it,
you don't have to check...

475
00:25:54,752 --> 00:25:56,454
You know, you don't have
to redo your thermal.

476
00:25:56,454 --> 00:25:58,522
You don't have to redo this.

477

00:25:58,522 --> 00:26:00,292
Let's do science."

478
00:26:01,493 --> 00:26:06,263
And so I came in one day
and this was on my door.

479
00:26:06,263 --> 00:26:08,667
The idle spacecraft is
the devil's playground.

480
00:26:10,068 --> 00:26:13,571
I swore for years that
one of the scientists

481
00:26:13,571 --> 00:26:15,173
had put that on my door.

482
00:26:15,173 --> 00:26:16,507
It was my boss.

483
00:26:16,507 --> 00:26:18,109
He put that on my door.

484
00:26:27,051 --> 00:26:28,253
- [Narrator] For the most part,

485
00:26:28,253 --> 00:26:30,521
the scientists
were accommodated,

486
00:26:30,521 --> 00:26:32,556
but the project's
priority was first

487
00:26:32,556 --> 00:26:34,793
getting safely past the Earth,

488
00:26:34,793 --> 00:26:37,862

which occurred in
the summer of 1999,

489
00:26:37,862 --> 00:26:41,866
giving Cassini another 12,000
miles per hour of speed.

490
00:26:47,805 --> 00:26:51,342
The next milestones were
passing beyond the orbit of Mars

491
00:26:51,342 --> 00:26:53,311
and the region of
the asteroid belt.

492
00:27:01,118 --> 00:27:02,621
Then came Jupiter,

493
00:27:03,654 --> 00:27:06,191
where Cassini saw raging storms,

494
00:27:06,191 --> 00:27:08,193
some centuries old.

495
00:27:09,594 --> 00:27:13,598
Cassini also teamed up with the
venerable Galileo spacecraft

496
00:27:13,598 --> 00:27:16,768
to jointly measure
Jupiter's magnetosphere,

497
00:27:16,768 --> 00:27:19,370
a bubble of charged
particles trapped

498
00:27:19,370 --> 00:27:22,140
within the planet's
magnetic field.

499
00:27:23,274 --> 00:27:27,345
At closest approach,
Cassini took this image.

500
00:27:27,345 --> 00:27:31,883
At that time, the most detailed
view of Jupiter ever seen.

501
00:27:44,662 --> 00:27:47,698
The Jupiter encounter served
as a full dress rehearsal

502
00:27:47,698 --> 00:27:49,334
for what awaited at Saturn.

503
00:27:50,502 --> 00:27:52,103
It revealed there
was work to be done

504
00:27:52,103 --> 00:27:55,306
in addressing Cassini's
design compromise.

505
00:27:55,306 --> 00:27:58,209
The lack of the scan platform
that would have allowed

506
00:27:58,209 --> 00:28:00,812
simultaneous use of
science instruments,

507
00:28:00,812 --> 00:28:04,382
needing either to move
or to be rock steady.

508
00:28:06,517 --> 00:28:08,419
- It meant you had to
turn the spacecraft

509

00:28:08,419 --> 00:28:11,356
every time you wanted to
point an instrument someplace.

510
00:28:11,356 --> 00:28:14,158
And we had 12 instruments,

511
00:28:14,158 --> 00:28:16,794
and each instrument
generally had

512
00:28:16,794 --> 00:28:19,830
different pointing
druthers, if not in fact,

513
00:28:19,830 --> 00:28:22,233
hard and fast
pointing requirements.

514
00:28:22,233 --> 00:28:24,936
And so there was an
awful lot of negotiation

515
00:28:24,936 --> 00:28:27,872
that went on between the
different science teams,

516
00:28:27,872 --> 00:28:30,875
the different instrument
representatives,

517
00:28:30,875 --> 00:28:33,043
in deciding who was
gonna get to control

518
00:28:33,043 --> 00:28:35,480
the pointing of the
spacecraft when.

519
00:28:35,480 --> 00:28:38,917

It took a lot of time,
a lot of negotiating,

520
00:28:38,917 --> 00:28:41,686
a lot of compromises
to make that work.

521
00:28:45,289 --> 00:28:46,958
- [Narrator] Despite
this restraint,

522
00:28:46,958 --> 00:28:49,760
Cassini could now boast
of being the most capable

523
00:28:49,760 --> 00:28:52,763
interplanetary
spacecraft ever sent out

524
00:28:52,763 --> 00:28:54,199
into the solar system.

525
00:29:13,918 --> 00:29:16,888
After a journey of
nearly seven years,

526
00:29:16,888 --> 00:29:21,425
Cassini and the Huygens probe
are nearing Saturn's doorstep.

527
00:29:21,425 --> 00:29:24,395
Whether two decades
of dreaming, planning,

528
00:29:24,395 --> 00:29:27,765
building, and undertaking
this arduous journey

529
00:29:27,765 --> 00:29:31,269
will be rewarded,

will soon be known.

530
00:29:31,269 --> 00:29:34,438
For just ahead is the
most dangerous moment

531
00:29:34,438 --> 00:29:36,607
that Cassini will face.

532
00:29:36,607 --> 00:29:38,442
SOI.

533
00:29:38,442 --> 00:29:40,445
Saturn Orbit Insertion.

534
00:29:43,380 --> 00:29:47,385
No one is more excited, or
anxious, about this moment

535
00:29:47,385 --> 00:29:49,553
than Charles Elachi.

536
00:29:49,553 --> 00:29:52,256
In addition to still
being the team lead

537
00:29:52,256 --> 00:29:54,458
for Cassini's radar experiment,

538
00:29:54,458 --> 00:29:56,160
he now heads JPL.

