1
00:00:09,000 --> 00:00:13,610
12, 11, 10, 9 launch sound, 8, 7, 6;
Oh, it was very exciting,

2
00:00:13,610 --> 00:00:17,290
it was the only one I have ever seen.
It was at 12:30 in the morning;

3
00:00:17,290 --> 00:00:20,860
so it was dark. My daughter
who is older was awake and

4
00:00:20,860 --> 00:00:24,550
knew what was going on,
my son was asleep and we woke

5
00:00:24,550 --> 00:00:29,570
him up just to see the launch.
Ignition and lift-off of Columbia,

6
00:00:29,570 --> 00:00:32,660
reaching new heights for women
and X-ray astronomy.

7
00:00:32,660 --> 00:00:36,510
When I stood there 3 plus miles away,
at the viewing stand,

8
00:00:36,510 --> 00:00:40,920
and the shuttle engines lit off,
you could hear the roar

9
00:00:40,920 --> 00:00:44,923
and my shirt was vibrating.
Most of the people who had come

10
00:00:44,923 --> 00:00:47,399
down to watch the launch,
we launched that was it.

11
00:00:47,399 --> 00:00:50,660
Everything was great.
For us of course it was

12
00:00:50,660 --> 00:00:53,480
a very very big step,
because now Chandra was

13
00:00:53,480 --> 00:00:57,140
off into space, But until
we saw x-rays coming through

14
00:00:57,140 --> 00:01:01,980
and everything worked we really
couldn■t be too overconfident

15
00:01:01,980 --> 00:01:07,000
or relaxed or assured of success.
Nothing as beautiful as Chandra

16
00:01:07,000 --> 00:01:12,180
trailing off on its way to work.
Control room sounds.

17
00:01:12,180 --> 00:01:18,150
I felt ecstatic,
I felt unbelievably ecstatic,

18
00:01:18,150 --> 00:01:22,049
and when we saw those first x-rays
at the minute the first time

19
00:01:22,049 --> 00:01:25,780
the door opened and I could
see they were being focused

20
00:01:25,780 --> 00:01:30,330
more or less into the right area,
I just broke into the biggest smile

21
00:01:30,330 --> 00:01:35,840
you■ve ever seen. We looked at Cas A,
supernova remnant of a star that

22
00:01:35,840 --> 00:01:40,780
exploded about 300 years ago,
it■s the neutron star the core

23
00:01:40,780 --> 00:01:45,400
of the star, exploded, collapses
and forms a neutron star. And we

24
00:01:45,400 --> 00:01:48,740
made that discovery in this
official first light image as well.

25
00:01:48,740 --> 00:01:51,720
We were very excited.
That was an extraordinary time,

26
00:01:51,720 --> 00:01:56,649
I think when I first realized
the telescope was working,

27
00:01:56,649 --> 00:02:03,409
I had a real sense of relief,
a real sense of elation,

28
00:02:03,409 --> 00:02:07,730
because of all the hard work
that had gone on. Um, I was

29
00:02:07,730 --> 00:02:12,730
incredibly proud because of the team
and being part of that team!

30
00:02:12,730 --> 00:02:16,140
So the requirement was you had
to work for three years

31
00:02:16,140 --> 00:02:20,489
and the goal was five.
We■re 15 years into our 5 year lifetime■

32
00:02:20,489 --> 00:02:29,270
that■s not too bad (laughs).
Sound effect and music.

