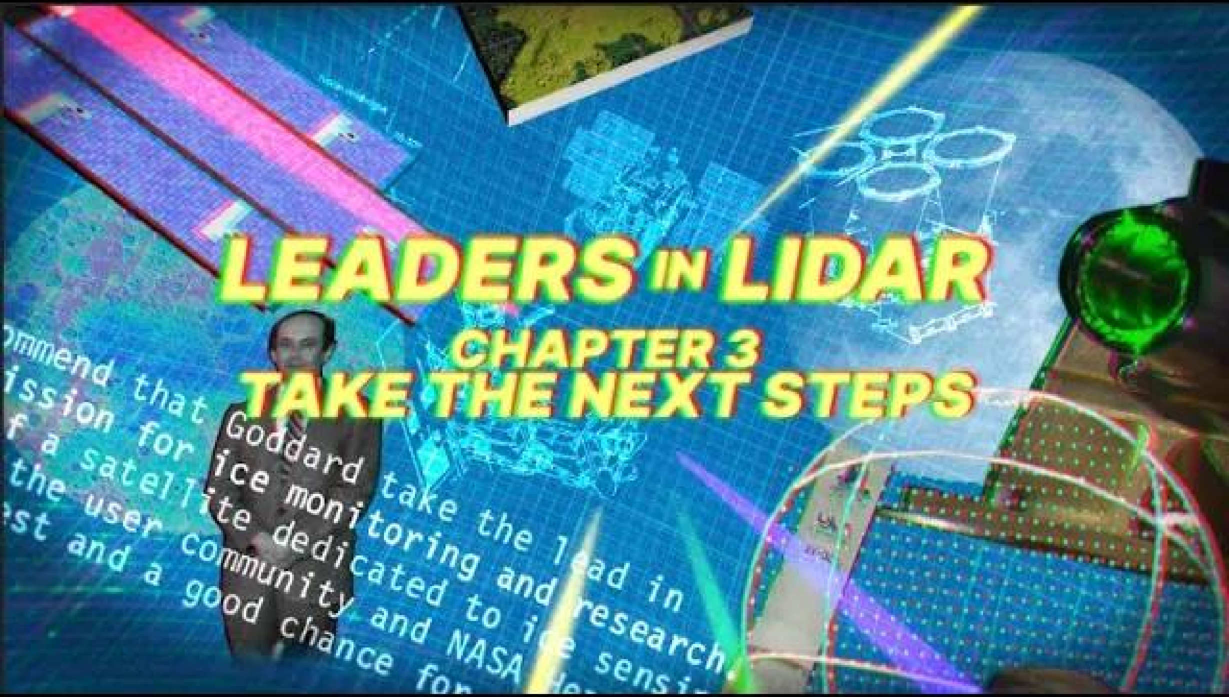
LEADERS IN LIDAR
CHAPTER 3
TAKE THE NEXT STEPS

1
00:00:00,000 --> 00:00:02,700
[music]

2
00:00:02,700 --> 00:00:03,633
Following MOLA,

3
00:00:03,633 --> 00:00:06,633
in some ways, we were in demand
to consider

4
00:00:06,633 --> 00:00:11,066
whether we could provide a laser altimeter
to another mission.

5
00:00:11,400 --> 00:00:13,266
A few missions, actually.

6
00:00:13,266 --> 00:00:16,700
It was no longer a question of if lidar could work,

7
00:00:16,700 --> 00:00:19,366
but where else it could work?

8
00:00:19,366 --> 00:00:23,033
But as the opportunities
to test the limits of lidar arose,

9
00:00:23,033 --> 00:00:24,866
so did the challenges ahead.

10
00:00:24,900 --> 00:00:33,000
[music]

11
00:00:33,000 --> 00:00:37,033
The Goddard team quickly began
to see the evolution of lidar missions,

12
00:00:37,033 --> 00:00:41,233

building on the successes of new frontiers
mapped by MOLA.

13
00:00:41,233 --> 00:00:44,133
We've measured the changes,
the seasonal changes

14
00:00:44,133 --> 00:00:45,800
in the Mars icecaps,

15
00:00:45,800 --> 00:00:47,866
both the North Pole and South Pole.

