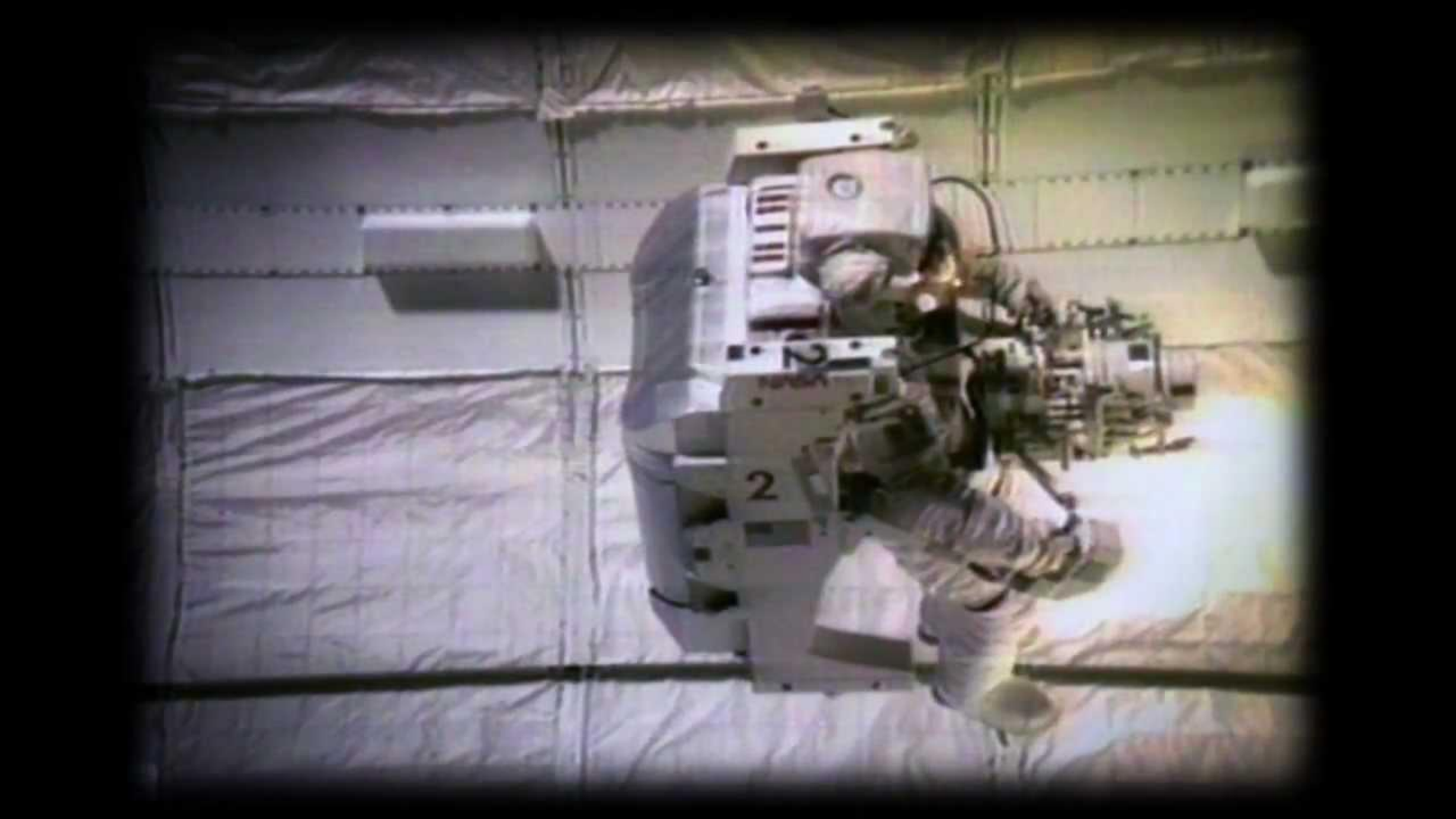
2

1
00:00:08,080 --> 00:00:04,040
(music)

2
00:00:08,100 --> 00:00:12,100
(beeping)

3
00:00:12,120 --> 00:00:16,150
Narrator: These days, one word drives high tech.