33
00:02:29,270 --> 00:02:31,950
So many people have contributed
much of their careers to the

34
00:02:31,950 --> 00:02:35,840
success of the Chandra mission and
we■re just continuing to reap

35
00:02:35,840 --> 00:02:40,370
the benefits of those sacrifices
that they made, and the excellent

36
00:02:40,370 --> 00:02:42,940
science return that we are
seeing from the mission. And we

37
00:02:42,940 --> 00:02:52,450
hope those continue for years to come.
So if you want to find Black Holes

38
00:02:52,450 --> 00:02:57,970
you wanna use an X-ray telescope.
From various astronomical observatories,

39
00:02:57,970 --> 00:03:02,350
in space and on the ground, in
particular Chandra being a major player,

40
00:03:02,350 --> 00:03:07,720
we■ve determined that most galaxies
that are as massive as our Milky Way

41
00:03:07,720 --> 00:03:13,239
or more have what we call a Super
massive black hole in the center of

42
00:03:13,239 --> 00:03:17,590
the galaxy. Super Massive means that
they weigh in at anywhere between

43
00:03:17,590 --> 00:03:21,550
a million to 10 Billion times the
mass of our own sun. What we are

44
00:03:21,550 --> 00:03:25,200
tending to find is that the cluster
of galaxies, have a bright central

45
00:03:25,200 --> 00:03:28,970
galaxy in the middle, it is often
and active galaxy or a quasar.

46
00:03:28,970 --> 00:03:32,380
So a Super Massive Black Hole
in the middle of a galaxy,

47
00:03:32,380 --> 00:03:35,441
because when the cluster is
forming a lot of the material

48
00:03:35,441 --> 00:03:39,870
tends to fall towards the middle■
so you get the biggest galaxy in

49
00:03:39,870 --> 00:03:43,560
the middle. So you have cool material
falling in forming stars, eventually

50
00:03:43,560 --> 00:03:48,170
some of that gets to the BH, the
Black Hole can■t take it all in,

51
00:03:48,170 --> 00:03:51,590
so some of it is blown out in
radio jets. That heats up the

52
00:03:51,590 --> 00:03:55,330
material that is coming back down.
So there is a kind of feedback loop

53
00:03:55,330 --> 00:04:00,659
between the growing black hole
in the middle and the star formation

54
00:04:00,659 --> 00:04:07,620
that is happening in the cluster itself.
Sound effect.

55
00:04:07,620 --> 00:04:10,629
We have known about the existence of
dark matter for a long time,

56
00:04:10,629 --> 00:04:13,989
it used to be called missing matter,
but now it■s just dark matter

57
00:04:13,989 --> 00:04:19,930
because we know that it is there.
We know this in a number of different ways.

58
00:04:19,930 --> 00:04:27,280
So Chandra■s discovery of some things
like the Bullet Cluster, is not a great

59
00:04:27,280 --> 00:04:31,810
surprise but this is a situation,
one of these train wrecks that

60
00:04:31,810 --> 00:04:37,990
you can see and you can see these
galaxies collided with one another.

61
00:04:37,990 --> 00:04:43,330
And what is happening is very interesting
and shows the presence of Dark Matter

62
00:04:43,330 --> 00:04:48,460
in a beautiful way. What we have now seen,
when there are two clusters that have

63
00:04:48,460 --> 00:04:53,150
passed through each other and the
gas got stripped out and Dark Matter

64
00:04:53,150 --> 00:05:00,140
kept going. So they have actually enabled
us really the only opportunity in the

65
00:05:00,140 --> 00:05:08,000
Universe that I■m aware of to clearly
separate the existence of Dark Matter,

66
00:05:08,000 --> 00:05:14,030
which then you can detect by this thing
called gravitational lens effect and

67
00:05:14,030 --> 00:05:22,190
the gas. And so this is like a key
scientific discovery to understand

68
00:05:22,190 --> 00:05:25,980
the nature of dark matter versus
normal matter in the universe.

69
00:05:25,980 --> 00:05:31,240
And that■s a very beautiful image,
for me it is beautiful because it

70
00:05:31,240 --> 00:05:36,820
combines together data from Chandra,
Hubble Space Telescope as well as

71
00:05:36,820 --> 00:05:39,990
the Magellan telescope, a very
powerful ground based telescope.