16
00:00:48,200 --> 00:00:49,400
We've measured the volumes.

17
00:00:49,400 --> 00:00:51,700
We've measured the mass
that's involved in it.

18
00:00:51,700 --> 00:00:53,033
We now have a density.

19
00:00:53,033 --> 00:00:55,833
So now we know the kind of processes that--

20
00:00:55,833 --> 00:00:57,366
Dave Smith invited me

21
00:00:57,366 --> 00:01:01,266
to be on the MOLA Altimetry Science Team.

22
00:01:01,766 --> 00:01:05,366
And that was because of my experience with using

23
00:01:05,900 --> 00:01:07,466
altimetry over

24

00:01:07,466 --> 00:01:10,466
land rather than ocean processes.

25
00:01:10,600 --> 00:01:15,300
Zwally was an obvious choice
to study the Martian ice caps for MOLA,

26
00:01:15,300 --> 00:01:19,200
given his decades of expertise
with our own polar regions

27
00:01:19,200 --> 00:01:24,500
studying the ice sheets of Greenland
and Antarctica through the 1970s and 80s.

28
00:01:24,500 --> 00:01:27,533
And then as we went into the eighties,

29
00:01:27,533 --> 00:01:29,933
NASA was sort of the beginning

30
00:01:29,933 --> 00:01:32,833
of the development of the Earth Observations Program.

31
00:01:33,000 --> 00:01:36,900
So the Earth Observing System,
I think, will be the first effort

32
00:01:36,900 --> 00:01:39,900
targeted at looking at the whole Earth system

33
00:01:39,900 --> 00:01:41,266
as a system,

34
00:01:41,466 --> 00:01:44,600
rather than just the little components that make it up.

35
00:01:44,933 --> 00:01:49,400
Somewhere along then I teamed up with Jim Abshire.

36
00:01:49,633 --> 00:01:53,766
Jay had been pushing for a long time
for a dedicated ice

37
00:01:53,766 --> 00:01:57,266
altimetry mission, which turned into ICESat-1.

38
00:01:57,466 --> 00:02:00,333
Designing ICESat-1 marked a major leap

39
00:02:00,333 --> 00:02:04,266
in what lidar needed to do
and how challenging it would be to do it.

40
00:02:04,400 --> 00:02:08,900
To measure the changing ice sheets,
the lidar had to be far more precise,

41
00:02:08,900 --> 00:02:12,733
cover the same tracks season to season,
and it needed more power

42
00:02:12,733 --> 00:02:14,900
and a larger instrument,

43
00:02:14,900 --> 00:02:17,100
which meant much more time to build.

44
00:02:17,633 --> 00:02:20,166
We built a simulator for ICESat-1

45
00:02:20,166 --> 00:02:22,066
that allowed us to sort of

46
00:02:22,066 --> 00:02:23,966
figure out how precise it could be,

47

00:02:23,966 --> 00:02:27,000
how we would process the waveform data coming back,

48
00:02:27,000 --> 00:02:28,600
how we would track the surface.

49
00:02:28,600 --> 00:02:30,300
This algorithm

50
00:02:30,300 --> 00:02:32,033
was much more complicated

51
00:02:32,033 --> 00:02:34,300
than anything I had ever worked on before.

52
00:02:34,500 --> 00:02:38,300
But all this meant essentially for
for the ICESat mission,

53
00:02:38,300 --> 00:02:42,466
you needed a much more advanced version of MOLA.

54
00:02:43,000 --> 00:02:43,700
On Mars,

55
00:02:43,700 --> 00:02:47,500
we really didn't know what was there
until we got the measurements.

56
00:02:47,500 --> 00:02:49,200
So we were doing discovery.

57
00:02:49,200 --> 00:02:52,600
On Earth, we have to make quantitative
measurements about what's happening.

58
00:02:52,933 --> 00:02:56,466
Four, three, two, one,

59
00:02:57,600 --> 00:02:59,666
and we have ignition and liftoff

60
00:02:59,666 --> 00:03:04,433
for NASA's ICESat and CHIPSat spacecraft
looking at stars and ice.