539
00:29:56,160 --> 00:30:00,098
- Cassini is probably one of
the most exciting missions

540
00:30:00,098 --> 00:30:05,103
ever undertaken by the US
and it deserves more credit.

541
00:30:06,304 --> 00:30:08,739
So when we come to
the orbit insertion,

542
00:30:08,739 --> 00:30:11,242
after advocating
for it, selling it,

543
00:30:11,242 --> 00:30:14,278
building it and flying it,

544
00:30:14,278 --> 00:30:17,182
it was a really very
sobering moment.

545
00:30:18,783 --> 00:30:23,454
The engine better
fire, otherwise we'll
end with a fly by.

546
00:30:24,922 --> 00:30:27,958
You have to remember that
we had the Mars Observer,

547
00:30:27,958 --> 00:30:31,062
where when we turned on the
engine, the thing disappeared.

548
00:30:33,730 --> 00:30:35,633
- [Narrator] 11 years before,

549
00:30:35,633 --> 00:30:38,302
as Mars Observer was
approaching Mars,

550
00:30:38,302 --> 00:30:40,971
the spacecraft was
commanded to pressurize

551
00:30:40,971 --> 00:30:42,473
its propulsion system.

552
00:30:43,908 --> 00:30:47,045
The spacecraft was
never heard from again.

553
00:30:49,780 --> 00:30:53,117
It's believed a massive rupture
in the fuel lines occurred,

554
00:30:53,117 --> 00:30:57,021
putting the spacecraft
into an unrecoverable spin.

555
00:31:02,159 --> 00:31:04,095
We have about 15, 20 minutes.

556
00:31:04,095 --> 00:31:06,731
This is Bob Mitchell, who
is the project manager.

557
00:31:08,165 --> 00:31:10,501
- Okay, well, I think
we've got what'll be

558
00:31:10,501 --> 00:31:13,037
a rather interesting
program laid out here

559
00:31:13,037 --> 00:31:14,304
for you this evening.

560
00:31:14,304 --> 00:31:16,974
Certainly gonna have
a little drama to it.

561
00:31:16,974 --> 00:31:21,880
I was kinda confident, but

I was worried, concerned.

562
00:31:23,314 --> 00:31:25,884
Nervous might be the
best word as well.

563
00:31:30,655 --> 00:31:33,157
- [Narrator] To slow down
enough to be captured

564
00:31:33,157 --> 00:31:34,758
by Saturn's gravity,

565
00:31:34,758 --> 00:31:38,296
Cassini will have to turn
on its seldom used engine

566
00:31:38,296 --> 00:31:40,564
for 96 minutes.

567
00:31:40,564 --> 00:31:43,768
Anything less could result
in flying past the planet,

568
00:31:44,736 --> 00:31:46,137
never to return.

569
00:31:50,942 --> 00:31:53,444
The flight path will take
Cassini and the probe

570
00:31:53,444 --> 00:31:57,815
up through and back down
a gap in Saturn's rings.

571
00:31:57,815 --> 00:31:59,650
There's worry that
there could be particles

572

00:31:59,650 --> 00:32:01,985
in these regions large
enough to damage,

573
00:32:01,985 --> 00:32:05,822
or even destroy, the spacecraft.

574
00:32:05,822 --> 00:32:07,591
- I think as a ring scientist,

575
00:32:07,591 --> 00:32:10,661
my greatest concern was really
crossing through that gap

576
00:32:10,661 --> 00:32:12,663
in the F and G rings.

577
00:32:12,663 --> 00:32:16,500
It would only have taken
one marble sized particle

578
00:32:16,500 --> 00:32:18,469
in the wrong place
in the spacecraft

579
00:32:18,469 --> 00:32:20,271
to perhaps have
ended the mission.

580
00:32:20,271 --> 00:32:23,307
So for me, the most,
you know, breathtaking,

581
00:32:23,307 --> 00:32:25,175
the heart stopping
time, was really

582
00:32:25,175 --> 00:32:26,878
crossing through the ring plane.

583
00:32:28,712 --> 00:32:30,514
- [Narrator] To reduce the risk,

584
00:32:30,514 --> 00:32:33,818
Cassini will fly through the
gaps with its high gain antenna

585
00:32:33,818 --> 00:32:37,154
facing forward to
act as a shield.

586
00:32:37,154 --> 00:32:39,957
During these times, the only
signal coming back to Earth

587
00:32:39,957 --> 00:32:44,661
will be from a smaller antenna
transmitting a single tone.

588
00:32:44,661 --> 00:32:47,898
The pitch, or frequency,
of the tone will vary

589
00:32:47,898 --> 00:32:50,734
with changes to the
spacecraft's speed.

590
00:32:50,734 --> 00:32:52,937
What's known as
the Doppler effect.

591
00:32:54,338 --> 00:32:57,408
This will tell engineers how
the spacecraft is performing...

592
00:32:58,409 --> 00:32:59,944
or not.

593
00:32:59,944 --> 00:33:02,379

- Zero is the
reference frequency,

594
00:33:02,379 --> 00:33:04,548
the nominal frequency
that we would see

595
00:33:04,548 --> 00:33:06,183
if there were no burn.

596
00:33:06,183 --> 00:33:07,819
So if the motor never ignited,

597
00:33:07,819 --> 00:33:10,020
what would happen
is this line up here

598
00:33:10,020 --> 00:33:12,556
would just go right
straight across.

599
00:33:12,556 --> 00:33:14,324
I would lie in bed at
night and think about

600
00:33:14,324 --> 00:33:16,894
what other tests should we do?

601
00:33:16,894 --> 00:33:19,429
What other question
should I be asking?

602
00:33:19,429 --> 00:33:22,399
What should we be poking at
here that we haven't done yet?