4
00:00:16,170 --> 00:00:20,200
Creativity. If nothing else,

5
00:00:20,220 --> 00:00:24,210
NASA’s Robotic Refueling Mission…RRM… is

6
00:00:24,230 --> 00:00:28,300
creativity embodied…and like all things creative, it’s not without

7
00:00:28,320 --> 00:00:32,380
challenges. Ben Reed: It’s not loading groceries into your shopping cart. It has

8
00:00:32,400 --> 00:00:36,600
It’s in a harsher environment. It’s going 18,000

9
00:00:36,620 --> 00:00:40,790
mph up in space. Spacecraft usually travel to orbit like museum

10
00:00:40,810 --> 00:00:44,870
pieces. They’re not meant to be fiddled with once they’re hung in their final destinations.

11
00:00:44,890 --> 00:00:48,900
But satellites are machines, and like all machines,

12
00:00:48,920 --> 00:00:52,920
fuel runs low. Parts wear out.

13
00:00:52,940 --> 00:00:57,000

RRM set out to prove that robots could repair them in space,

14
00:00:57,020 --> 00:01:01,050
without placing an astronaut at risk. It’s really hard to do…

15
00:01:01,070 --> 00:01:05,080
full of challenging problems.

16
00:01:05,100 --> 00:01:09,140
Ross Henry: …any problem is a solvable problem…and repairing satellites in space

17
00:01:09,160 --> 00:01:13,190
is not a new problem to solve.

18
00:01:13,210 --> 00:01:17,250
NASA has been wrestling with spacecraft on orbit for decades.

19
00:01:17,270 --> 00:01:21,380
Early efforts demanded human muscle. In 1984

20
00:01:21,400 --> 00:01:25,450
astronauts captured the Solar Max satellite for an

21
00:01:25,470 --> 00:01:29,500
astounding zero-G trip to the doctor. After a little TLC,

22
00:01:29,520 --> 00:01:33,630
it went back to work, good as new.

23
00:01:33,650 --> 00:01:37,670
The most famous orbital repairs happened with the Hubble Space Telescope.

24
00:01:37,690 --> 00:01:41,700
When astronauts paid it a final house-call in 2009,

25
00:01:41,720 --> 00:01:45,740
the billion dollar instrument got a new lease on life.

26
00:01:45,760 --> 00:01:49,830
Hugely expensive, extremely risky, the Hubble repair mission

27
00:01:49,850 --> 00:01:53,900
tested the bounds of human on-orbit capabilities…not to mention

28
00:01:53,920 --> 00:01:57,920
cost-benefit analysis. But mission success rein-

29
00:01:57,940 --> 00:02:02,040
reinforced the value of on-orbit repairs and the great Hubble Space Telescope

30
00:02:02,060 --> 00:02:06,140
continues to operate to this day.

31
00:02:06,160 --> 00:02:10,250
Complex machines, satellites are neither easily built nor replaced.

32
00:02:10,270 --> 00:02:14,320
Refueling and repairing them in space just makes

33
00:02:14,340 --> 00:02:18,390
sense. Ben Reed: Robots can do things that humans can’t do

34
00:02:18,410 --> 00:02:22,430
in terms of precision, in terms of control. Holding a particular spot

35
00:02:22,450 --> 00:02:26,530
for six hours while engineers on the ground debate what to do: we can’t

36
00:02:26,550 --> 00:02:30,550
ask a human to do that.

37
00:02:30,570 --> 00:02:34,580
Narrator: Will robots make astronauts obsolete?

38
00:02:34,600 --> 00:02:38,640

Not a chance, and the reason why is pretty awesome.

39
00:02:38,660 --> 00:02:42,750
Think of a car…like this…in for repairs.

40
00:02:42,770 --> 00:02:46,790
A mechanic can slide underneath…try to reach tough spots. But with

41
00:02:46,810 --> 00:02:50,890
a mechanical lift, repair options expand.

42
00:02:50,910 --> 00:02:54,940
Machines like this…like robots…act as enablers rather than

43
00:02:54,960 --> 00:02:58,960
replacements. Robots free astronauts from certain time consuming

44
00:02:58,980 --> 00:03:03,020
and risky operations. Astronaut time is better spent on

45
00:03:03,040 --> 00:03:07,110
command and control issues, as well as valuable research and exploration.

46
00:03:07,130 --> 00:03:11,160
Robots can also travel places astronauts are not

47
00:03:11,180 --> 00:03:15,170
likely to go. Teri Gregory: Other projects have been out to geosynchronous orbit

48
00:03:15,190 --> 00:03:19,270
and have spacecraft there and have been there for years. So we know what materials

49
00:03:19,290 --> 00:03:23,390
work there, we know what the environment is there, and we can use that information

50
00:03:23,410 --> 00:03:27,420
to build on what we're going to do when we build our spacecraft to go there.