61
00:03:05,100 --> 00:03:07,200
But after we'd worked on GLAS

62
00:03:07,200 --> 00:03:09,466
at that point, more than a decade,

63
00:03:09,466 --> 00:03:10,600
and it had already launched,

64
00:03:10,600 --> 00:03:12,666
and usually it's like, okay, now we're going to be able

65
00:03:12,666 --> 00:03:14,633
to enjoy the data coming down,

66
00:03:14,633 --> 00:03:16,366
and what can we see in the data?

67
00:03:17,100 --> 00:03:20,566
But there was much more, what is this mystery we're seeing?

68
00:03:20,566 --> 00:03:22,600
Why is the laser energy going down?

69
00:03:22,833 --> 00:03:26,233
Things were not working
the way we expected them to,

70
00:03:26,233 --> 00:03:28,700
and there were mysteries,
and we weren't expecting--

71
00:03:28,700 --> 00:03:31,800
after MOLA particularly--
to have mysteries at that point.

72
00:03:31,800 --> 00:03:35,533
One of these unexpected mysteries
came down to the wire.

73
00:03:35,533 --> 00:03:37,600
Several wires actually.

74
00:03:37,600 --> 00:03:39,900
What happened on GLAS was the laser diodes

75
00:03:39,900 --> 00:03:44,000
had gold bond wires and indium solder.

76
00:03:44,066 --> 00:03:45,533
If you bring these two metals together,

77
00:03:45,533 --> 00:03:49,466
even though they're not reactive, they do combine to form gold indide.

78
00:03:49,700 --> 00:03:54,600
The gold indide ate away at the wires,
leading to added thermal stress

79
00:03:54,600 --> 00:03:57,433
and eventually the failure of the first laser.

80
00:03:57,433 --> 00:04:00,733
And the second and third lasers were degrading as well.

81
00:04:00,733 --> 00:04:02,800
Tough decisions were ahead.

82
00:04:02,800 --> 00:04:04,000

When these missions operate,

83
00:04:04,000 --> 00:04:05,566
there's a lot riding on the missions.

84
00:04:05,566 --> 00:04:07,900
You don't want to make any mistakes.

85
00:04:07,900 --> 00:04:11,333
You want to optimize things as best you can.

86
00:04:11,566 --> 00:04:14,833
The question was,
given that we would have so much

87
00:04:14,833 --> 00:04:18,233
lifetime expectancy from the lasers,

88
00:04:18,233 --> 00:04:21,000
well, the scientific decision was

89
00:04:21,000 --> 00:04:24,766
the best way to use that was to operate for periods

90
00:04:24,766 --> 00:04:28,233
of about a month and do that three times a year.

91
00:04:28,500 --> 00:04:32,500
That decision paid off when ICESat
showed dramatic change in land ice

92
00:04:32,500 --> 00:04:36,600
around Greenland, and it also proved
that lidar could be used to measure

93
00:04:36,600 --> 00:04:39,666
something called sea ice freeboard,

94

00:04:39,666 --> 00:04:43,133
a major breakthrough in determining sea ice thickness

95
00:04:43,133 --> 00:04:47,600
and an essential science goal for
the future of ice-measuring satellites.

96
00:04:47,600 --> 00:04:50,533
Even though the ICESat project required much

97
00:04:50,533 --> 00:04:54,500
more care and feeding,
it really laid the groundwork

98
00:04:54,500 --> 00:04:58,766
for all the subsequent missions
that Goddard has has flown.

99
00:04:58,766 --> 00:05:01,300
[music]

100
00:05:01,300 --> 00:05:03,800
Around the same time that ICESat was developed,

101
00:05:03,800 --> 00:05:06,333
Goddard was tasked with designing a laser

102
00:05:06,333 --> 00:05:10,000
for measuring a place far from any icy poles.

103
00:05:10,766 --> 00:05:14,966
Sean Solomon was the PI of Messenger,
and he said,

104
00:05:14,966 --> 00:05:18,433
You know, I've been asked to PI
a mission to Mercury.

105
00:05:18,866 --> 00:05:21,033

I really want a laser altimeter on board.

106
00:05:21,300 --> 00:05:23,100
Can you make one that will work there?