603
00:33:22,399 --> 00:33:25,236
And this corner right
here corresponds to

604
00:33:25,236 --> 00:33:27,104
where the burn should end.

605
00:33:27,104 --> 00:33:30,340
There wasn't any single
thing that I could point to

606
00:33:30,340 --> 00:33:32,309
and say that thing right there

607
00:33:32,309 --> 00:33:34,545
has a fair chance of biting us.

608
00:33:34,545 --> 00:33:36,346
There just wasn't
anything like that.

609
00:33:36,346 --> 00:33:40,785
But when you consider all the
things that had to happen...

610
00:33:40,785 --> 00:33:42,986
or not happen,

611
00:33:42,986 --> 00:33:46,290
there were enough of them
that the aggregate of them

612
00:33:46,290 --> 00:33:48,225
was cause for being nervous.

613
00:33:48,225 --> 00:33:49,459
And I was.

614
00:33:49,459 --> 00:33:52,697
That would be cause for
some level of concern.

615

00:33:59,170 --> 00:34:03,341
- [Julie] SOI was such a,
just such a team effort.

616
00:34:04,541 --> 00:34:06,343
We chased everything
that could go wrong

617
00:34:06,343 --> 00:34:07,611
down the rabbit hole.

618
00:34:07,611 --> 00:34:09,881
We went down every path
of, if this goes wrong,

619
00:34:12,883 --> 00:34:11,048
what do we do?

620
00:34:12,883 --> 00:34:17,889
There were 10,000 tests run to
put together that insertion.

621
00:34:22,459 --> 00:34:24,662
- Something we've
been preparing for

622
00:34:24,662 --> 00:34:28,198
for four or five years,
testing and testing,

623
00:34:28,198 --> 00:34:31,602
awfulizing all of the possible
things that could go wrong.

624
00:34:31,602 --> 00:34:35,238
And this was one of those
moments where you're either

625
00:34:35,238 --> 00:34:37,942
in orbit or you're a

billion dollar fly by.

626
00:34:46,417 --> 00:34:49,020
- Things continue to go well
in Cassini mission control.

627
00:34:49,020 --> 00:34:52,523
We're approximately 33
minutes from burn start.

628
00:34:52,523 --> 00:34:54,692
There's our flight
director, Julie Webster.

629
00:34:56,160 --> 00:34:59,163
This is one person we hope
to not hear from tonight.

630
00:34:59,163 --> 00:35:02,967
This is system fault protection
engineer, Paula Morgan.

631
00:35:02,967 --> 00:35:04,935
And if we hear from
fault protection,

632
00:35:04,935 --> 00:35:07,638
that means we've had some sort
of anomaly on the spacecraft.

633
00:35:07,638 --> 00:35:10,774
Doug Johnson, our radio
science and SOI communicator.

634
00:35:10,774 --> 00:35:13,410
He's the one reporting most of
the events we'll see tonight

635
00:35:13,410 --> 00:35:14,812
through that Doppler signal.

636
00:35:15,946 --> 00:35:19,016
- [Narrator] Also on
console is Jan Berkeley.

637
00:35:19,016 --> 00:35:22,386
She first worked at JPL
as a college intern.

638
00:35:22,386 --> 00:35:25,790
Now she's a key member
of the Cassini team

639
00:35:25,790 --> 00:35:28,158
that creates the computer
sequence commands

640
00:35:28,158 --> 00:35:30,594
that operate the spacecraft.

641
00:35:30,594 --> 00:35:32,363
- We would run them,
make sure that there were

642
00:35:32,363 --> 00:35:33,864
no problems with that.

643
00:35:33,864 --> 00:35:36,300
If we needed to do testing,
we would schedule testing.

644
00:35:36,300 --> 00:35:38,869
We were the ones that actually
sent them to the spacecraft.

645
00:35:38,869 --> 00:35:40,705
And then we watched
them clock out.

646

00:35:40,705 --> 00:35:43,040
That was the tense moment,
was not pushing the button,

647
00:35:43,040 --> 00:35:45,610
it was waiting for it to
come back, that it worked.

648
00:35:47,011 --> 00:35:50,280
And Saturn was so far away
that it would take three hours

649
00:35:50,280 --> 00:35:52,049
just to get there and come back.

650
00:35:53,216 --> 00:35:55,319
- Current speed of the
Cassini spacecraft:

651
00:35:55,319 --> 00:35:57,754
22.2 kilometers per second,

652
00:35:57,754 --> 00:36:00,290
which is just under
50,000 miles an hour.

653
00:36:00,290 --> 00:36:03,693
And increasing as Saturn's
gravity draws us in.

654
00:36:03,693 --> 00:36:07,498
That's Shin Huh, our
SOI systems engineer.

655
00:36:07,498 --> 00:36:11,102
Shin has eaten, breathed,
slept, and lived SOI

656
00:36:11,102 --> 00:36:12,670
for many years.

657
00:36:12,670 --> 00:36:15,138
Tonight is his big night.

658
00:36:15,138 --> 00:36:17,607
- All stations on
that SOI systems.

659
00:36:17,607 --> 00:36:19,410
Just an advisory, we're
coming up on the time

660
00:36:19,410 --> 00:36:21,679
for the critical sequence
will initiate the turn

661
00:36:21,679 --> 00:36:23,280
to the SOI burn attitude.

662
00:36:23,280 --> 00:36:28,019
The burn command will be sent
at 7:35:35 PM local time.

663
00:36:29,986 --> 00:36:31,521
Flight director, SOI systems,

664
00:36:31,521 --> 00:36:34,325
all subsystems report the
spacecraft data is nominal

665
00:36:34,325 --> 00:36:36,293
and ready to support SOI.

666
00:36:36,293 --> 00:36:37,528
- [Man] Okay, I copy that.