72
00:05:39,990 --> 00:05:46,320
And it really shows form me how
Chandra■s science can be very powerful

73
00:05:46,320 --> 00:05:51,539
in multi-wavelength space.
Sound effect.

74
00:05:51,539 --> 00:05:58,242
An important discovery in astronomy
and astrophysics was the discovery

75
00:05:58,242 --> 00:06:04,430
of Dark Energy and that is that
the Universe is accelerating apart.

76
00:06:04,430 --> 00:06:09,930
What people are trying to do using
various different techniques and

77
00:06:09,930 --> 00:06:14,360
again in all the different wavelength
bands is to measure the parameters

78
00:06:14,360 --> 00:06:19,870
to characterize the Dark Energy.
Chandra and X-ray astronomy is playing

79
00:06:19,870 --> 00:06:24,850
an important role in these measurements.
Well the Universe evolves differently,

80
00:06:24,850 --> 00:06:29,431
it■s not the same Universe we■re in
without it. I think that■s most

81
00:06:29,431 --> 00:06:35,199
important and secondly if we are ever
going to try and understand cosmology,

82
00:06:35,199 --> 00:06:40,850
that is the growth and evolution of
the Universe, these are important

83
00:06:40,850 --> 00:06:46,410
constraints- boundary conditions-
that have to be satisfied by any

84
00:06:46,410 --> 00:06:51,110
model that you may have.
I usually make the mistake of saying

85
00:06:51,110 --> 00:06:55,569
Dark Energy didn■t exist at the time
that we designed Chandra, well of

86
00:06:55,569 --> 00:06:59,660
course it existed, we didn■t know
of the existence of Dark Matter

87
00:06:59,660 --> 00:07:03,410
when we designed Chandra.
So you see the power of an observatory,

88
00:07:03,410 --> 00:07:08,590
an observatory like Chandra with a
state-of-the-art telescope and these

89
00:07:08,590 --> 00:07:12,949
imaging and spectroscopic capabilities
of its science instruments can do things

90
00:07:12,949 --> 00:07:15,639
that maybe weren■t even things you
planned on doing because you didn■t

91
00:07:15,639 --> 00:07:21,710
know about them at the time.
A lot of science falls into that category.

92
00:07:21,710 --> 00:07:30,010
Sound effect.
Yeah, the Universe is a big big place.

93
00:07:30,010 --> 00:07:33,610
I think in this mature phase what we
can do which would have been harder

94
00:07:33,610 --> 00:07:36,780
to do in the early years, when you
want to look at a lot of different

95
00:07:36,780 --> 00:07:44,139
things and satisfy a lot of observers
is taking really longer exposures.

96
00:07:44,139 --> 00:07:46,789
Chandra has very sharp vision
but if you don■t look for very

97
00:07:46,789 --> 00:07:51,250
long you don■t capture many photons
and so you can■t really populate that

98
00:07:51,250 --> 00:07:55,819
digital image with much detail.
But if we stare at that one region

99
00:07:55,819 --> 00:08:00,289
for really long time we gather so
many photons that we can really

100
00:08:00,289 --> 00:08:03,479
understand the subtleties, we can
see thousands of stars. We can

101
00:08:03,479 --> 00:08:09,639
understand how they change with time.
We can look at the full zoo of

102
00:08:09,639 --> 00:08:13,949
denizens in star forming regions.
We■re in the middle of a two million

103
00:08:13,949 --> 00:08:17,680
second observation with Chandra
of something called 30 Duradus,

104
00:08:17,680 --> 00:08:19,260
the Tarancula Nebula.
We have only got a million seconds

105
00:08:19,260 --> 00:08:23,729
so far, we see hundreds of stars,
some of them are very unusual and

106
00:08:23,729 --> 00:08:29,410
look like they are interacting binaries.
We see strange diffuse shock emissions

107
00:08:29,410 --> 00:08:32,520
we don■t even understand yet.
Another thing we can do with Chandra

108
00:08:32,520 --> 00:08:38,560
is to look wider so we can mapping
regions that are degrees across

109
00:08:38,560 --> 00:08:42,830
on the sky; very complex fields.
We■ve done this once already with

110
00:08:42,830 --> 00:08:47,830
the great nebula in Carina.
We mapped the Carina star forming

111
00:08:47,830 --> 00:08:53,000
complex, from that we found over
14,000 young stars and we find a

112
00:08:53,000 --> 00:08:57,960
distributed population of young
stars as well as these dense clusters.