107
00:05:23,100 --> 00:05:25,133
So the short answer
seemed to be,

108
00:05:25,133 --> 00:05:27,300
yeah, I don't see why not,
but there will be

109
00:05:27,300 --> 00:05:30,300
extreme thermal circumstances
that we'd have to worry about.

110
00:05:30,333 --> 00:05:32,266
That was a really tough one
because you fly in close

111
00:05:32,266 --> 00:05:37,066
to the 800-degree planet and then,
you know, you have a 12-hour orbit.

112
00:05:37,066 --> 00:05:39,566
The temperature changes by

113
00:05:39,566 --> 00:05:42,633
tens of degrees
in a few minutes.

114
00:05:42,633 --> 00:05:47,466
It had to always shield itself
from the Sun constantly,

115
00:05:47,466 --> 00:05:52,266
which meant that in orbit
it was often at a very high angle.

116
00:05:52,266 --> 00:05:55,633
It was a challenge
to try to continually figure out where

117
00:05:55,633 --> 00:05:57,433
the surface of Mercury was.

118
00:05:57,433 --> 00:05:59,166
And then they wanted to be small,

119
00:05:59,166 --> 00:06:01,533
much smaller than a MOLA.

120
00:06:01,533 --> 00:06:05,366
I think it's up to a quarter or fifth of the size.

121
00:06:05,400 --> 00:06:09,933
But I remember the manager
who was running it for us at the time

122
00:06:09,933 --> 00:06:16,133
kind of said, you realize I've thinned
every wire in this electronic package

123
00:06:16,133 --> 00:06:19,800
so thin that you better not
look at it twice because it might break.

124
00:06:19,800 --> 00:06:23,266
But that's the level we had to go to get
within the seven kilograms.

125
00:06:24,300 --> 00:06:28,300
And MLA was the laser altimeter that we proposed,

126
00:06:28,300 --> 00:06:31,866
and this was really pushed the limits

127

00:06:31,866 --> 00:06:34,366
of what we could reasonably expect to do.

128
00:06:35,966 --> 00:06:39,033
Despite the extreme environmental gauntlet,

129
00:06:39,166 --> 00:06:43,800
the Mercury Laser Altimeter
kept on collecting data for four years,

130
00:06:43,800 --> 00:06:48,900
right up until the very end, when
MESSENGER crashed into Mercury in 2015.

131
00:06:49,266 --> 00:06:54,200
But before that, it captured historic
views of the planet's topography.

132
00:06:54,200 --> 00:06:56,700
[music]

133
00:06:56,700 --> 00:07:00,966
It is time for America to take the next steps.

134
00:07:01,400 --> 00:07:04,333
Beginning no later than 2008,

135
00:07:04,333 --> 00:07:09,300
we will send a series of robotic missions
to the lunar surface to research

136
00:07:09,300 --> 00:07:13,566
and prepare for future human exploration.

137
00:07:13,800 --> 00:07:17,233
And then one day, the President,
I think it was George Bush, suddenly

138
00:07:17,233 --> 00:07:18,866

decided we're going to go back to the Moon.

139
00:07:18,866 --> 00:07:20,633
Well, all of a sudden, okay!

140
00:07:20,966 --> 00:07:26,033
We've been thinking of putting the lidar
around the Moon for a long time, actually.

141
00:07:26,166 --> 00:07:31,066
And I really wanted to have a crack
at doing a good one--instrument--for

142
00:07:31,500 --> 00:07:32,166
the Moon.

143
00:07:32,166 --> 00:07:35,833
I mean, my interest was in gravity
and topography, two things

144
00:07:35,833 --> 00:07:38,533
that need to come together
to measure the structure of a planet.

145
00:07:39,766 --> 00:07:43,200
And then all of a sudden,
we got a call from Headquarters.

146
00:07:43,200 --> 00:07:48,966
Can you design the lidar around the Moon
to map the Moon, to map the topography?

147
00:07:49,066 --> 00:07:52,766
And so the instruments
were chosen from proposals

148
00:07:52,766 --> 00:07:56,500
based on the ability to help select sites

149

00:07:56,500 --> 00:08:01,033
and determine the the safety of landing
in particular sites on the Moon.