667
00:36:48,805 --> 00:36:50,408
SOI, comms flight director...

668
00:36:51,742 --> 00:36:52,777
- [Todd] We're waiting.

669
00:36:52,777 --> 00:36:53,611
- Copy telecomm

670
00:37:08,425 --> 00:37:10,160
A JPL tradition has begun,

671
00:37:10,160 --> 00:37:12,329
starting in the back of
the Mission Support Area.

672
00:37:12,329 --> 00:37:16,000
This is the consuming of
the lucky JPL peanuts.

673
00:37:24,241 --> 00:37:26,410
Doug Johnson just
reported a signal,

674
00:37:26,410 --> 00:37:28,078
we've survived the
ring plane crossing

675
00:37:28,078 --> 00:37:29,780
through the F and G rings.

676
00:37:29,780 --> 00:37:32,016
(applause)

677
00:37:35,453 --> 00:37:38,789
One hurdle down, one to go,
with the start of the burn

678
00:37:38,789 --> 00:37:40,991
a meer nine minutes away.

679

00:37:40,991 --> 00:37:43,828
- [Julie] ACE flight
director on FSL court.

680
00:37:43,828 --> 00:37:46,964
Are you still tracking
Canberra on B2?

681
00:37:48,699 --> 00:37:50,901
- [Man] That's affirmative.

682
00:37:50,901 --> 00:37:53,304
- Let's go ahead and switch
Canberra over to B-Zero.

683
00:37:59,577 --> 00:38:01,078
Go ahead, NAV-1.

684
00:38:01,078 --> 00:38:03,113
- [Man] We can confirm
that we are receiving

685
00:38:03,113 --> 00:38:04,448
one way data from the DSN.

686
00:38:05,616 --> 00:38:08,551
- [Julie] One way
Doppler from DSS14?

687
00:38:08,551 --> 00:38:10,421
- [Man] Yes, that's affirmative.

688
00:38:12,756 --> 00:38:15,292
- Navigation can also
confirm we're receiving

689
00:38:15,292 --> 00:38:16,794
the Doppler data.

690

00:38:16,794 --> 00:38:18,795
We've been able to
verify that the turn

691
00:38:18,795 --> 00:38:21,031
to the SY burn
attitude is complete.

692
00:38:21,031 --> 00:38:25,202
We're approaching two
minutes before the SOI burn.

693
00:38:25,202 --> 00:38:27,938
Hopes and dreams of
thousands of scientists

694
00:38:27,938 --> 00:38:31,241
and engineers are resting
on the next few moments.

695
00:38:31,241 --> 00:38:33,477
So Godspeed, Cassini Huygens.

696
00:38:33,477 --> 00:38:34,679
May we see you in orbit.

697
00:38:36,013 --> 00:38:37,114
- We're gonna drop in.

698
00:38:38,816 --> 00:38:40,885
- On the Doppler display,
what we're looking for

699
00:38:40,885 --> 00:38:43,887
is a turning of the corner
to start to follow that line

700
00:38:43,887 --> 00:38:45,789
down to the lower right.

701
00:38:45,789 --> 00:38:48,025
And that's our indication
the burn has begun.

702
00:38:52,263 --> 00:38:53,497
Flight, SOI comms..

703
00:38:53,497 --> 00:38:54,965
- [Julie] Go ahead.

704
00:38:54,965 --> 00:38:57,301
- [Man] We have a Doppler
signature consistent

705
00:38:57,301 --> 00:38:59,236
with engine turn on.

706
00:38:59,236 --> 00:39:02,373
(cheers and applause)

707
00:39:10,648 --> 00:39:12,349
- [Todd] Lots of high
fives and celebrations

708
00:39:12,349 --> 00:39:13,317
in mission control.

709
00:39:18,822 --> 00:39:21,125
Congratulations all of you
that have worked so hard

710
00:39:21,125 --> 00:39:21,959
for this moment.

711
00:39:26,997 --> 00:39:30,201
One minute down, about
96 minutes to go.

712

00:39:35,039 --> 00:39:37,408
We're continuing to follow
the nominal predicted curve

713
00:39:37,408 --> 00:39:38,375
on the Doppler.

714
00:39:38,375 --> 00:39:39,542
So the fact we turned the corner

715
00:39:39,542 --> 00:39:40,778
means the engine has started.

716
00:39:40,778 --> 00:39:42,246
The fact that we're
following the line

717
00:39:42,246 --> 00:39:43,881
means we're getting the right
thrust out of the engine.

718
00:39:43,881 --> 00:39:46,884
So more good news for the
Cassini Huygens spacecraft.

719
00:39:56,460 --> 00:39:57,428
- Way to go.

720
00:39:57,428 --> 00:39:58,895
Way to go.

721
00:39:58,895 --> 00:40:01,565
- [Narrator] There's now
90 minutes of waiting

722
00:40:01,565 --> 00:40:04,502
until Cassini's engine
is to stop firing.

723

00:40:04,502 --> 00:40:07,905
The lull in the action
affords a rare opportunity

724
00:40:07,905 --> 00:40:10,407
to give members of
Congress who are on hand

725
00:40:10,407 --> 00:40:13,277
a very up close
and personal tour.

726
00:40:26,557 --> 00:40:29,526
It's a moment to witness
history in the making,

727
00:40:29,526 --> 00:40:31,828
and, as politicians well-know,

728
00:40:31,828 --> 00:40:34,865
to take advantage of
an excellent photo op.

729
00:40:39,136 --> 00:40:44,141
- It's 7:42 PM in NASA's
Cassini mission control.

730
00:40:45,543 --> 00:40:49,180
The next thing we'll look
for is an occultation

731
00:40:49,180 --> 00:40:53,149
by the A ring around 8:05
PM Pacific time local.