51
00:03:27,440 --> 00:03:31,450
Narrator: As NASA prepared to launch the final space

52
00:03:31,470 --> 00:03:35,580
shuttle, the Satellite Servicing Capabilities Office pressed forward

53
00:03:35,600 --> 00:03:39,650
with an idea. A test…designed to see if robot

54
00:03:39,670 --> 00:03:43,730
technology was up to the job. In eighteen months

55
00:03:43,750 --> 00:03:47,750
the team designed the essential RRM experiments,

56
00:03:47,770 --> 00:03:51,930
getting hardware built, launched, and installed on the International Space Station.

57
00:03:51,950 --> 00:03:55,960
Teri Gregory: “We had a very aggressive schedule to launch in 2011 to make it

58
00:03:55,980 --> 00:03:59,970
onto the last shuttle flight, which we succeeded in doing. Ross Henry: So

59
00:03:59,990 --> 00:04:04,000
We always say we want to test as we fly. We want to test, test, and test

60
00:04:04,020 --> 00:04:08,070
again. Narrator: They did. The team completed a series

61
00:04:08,090 --> 00:04:12,170
delicate maneuvers, custom robotic tools standing in

62
00:04:12,190 --> 00:04:16,210
for astronaut fingers. RRM’s to-do

63
00:04:16,230 --> 00:04:20,270

list looked easy. Unscrew this, cut that, refill a tank like

64
00:04:20,290 --> 00:04:24,310
pulling up to the low octane pump, right? No.

65
00:04:24,330 --> 00:04:28,340
Not easy at all. Day two, in fact came to a halt

66
00:04:28,360 --> 00:04:32,400
halfway in the middle when engineers overseeing the robotic arm had some concerns.

67
00:04:32,420 --> 00:04:36,440
A crisis? Ben Reed: It certainly caught our attention, but it

68
00:04:36,460 --> 00:04:40,190
wasn’t a heart pounding moment. Not by any stretch. Narrator: And that’s the thing about missions

69
00:04:40,210 --> 00:04:44,300
like this. They demand the best from teams, and people

70
00:04:44,320 --> 00:04:48,450
don’t get on the team unless they’re willing to bring their A-game.

71
00:04:48,470 --> 00:04:52,600
On Day six,

72
00:04:52,620 --> 00:04:56,620
the team put three years of planning to work. With ethanol streaming

73
00:04:56,640 --> 00:05:00,710
into a test tank on orbit, engineers watched the data stream back to earth.

74
00:05:00,730 --> 00:05:04,740
There wasn’t much to see…but that wasn’t the point.

75
00:05:04,760 --> 00:05:08,770
It was a first. Word came over comms, loud and clear.

76
00:05:08,790 --> 00:05:12,820
SOT “you would agree…we have fluid transfer in progress.”

77
00:05:12,840 --> 00:05:16,840
No cheering yet. The team was still in

78
00:05:16,860 --> 00:05:20,920
the mission, and there were still jobs to do.

79
00:05:20,940 --> 00:05:25,030
Finally,

80
00:05:25,050 --> 00:05:29,090
simulated fuel transferred, the team moved to detach the valve.

81
00:05:29,110 --> 00:05:33,200
(music)

82
00:05:33,220 --> 00:05:37,280
Real experiments often yield interesting results.

83
00:05:37,300 --> 00:05:41,370
But after so much hard work, some things

84
00:05:41,390 --> 00:05:45,420
are just to be expected. (clapping)

85
00:05:45,440 --> 00:05:49,450
NASA’s reasons for doing this work go beyond the obvious. In

86
00:05:49,470 --> 00:05:53,590
fact, the deeper value for the nation…is ingenious.

87
00:05:53,610 --> 00:05:57,700
Ben Reed: I don’t want my job to be refueling communication birds for a living.

88
00:05:57,720 --> 00:06:01,730

I truly do not. I want to do it one time, kickstart a commercial

89
00:06:01,750 --> 00:06:05,750
industry that can then do it competitively. Narrator: This work helps

90
00:06:05,770 --> 00:06:09,820
open the door to a whole new kind of aerospace business.

91
00:06:09,840 --> 00:06:13,870
Big business. Engineering in space:

92
00:06:13,890 --> 00:06:17,940
inventive, daring, smart…and RRM

93
00:06:17,960 --> 00:06:22,070
delivered them all. But the big picture? There's only one

94
00:06:22,090 --> 00:06:26,110
word that will suffice: …creative.

95
00:06:26,130 --> 00:06:30,180
Ross Henry: If you think RRM was incredible you guys haven't seen anything yet.

96
00:06:30,200 --> 00:06:34,330
(beeping)