150
00:08:01,233 --> 00:08:06,100
The lidar would be the Lunar Orbiter Laser Altimeter, or LOLA,

151
00:08:06,100 --> 00:08:08,766
and it marked another leap into laser altimetry.

152
00:08:08,766 --> 00:08:11,700
We also came up with the idea

153
00:08:11,700 --> 00:08:13,866
of having multiple beams.

154
00:08:14,100 --> 00:08:17,700
We managed to put five beams
on the surface, and that kind of

155
00:08:17,700 --> 00:08:21,200
changed the observational strategy,
if you know what I mean.

156
00:08:21,200 --> 00:08:23,000
Five parallel beams.

157
00:08:23,000 --> 00:08:28,600
[rocket launching]

158
00:08:28,600 --> 00:08:32,433
But after launch, LOLA was suspiciously silent.

159
00:08:32,433 --> 00:08:34,900
When LOLA started,
I think that was just devastating.

160
00:08:34,900 --> 00:08:39,366
We didn't get any measurement at nighttime

when we first turned on.

161
00:08:39,366 --> 00:08:44,533
So it was quite a shock, and
it was the first lidar that didn't work

162
00:08:44,533 --> 00:08:46,366
at the initial turn on.

163
00:08:46,366 --> 00:08:49,233
The people that are heavily involved
in the instrument development,

164
00:08:49,233 --> 00:08:52,766
you're pulled back in
if there's surprises that occur.

165
00:08:52,800 --> 00:08:55,233
On LOLA, the blankets were all tied

166
00:08:55,233 --> 00:08:58,366
tightly to the beam expander
and the telescope and this Germanium

167
00:08:58,366 --> 00:09:02,166
black Kapton, which we didn't test with was very strong.

168
00:09:02,233 --> 00:09:04,700
And then we caused a misalignment.

169
00:09:04,800 --> 00:09:08,700
I remember we discussed
whether we wanted to check the alignment

170
00:09:08,700 --> 00:09:12,500
at spacecraft level, and I, you know,
we just decided not to do it.

171
00:09:12,533 --> 00:09:15,800

I think that was my
fault because we could have.

172
00:09:16,233 --> 00:09:20,000
We started in the worst possible orbit
for that failure mechanism,

173
00:09:20,000 --> 00:09:23,433
and so we were out of alignment,
and we had no signal at all.

174
00:09:23,433 --> 00:09:27,033
And it was just--it was a tough couple of weeks.

175
00:09:27,033 --> 00:09:27,466
Yeah.

176
00:09:27,466 --> 00:09:31,366
It is a lessons learned for life for me.

177
00:09:31,500 --> 00:09:34,933
Couple of weeks later, we noticed
a little blip at the South Pole.

178
00:09:35,600 --> 00:09:37,766
And so we had some hope.

179
00:09:39,433 --> 00:09:42,833
And it eventually just,
you know, as the orbit progressed,

180
00:09:42,833 --> 00:09:46,333
the signal kept getting stronger
and stronger on the daylight side.

181
00:09:46,333 --> 00:09:50,400
Despite a bumpy start, in time LOLA
and the Lunar Reconnaissance

182

00:09:50,400 --> 00:09:54,366
Orbiter mission became revolutionary
in mapping our Moon.

183
00:09:54,366 --> 00:09:57,800
And it turned out to be exceptional in terms of

184
00:09:57,800 --> 00:10:00,233
describing the topography of the Moon.

185
00:10:00,233 --> 00:10:03,000
As a result of LOLA, I think largely,

186
00:10:03,000 --> 00:10:04,400
if not the others as well,

187
00:10:04,400 --> 00:10:06,666
the doubts about whether a laser altimeter,

188
00:10:06,666 --> 00:10:08,466
for example, could last--

189
00:10:08,466 --> 00:10:10,800
age limits, lifetime limits

190
00:10:10,800 --> 00:10:13,000
on the laser altimeter--

191
00:10:13,000 --> 00:10:14,233
were dispelled.

192
00:10:16,833 --> 00:10:20,966
The shape of what we build, live,
work, study, operate on,