732
00:40:53,149 --> 00:40:55,752
At that time, we'll
see an increased noise

733
00:40:55,752 --> 00:40:57,287

in the Doppler signal,

734
00:40:57,287 --> 00:41:00,624
similar to the increased
noise there at the far left

735
00:41:00,624 --> 00:41:01,991
of the Doppler plot.

736
00:41:01,991 --> 00:41:04,862
And our final scary
moment of the evening

737
00:41:04,862 --> 00:41:07,398
will be to make sure to
get the burn shut down.

738
00:41:08,865 --> 00:41:12,036
The history making day for
JPL, NASA, and the world.

739
00:41:15,372 --> 00:41:16,707
- [Man] Flight, SOI comm.

740
00:41:16,707 --> 00:41:18,275
- Go ahead, SOI comm.

741
00:41:18,275 --> 00:41:21,444
- [Man] We have hit
the A ring pretty hard.

742
00:41:21,444 --> 00:41:23,280
- All right.

743
00:41:23,280 --> 00:41:25,716
- [Todd] More good news
from SOI Comm there,

744
00:41:25,716 --> 00:41:28,719

the frightening looking
change to our Doppler data

745
00:41:28,719 --> 00:41:30,420
is totally anticipated.

746
00:41:30,420 --> 00:41:32,623
This proves that Saturn's A
ring is where we think it is.

747
00:41:32,623 --> 00:41:36,594
And the Cassini spacecraft is
where we think it is as well.

748
00:41:38,328 --> 00:41:41,932
- [Man] We're continuing to
track a two to three DB signal

749
00:41:41,932 --> 00:41:44,868
with occasional outages
through the A ring.

750
00:41:44,868 --> 00:41:46,069
And we expect to see
a nice strong signal,

751
00:41:46,069 --> 00:41:48,405
we have the main
division coming up.

752
00:41:48,405 --> 00:41:49,874
- [Julie] Copy
that, sounds good.

753
00:41:51,876 --> 00:41:55,345
(phone ringing)

754
00:41:55,345 --> 00:41:57,982
- [Todd] As we see, we're
approaching the B ring,

755
00:41:59,450 --> 00:42:01,785
and we must remember tonight,
everything happening at Saturn

756
00:42:01,785 --> 00:42:03,887
occurred an hour and
24 minutes earlier

757
00:42:03,887 --> 00:42:07,457
due to that pesky speed of
light, 186,000 miles per second,

758
00:42:07,457 --> 00:42:09,993
our interplanetary speed
limit, if you will.

759
00:42:09,993 --> 00:42:11,662
- [Julie] Go ahead SOI Comm.

760
00:42:11,662 --> 00:42:13,830
- [Man] After a brief
peak up to 11DB,

761
00:42:13,830 --> 00:42:17,067
we have now exited the division.

762
00:42:17,067 --> 00:42:18,068
- Copy.

763
00:42:18,068 --> 00:42:20,437
- [Man] What just happened?

764
00:42:20,437 --> 00:42:23,439
- They just announced
that we are now

765
00:42:23,439 --> 00:42:25,642
a captured object around Saturn.

766
00:42:25,642 --> 00:42:27,878
We are now an
orbit... an orbiter.

767
00:42:29,146 --> 00:42:31,882
- First in history
around Saturn.

768
00:42:31,882 --> 00:42:33,016
- There you go.

769
00:42:33,016 --> 00:42:34,852
First man-made
orbiter around Saturn.

770
00:42:36,052 --> 00:42:38,055
Voyager, eat your heart out.

771
00:42:39,956 --> 00:42:41,992
- [Man] SOI systems,
this is contingency.

772
00:42:43,626 --> 00:42:46,563
- Closest approach is just a
little over two minutes away.

773
00:42:46,563 --> 00:42:49,332
And given that, it's
probably about time

774
00:42:49,332 --> 00:42:52,001
for our Saturnian
weather forecast.

775
00:42:52,001 --> 00:42:55,872
Predicted temps today,
-226 degrees Fahrenheit

776

00:42:55,872 --> 00:42:58,775
or -143 degrees Celsius.

777
00:42:58,775 --> 00:43:02,146
Winds of 1100 miles
per hour or so.

778
00:43:02,146 --> 00:43:06,550
Chance of helium rain
inside the interior, 100%.

779
00:43:06,550 --> 00:43:09,086
Hurricanes the
size of the Earth.

780
00:43:09,086 --> 00:43:11,722
Cassini would do well to
batten down the hatches.

781
00:43:13,723 --> 00:43:16,859
Closest approach is
upon us with a speed

782
00:43:16,859 --> 00:43:19,296
of almost 69,000 miles per hour.

783
00:43:19,296 --> 00:43:21,765
And the speed HAS
started slowing.

784
00:43:52,196 --> 00:43:53,463
- [Man] Flight, SOI Comm.

785
00:43:53,463 --> 00:43:54,731
- [Julie] Go ahead, SOI Comm.

786
00:43:54,731 --> 00:43:57,868
- [Man] The Doppler
has flattened out.

787
00:43:57,868 --> 00:44:01,038
(cheers and applause)

788
00:44:01,038 --> 00:44:04,108
(indistinct chatter)

789
00:44:08,912 --> 00:44:11,448
- [Todd] Okay, we have
burn complete here,

790
00:44:11,448 --> 00:44:13,083
for the SOI orbit
insertion burn.

791
00:44:18,822 --> 00:44:20,790
Congratulations continue
in mission control.

792
00:44:20,790 --> 00:44:22,726
The high-fives begin in the back

793
00:44:22,726 --> 00:44:24,128
of our mission support area.

794
00:44:33,737 --> 00:44:35,706
I'm just hearing a
report from radio...

795
00:44:38,642 --> 00:44:39,809
- You did great.