113
00:08:57,960 --> 00:09:02,200
We also see an amazing array of
diffuse x-ray emission. If we

114
00:09:02,200 --> 00:09:05,380
look at them in the optical what
we see is a lot of galaxies,

115
00:09:05,380 --> 00:09:09,790
very pretty, if we look in the
X-ray, we see the hot gas, which

116
00:09:09,790 --> 00:09:15,190
is actually much more of the material
in the cluster- about 10X more than

117
00:09:15,190 --> 00:09:19,300
the material in the galaxies■
and that surrounds those galaxies.

118
00:09:19,300 --> 00:09:27,279
So many people that have been important
to success, continued success of Chandra.

119
00:09:27,279 --> 00:09:31,610
Obviously at the head of the list
goes Riccardo Giacconi he conceived

120
00:09:31,610 --> 00:09:37,970
of this, need for this observatory
9 months after he discovered the

121
00:09:37,970 --> 00:09:43,860
first x-ray source, Scorpius X 1.
He discovered that in 1962,

122
00:09:43,860 --> 00:09:48,180
so that was in 1963.
You have to mention Leon Van

123
00:09:48,180 --> 00:09:54,580
Speybroeck, the Chandra telescope
scientist whose brilliance and

124
00:09:54,580 --> 00:09:59,240
understanding of X-ray optics
was such an important factor

125
00:09:59,240 --> 00:10:02,959
in being able to build this telescope.
And coming up with techniques,

126
00:10:02,959 --> 00:10:07,700
how to do it, that weren■t going
to break the bank. We solved the

127
00:10:07,700 --> 00:10:12,390
problems we encountered. When we
started Chandra we did not know

128
00:10:12,390 --> 00:10:15,891
how to build it. We knew the
science we wanted to do.

129
00:10:15,891 --> 00:10:23,950
This was a purely science driven program.
Chandra X-ray Center has a very strong team;

130
00:10:23,950 --> 00:10:27,401
that works very well as a team.
The biggest amount of credit for that goes

131
00:10:27,401 --> 00:10:33,190
for building that team goes to recently
retired director Harvey Tananbaum.

132
00:10:33,190 --> 00:10:37,981
Who was really maybe the mother of Chandra,
all the way along. Sheparded through

133
00:10:37,981 --> 00:10:45,709
the original process to get it
approved and built the X-ray Center team.

134
00:10:45,709 --> 00:10:50,870
So it was incredibly well built.
It was designed with very robust

135
00:10:50,870 --> 00:10:55,260
and reliable parts. The science
instruments were basically new

136
00:10:55,260 --> 00:10:58,990
and the telescope was certainly
state of the art. We tested the heck

137
00:10:58,990 --> 00:11:05,160
out of things in the lab,
before delivering, we tested at Marshall

138
00:11:05,160 --> 00:11:10,600
during the calibration, there was
testing during full up integration.

139
00:11:10,600 --> 00:11:13,170
There were some problems, there were
some issues, we fixed everything

140
00:11:13,170 --> 00:11:17,959
we could find. I think we had again
from a team perspective, we had great

141
00:11:17,959 --> 00:11:24,040
leadership at Marshall and throughout
all of the contractors and the

142
00:11:24,040 --> 00:11:29,700
science team involved. So by all
of these metrics Chandra is one

143
00:11:29,700 --> 00:11:34,209
of the most productive missions
that there have been scientifically.