796
00:44:39,809 --> 00:44:41,078
You did great.
- Thank you.

797
00:44:41,078 --> 00:44:42,345
- My pleasure.

798

00:44:42,345 --> 00:44:45,549
Here's to our lucky
propulsion engineers.

799
00:44:46,449 --> 00:44:47,651
Did a wonderful job tonight.

800
00:44:47,651 --> 00:44:49,886
- Knowing that it
survived and was there

801
00:44:49,886 --> 00:44:51,387
and we were ready to, you know,

802
00:44:51,387 --> 00:44:54,424
get to the meat of the science
and get these great images.

803
00:44:54,424 --> 00:44:55,492
It was a wonderful moment.

804
00:44:55,492 --> 00:44:56,826
The voyage begins.

805
00:44:56,826 --> 00:44:58,328
We made it, like, we did it.

806
00:45:02,466 --> 00:45:04,133
- Fantastic job.

807
00:45:04,133 --> 00:45:06,169
- Now we're gonna
put your ECAP in.

808
00:45:06,169 --> 00:45:08,439
(laughing)

809
00:45:09,939 --> 00:45:12,409
- [Todd] I was just

informed by my management,

810
00:45:12,409 --> 00:45:14,878
she'll put my performance
evaluation in.

811
00:45:14,878 --> 00:45:17,181
I'm glad she waited until
our success tonight.

812
00:45:21,285 --> 00:45:20,150
It's alive.

813
00:45:36,133 --> 00:45:38,736
(gentle music)

814
00:45:42,038 --> 00:45:44,274
- So there's this
amazing elation

815
00:45:44,274 --> 00:45:47,311
and then almost
immediately a crash,

816
00:45:47,311 --> 00:45:50,547
just because we're
exhausted and tired,

817
00:45:50,547 --> 00:45:52,015
but I couldn't sleep.

818
00:45:52,015 --> 00:45:54,217
And so I stayed in the MSA,

819
00:45:54,217 --> 00:45:59,089
and the images of the
rings were playing back,

820
00:45:59,089 --> 00:46:03,626

and slowly people started to
gather around these images,

821
00:46:03,626 --> 00:46:06,296
which no one had
seen close up images

822
00:46:06,296 --> 00:46:08,298
flying right over the
tops of the rings.

823
00:46:09,932 --> 00:46:13,870
And there were just goosebumps.

824
00:46:13,870 --> 00:46:15,739
That's a memory I
will never forget.

825
00:46:16,840 --> 00:46:21,611
- This is way more
ringlets, little pieces.

826
00:46:21,611 --> 00:46:23,713
- [Narrator] Until now,
the mission has been

827
00:46:23,713 --> 00:46:26,049
mostly the province
of engineers.

828
00:46:26,049 --> 00:46:29,786
With these first ever closeup
images of Saturn's rings,

829
00:46:29,786 --> 00:46:33,056
the shift to science
begins in earnest,

830
00:46:33,056 --> 00:46:36,626
and there are hints of

major discoveries ahead

831
00:46:36,626 --> 00:46:38,362
from what already can be seen.

832
00:46:39,529 --> 00:46:42,332
- I don't think you have
to be a ring scientist

833
00:46:42,332 --> 00:46:44,901
to imagine what last
night was for us.

834
00:46:44,901 --> 00:46:47,638
It was beyond
description really.

835
00:46:47,638 --> 00:46:49,205
It was mind blowing.

836
00:46:49,205 --> 00:46:51,708
It was every adjective
you could think of.

837
00:46:51,708 --> 00:46:55,311
I'm surprised at how
surprised I am at the beauty

838
00:46:55,311 --> 00:46:56,813
and the clarity of these images.

839
00:46:56,813 --> 00:46:59,015
They are shocking to me.

840
00:46:59,015 --> 00:47:02,519
The spacecraft allows us
a very steady platform.

841
00:47:02,519 --> 00:47:06,423

This machine, you turn it, you
point it, and it stays there.

842
00:47:06,423 --> 00:47:08,692
It's like a tripod in space.

843
00:47:08,692 --> 00:47:11,628
Anyway, I think ring scientists
are gonna have a field day.

844
00:47:11,628 --> 00:47:13,030
So thank you.

845
00:47:16,033 --> 00:47:17,134
Wow.

846
00:47:17,134 --> 00:47:19,369
(applause)

847
00:47:28,611 --> 00:47:30,781
- [Narrator] Cassini's
arrival coincided

848
00:47:30,781 --> 00:47:34,417
with a time when the planet
was well lit by sunlight,

849
00:47:34,417 --> 00:47:37,821
providing extraordinary
views of the rings.

850
00:47:39,255 --> 00:47:43,360
Saturn, plus the rings, span
about a quarter million miles,

851
00:47:43,360 --> 00:47:46,730
and they would fit in between
the Earth and its moon.

852

00:47:47,930 --> 00:47:50,433
And yet for all of
its wide expanse,

853
00:47:50,433 --> 00:47:53,470
the rings themselves
are paper thin,

854
00:47:53,470 --> 00:47:56,707
only about 10 feet thick.

855
00:47:57,874 --> 00:48:00,310
If you could scoop up
all the ring particles,

856
00:48:00,310 --> 00:48:03,213
there would be less mass
than one of Saturn's

857
00:48:03,213 --> 00:48:04,781
small moons named Mimas.

858
00:48:08,484 --> 00:48:09,820
- [Narrator] From a distance,

859
00:48:09,820 --> 00:48:12,688
the rings cast off
a sense of serenity,

860
00:48:12,688 --> 00:48:16,493
but they are as complex and
chaotic as they are beautiful.