144
00:11:34,209 --> 00:11:38,700
And we are working extremely hard
to maintain those levels.

145
00:11:38,700 --> 00:11:43,089
Looking at all the components in detail
their condition now versus their condition

146
00:11:43,089 --> 00:11:47,290
at launch versus their projection of
how long they can last up there,

147
00:11:47,290 --> 00:11:52,839
and no show stoppers came up in
that study. And all the things

148
00:11:52,839 --> 00:11:56,820
the engineering team could be
doing to mitigate aging,

149
00:11:56,820 --> 00:12:00,149
are already being done.
Flight Ops team and the Science Ops team

150
00:12:00,149 --> 00:12:04,589
they continue to work together to
really perform, to maximize our

151
00:12:04,589 --> 00:12:08,149
science while maintaining and
protecting the health and safety

152
00:12:08,149 --> 00:12:09,149
of the vehicle.
The operations team is great■

153
00:12:09,149 --> 00:12:10,149
primary reason it is still operating today.
They keep an eye on the components

154
00:12:10,149 --> 00:12:11,149
of the spacecraft. Their Monitoring
and planning is excellent!

155
00:12:11,149 --> 00:12:13,260
We do have an extraordinary team
and they have worked together since

156
00:12:13,260 --> 00:12:17,529
the beginning of the mission and
right through development before that,

157
00:12:17,529 --> 00:12:24,020
it includes the ground control team,
the science center, the flight

158
00:12:24,020 --> 00:12:28,160
operations team, the science
instruments teams, the factory support

159
00:12:28,160 --> 00:12:32,240
from Northrup Grumman and our colleages
at Marshall Space Flight Center.

160
00:12:32,240 --> 00:12:36,160
The quality of the science with Chandra,
I think the legacy will be that

161
00:12:36,160 --> 00:12:40,930
really serious science.
It was in there toe to toe with

162
00:12:40,930 --> 00:12:45,100
all the other branches of astronomy and
astrophysics; pushing the envelope.

163
00:12:45,100 --> 00:12:50,860
Everything we look at is high drama
in space and it■s a lot of fun.

164
00:12:50,860 --> 00:12:56,720
Well I think Chandra■s Legacy will
be profound. Huge archive of Chandra

165
00:12:56,720 --> 00:13:01,420
observations continues to be used
and new things come out of it.

166
00:13:01,420 --> 00:13:07,040
The cleverness of the scientific
community can■t be underrated.

167
00:13:07,040 --> 00:13:11,480
People are smart and they have ideas
and they run the range from studying

168
00:13:11,480 --> 00:13:16,040
the interaction of exo-planets with
their nearby stars and that

169
00:13:16,040 --> 00:13:23,029
influence on the planets themselves;
an interesting topic of it■s own,

170
00:13:23,029 --> 00:13:28,730
to what is out there in the deep fields.
We are going to increase the amount of

171
00:13:28,730 --> 00:13:33,510
observing time, and I anticipate
depending on the outcome of that

172
00:13:33,510 --> 00:13:37,300
we may go even deeper.
You never know what you are going to

173
00:13:37,300 --> 00:13:41,320
see if you haven■t seen it before.
So this is the same thing I said

174
00:13:41,320 --> 00:13:45,829
before launch, I said I can tell
you about 25 things that this

175
00:13:45,829 --> 00:13:49,290
observatory is going to do that
are absolutely fantastic science

176
00:13:49,290 --> 00:13:52,490
and they will be dwarfed by the
25 things that I couldn■t tell

177
00:13:52,490 --> 00:13:56,510
you about, because if I could
tell you about them my name

178
00:13:56,510 --> 00:13:59,760
would be Ricardo Giaconni
or somebody like him and I

179
00:13:59,760 --> 00:14:04,260
would be sitting somewhere
else with my Nobel Prize.

180
00:14:04,260 --> 00:14:08,029
I think it is proven
confidence that Chandra will