861
00:48:17,694 --> 00:48:19,462
For they are made up
of countless numbers

862
00:48:19,462 --> 00:48:22,933
of disorderly objects of
different sizes and shapes.

863
00:48:26,136 --> 00:48:29,940
This is a simulated image
based on radar observations,

864
00:48:29,940 --> 00:48:33,143
showing particles sizes
found in different regions

865
00:48:33,143 --> 00:48:34,510
of the rings.

866
00:48:34,510 --> 00:48:36,813
The color purple
represents where there is

867
00:48:36,813 --> 00:48:40,050
a preponderance of objects
smaller than two inches.

868
00:48:40,050 --> 00:48:43,886
Particles in green are
about an inch in size.

869
00:48:43,886 --> 00:48:46,390
The blueish bands
are still smaller.

870
00:48:47,857 --> 00:48:51,261
The white bands are dense
regions that radio signals

871
00:48:51,261 --> 00:48:52,763
were unable to penetrate.

872
00:48:55,098 --> 00:48:58,335
This false color image
highlights what can be seen

873

00:48:58,335 --> 00:48:59,503
in the ultraviolet.

874
00:49:00,737 --> 00:49:03,473
The turquoise colors
represent water ice.

875
00:49:03,473 --> 00:49:07,010
The red colors are a
different kind of particle.

876
00:49:07,010 --> 00:49:09,146
Uncertain as to
what it might be,

877
00:49:09,146 --> 00:49:12,082
the scientists decided
to name it dirt.

878
00:49:13,283 --> 00:49:15,318
- Cassini was also
able to measure

879
00:49:15,318 --> 00:49:17,788
the temperature of
the ring particles,

880
00:49:17,788 --> 00:49:21,291
and the rings that had
the most dirt or pollution

881
00:49:21,291 --> 00:49:26,162
were slightly warmer than
the bright icy rings.

882
00:49:26,162 --> 00:49:28,097
- [Narrator] And,
despite being made of

883
00:49:28,097 --> 00:49:30,299

mostly cosmic dust and ice,

884
00:49:30,299 --> 00:49:34,637
the rings contained some
structures as large as a house.

885
00:49:34,637 --> 00:49:38,174
And as scientists discovered
to their astonishment,

886
00:49:38,174 --> 00:49:40,944
even transitory mountains.

887
00:49:40,944 --> 00:49:44,080
- There is a unique moment
in the Cassini mission

888
00:49:44,080 --> 00:49:46,550
where the sun was
edge onto the rings,

889
00:49:46,550 --> 00:49:49,352
and that allowed us to see
anything that would stick up

890
00:49:49,352 --> 00:49:53,523
above or below those
10 feet thick rings.

891
00:49:53,523 --> 00:49:57,560
Then lo and behold, we found
what looked like mountains

892
00:49:57,560 --> 00:50:00,897
casting huge shadows
on the rings.

893
00:50:00,897 --> 00:50:03,233
And it turns out that
the rings of Saturn

894
00:50:03,233 --> 00:50:05,268
are not like just
individual particles,

895
00:50:05,268 --> 00:50:08,537
but a lot of these
particles stick together

896
00:50:08,537 --> 00:50:12,175
and grow into larger
and larger particles.

897
00:50:12,175 --> 00:50:15,011
But these clumps of
particles are ephemeral.

898
00:50:15,011 --> 00:50:17,180
They don't last for a long time.

899
00:50:17,180 --> 00:50:21,952
They can be broken up and then
reformed in to new particles.

900
00:50:27,190 --> 00:50:29,593
- [Narrator] Saturn's
moons and smaller moonlets

901
00:50:29,593 --> 00:50:31,094
also influenced the rings.

902
00:50:32,628 --> 00:50:37,133
Even orbiting rubble
piles hold a kind of sway.

903
00:50:37,133 --> 00:50:40,002
Altogether, they help
shape the boundaries

904

00:50:40,002 --> 00:50:41,571
of Saturn's rings,

905
00:50:41,571 --> 00:50:44,207
herding in particles
that might otherwise

906
00:50:44,207 --> 00:50:46,409
rain down in a
torrent on the planet

907
00:50:46,409 --> 00:50:49,012
or escape into deep space.

908
00:50:50,847 --> 00:50:54,050
Meanwhile, particles from
some of Saturn's moons

909
00:50:54,050 --> 00:50:56,119
are constantly shedding off,

910
00:50:56,119 --> 00:51:01,091
helping to preserve existing
rings or creating new ones.

911
00:51:06,563 --> 00:51:09,866
Among the unexpected
discoveries within the rings

912
00:51:09,866 --> 00:51:12,436
were these propeller
like objects.

913
00:51:13,870 --> 00:51:17,773
- Propellers are these largest
clumps of ring particles,

914
00:51:17,773 --> 00:51:19,876
and they get big
enough so their gravity

915
00:51:19,876 --> 00:51:23,546
wants to push apart the
rings and open up a gap.

916
00:51:23,546 --> 00:51:25,015
And then there's not
quite enough gravity

917
00:51:25,015 --> 00:51:26,249
to open it up all the way.

918
00:51:26,249 --> 00:51:28,350
And so you see these
little propellers

919
00:51:28,350 --> 00:51:29,752
sprinkled throughout the rings,

920
00:51:29,752 --> 00:51:31,855
especially in Saturn's A ring.

921
00:51:34,090 --> 00:51:36,826
- [Narrator] A mystery
dating back to Voyager

922
00:51:36,826 --> 00:51:40,896
was the appearing and
disappearing of ghostly spokes.

923
00:51:40,896 --> 00:51:43,800
Cassini determined their cause.

924
00:51:43,800 --> 00:51:47,003
Electrostatic charges that
lift up dust particles,

925
00:51:47,003 --> 00:51:50,006
where they levitate for

a time above the rings.

926
00:51:53,610 --> 00:51:56,479
There remain two
fundamental questions

927
00:51:56,479 --> 00:51:58,814
lacking definitive answers.

928
00:51:58,814 --> 00:52:01,685
The first is knowing how
the rings came to be.

929
00:52:03,053 --> 00:52:06,556
- So many things about the
rings are unexplained even now.

930
00:52:07,724 --> 00:52:10,760
There are a lot of ideas
for how Saturn's rings

931
00:52:10,760 --> 00:52:12,428
initially formed.

932
00:52:12,428 --> 00:52:15,564
One of those is that
perhaps the rings formed

933
00:52:15,564 --> 00:52:18,234
from the material
that was left over

934
00:52:18,234 --> 00:52:19,803
from when Saturn formed.

935
00:52:19,803 --> 00:52:23,106
So if that's true,
then the rings are old,

936

00:52:23,106 --> 00:52:24,875
as old as Saturn itself.

937
00:52:26,309 --> 00:52:29,912
Other ideas: say perhaps
an object may be a comet,

938
00:52:29,912 --> 00:52:32,715
or a meteor, came in
too close to Saturn,

939
00:52:32,715 --> 00:52:35,685
was torn apart by
Saturn's gravity,

940
00:52:35,685 --> 00:52:38,187
and then created the rings.

941
00:52:38,187 --> 00:52:41,458
Or perhaps a moon wandered
too close to Saturn

942
00:52:41,458 --> 00:52:43,192
and was torn apart.

943
00:52:43,192 --> 00:52:46,662
And so then the rains could
be as young as maybe only 10

944
00:52:46,662 --> 00:52:48,899
or a hundred million years old.

945
00:52:51,100 --> 00:52:54,537
- [Narrator] Along
with determining the
origin of the rings,

946
00:52:54,537 --> 00:52:58,341
understanding their fate is
also an unanswered question.

947
00:52:59,475 --> 00:53:02,078
But the adage that
nothing lasts forever

948
00:53:02,078 --> 00:53:04,447
likely applies even to them.

949
00:53:05,815 --> 00:53:09,719
- As micro meteoroids
continue to bombard the rings,

950
00:53:09,719 --> 00:53:12,988
and some of the innermost
particles fall into Saturn

951
00:53:12,988 --> 00:53:15,157
and actually water the planet,

952
00:53:15,157 --> 00:53:18,261
the rings are getting lighter
and lighter with time.

953
00:53:18,261 --> 00:53:21,363
And so perhaps in another
few hundred million years,

954
00:53:21,363 --> 00:53:23,800
Saturn's rings as we
know it might be gone.

955
00:53:23,800 --> 00:53:26,303
Maybe we'll be left
with narrow rings

956
00:53:26,303 --> 00:53:28,572
like we see in
the Uranus system.

957

00:53:30,707 --> 00:53:33,009
- [Narrator] And one
day long from now,

958
00:53:33,009 --> 00:53:37,247
Saturn's glorious rings
might disappear altogether.

959
00:53:37,247 --> 00:53:40,350
One more reason to
enjoy them while we can.

960
00:53:48,024 --> 00:53:50,994
Next time on "JPL
and the Space Age",

961
00:53:50,994 --> 00:53:54,730
Part Two of "Triumph
at Saturn"...

962
00:53:54,730 --> 00:53:59,469
With Cassini safely in orbit,
science takes center stage,

963
00:54:00,937 --> 00:54:04,240
beginning with the dramatic
descent of the Huygens Probe

964
00:54:04,240 --> 00:54:07,444
to the surface of
Saturn's moon Titan.

965
00:54:08,611 --> 00:54:10,046
- [Man] We knew Titan
was a tough target,

966
00:54:10,046 --> 00:54:12,615
was going to hold
its secrets tightly.

967

00:54:12,615 --> 00:54:15,418
And so we designed
this mission to hit it

968
00:54:15,418 --> 00:54:17,387
with everything we've got.

969
00:54:17,387 --> 00:54:19,155
- [Narrator] In the
years that follow,

970
00:54:19,155 --> 00:54:22,925
one unexpected discovery
after another will be made,

971
00:54:22,925 --> 00:54:25,160
earning this
international mission

972
00:54:25,160 --> 00:54:27,497
accolades from around the world.

973
00:54:28,631 --> 00:54:30,966
- Science is about what is,

974
00:54:30,966 --> 00:54:34,504
and engineering is
about what can BE.

975
00:54:34,504 --> 00:54:37,707
The Cassini-Huygens
program has demonstrated

976
00:54:37,707 --> 00:54:39,242
the best of both.

977
00:54:39,242 --> 00:54:41,544
The number of your
new discoveries

978
00:54:41,544 --> 00:54:43,846
is nothing short of amazing.

979
00:54:43,846 --> 00:54:46,182
- [Woman] I would say
Cassini's discoveries

980
00:54:46,182 --> 00:54:50,853
fundamentally altered the way
we look at our solar system.

981
00:54:50,853 --> 00:54:53,789
Around one planet,
we find two moons

982
00:54:53,789 --> 00:54:57,026
that could potentially
be habitable,

983
00:54:57,026 --> 00:55:00,963
have the key ingredients
to support life.

984
00:55:00,963 --> 00:55:04,167
- I have more than a
passing interest in Saturn

985
00:55:04,167 --> 00:55:05,635
and its family of moons.

986
00:55:05,635 --> 00:55:10,473
When Cassini was launched,
we knew only 18 moons.

987
00:55:10,473 --> 00:55:14,210
I understand there's
now 60 and counting.

988
00:55:14,210 --> 00:55:17,113

I can't resist the
temptation to say,

989
00:55:17,113 --> 00:55:18,982
my God, it's full of moons.