
HYSTER
HYSTER
HE 401-271

1
00:00:00,020 --> 00:00:13,780
Launch Commentator: Go for main engine start. We have main engine start. 2, 1, booster ignition and the final

2
00:00:13,780 --> 00:00:15,540
Bob Cabana, Four-Time Shuttle Astronaut: The two solid rocket motors, that's a pretty

3
00:00:15,540 --> 00:00:21,500
rough ride, but you can feel the thrust tail off right before they separate and you get

4
00:00:21,500 --> 00:00:25,540
an indication, PC less than 50 and you know you're going to be there, two minutes,

5
00:00:25,540 --> 00:00:29,300
five seconds or so. They separate away. There's a huge flash in the front window,

6
00:00:29,300 --> 00:00:33,060
a big bang, you can hear those sep motors push away and then it's just as smooth as

7
00:00:33,060 --> 00:00:37,180
can be on those main engines. They're phenomenal pieces of machinery.

8
00:00:37,180 --> 00:00:40,870
NARRATOR: The space shuttle main engines have been one of the brightest success

9
00:00:40,870 --> 00:00:45,710
stories of the space shuttle's 30-year career. Powered by a combination of fuel

10
00:00:45,710 --> 00:00:51,360
and oxygen, a single SSME, as the engines are called, produces about 500,000

11
00:00:51,360 --> 00:00:56,430
pounds of thrust. Working with the two solid rocket boosters for the first two

12
00:00:56,430 --> 00:01:01,380
minutes of launch, three main engines push a shuttle up to Mach 25 and into orbit in

13
00:01:01,380 --> 00:01:04,290

eight and a half minutes.

14
00:01:04,290 --> 00:01:06,580
Daniel Hausman, Pratt & Whitney Rocketdyne: We call the SSME an extreme machine and

15
00:01:06,580 --> 00:01:11,820
it's extreme because on the inlet you've got liquid oxygen and liquid hydrogen and

16
00:01:11,820 --> 00:01:15,070
liquid hydrogen is minus 420 degrees Fahrenheit. So it's extremely cold propellant

17
00:01:15,070 --> 00:01:20,770
that we're putting through the turbo machinery and then we're burning it in the main

18
00:01:20,770 --> 00:01:26,700
combustion chamber at 6,000 degrees Fahrenheit, so that's hot enough to melt iron.

19
00:01:26,700 --> 00:01:30,590
NARRATOR: It can do that without melting because the engine pumps the cryogenic

20
00:01:30,590 --> 00:01:36,920
hydrogen through a series of 1,040 tubes lining the nozzle. The super-cold fuel keeps

21
00:01:36,920 --> 00:01:39,760
the flames from touching the sides of the nozzle.

22
00:01:39,760 --> 00:01:43,390
NARRATOR: There also are a pair of turbopumps that move the propellants through the

23
00:01:43,390 --> 00:01:48,880
machinery and into the combustion chamber quickly. The turbopumps alone produce more

24
00:01:48,880 --> 00:01:52,970
power than a locomotive, even though they would fit on a desk.

25
00:01:52,970 --> 00:01:56,830
NARRATOR: Providing that amount of power safely calls for extensive testing and

26
00:01:56,830 --> 00:02:01,830
inspections of each engine and their turbopumps. A main engine gets examined from

27
00:02:01,830 --> 00:02:05,480
the time the shuttle lands until liftoff. Highly trained technicians use long,

28
00:02:05,480 --> 00:02:11,960
flexible lenses called borescopes to look at each engine's insides for

29
00:02:11,960 --> 00:02:13,910
cracks or other defects.

30
00:02:13,910 --> 00:02:19,190
HERRIDGE: A skilled technician engineer can perform a real good borescope inspection

31
00:02:19,190 --> 00:02:26,070
of bearings, seals and actually the turbine blades, nozzle veins,

32
00:02:26,070 --> 00:02:30,820
pump blades and diffusers.

33
00:02:30,820 --> 00:02:36,000
NARRATOR: The engines' success did not come easy. Engineers began testing engine

34
00:02:36,000 --> 00:02:40,800
designs in 1975, at NASA's Stennis Space Center in Mississippi.

35
00:02:40,800 --> 00:02:45,880
Just getting the start-up sequence right took months and months of complex work.

36
00:02:45,880 --> 00:02:51,140
PLOWDEN: Well, of course the first test of a space shuttle main engine on the A1 test

37
00:02:51,140 --> 00:02:57,750
stand was like 20 milliseconds. I mean, it took a long time to develop the start

38
00:02:57,750 --> 00:03:03,680

sequence of the engine and it was 20 milliseconds, finally 40. They worked their way

39
00:03:03,680 --> 00:03:08,550
up to one and half seconds, which is a critical time period in the thrust build up

40
00:03:08,550 --> 00:03:12,350
of the start sequence and then it just went on from there.

41
00:03:12,350 --> 00:03:16,960
It took a long time to actually finally get to main stage.

42
00:03:16,960 --> 00:03:21,920
NARRATOR: The shuttle's main engines made their first flight test on April 12, 1981,

43
00:03:21,920 --> 00:03:26,400
along with the rest of the space shuttle system. Although the engines had been fired

44
00:03:26,400 --> 00:03:31,290
on test stands, no crew flew with them until Commander John Young and Pilot

45
00:03:31,290 --> 00:03:35,190
Bob Crippen rode them into orbit on STS-1.

46
00:03:35,190 --> 00:03:39,870
HAUSMAN: When that whole vehicle got together we put the crew in and we counted down

47
00:03:39,870 --> 00:03:44,800
and we saw engine ignition and all three engines come up, it is just an extremely

48
00:03:44,800 --> 00:03:51,040
rewarding experience to see that and see the SRBs fire and see that whole orbiter

49
00:03:51,040 --> 00:03:57,430
take off and fly was, it was hard to describe. Because of all the activities I know

50
00:03:57,430 --> 00:04:03,250
led up to that, and the people involved in it, to see that as a successful mission

51
00:04:03,250 --> 00:04:08,730
because we didn't have an opportunity to fly it unmanned before we flew it manned.

52
00:04:08,730 --> 00:04:13,480
So that's the first time this country really did an experiment with people on board.

53
00:04:13,480 --> 00:04:15,060
And it all worked.

54
00:04:15,060 --> 00:04:18,490
NARRATOR: Though the shuttle engines are smaller than the mammoth F-1s that

55
00:04:18,490 --> 00:04:23,110
powered the Saturn V's first stage, they had to be far more efficient.

56
00:04:23,110 --> 00:04:26,790
DANIEL HAUSMAN: This was the first time we had to design an engine that would operate

57
00:04:26,790 --> 00:04:31,820
for eight-and-a-half minutes. In the Apollo program, the first stage engines would

58
00:04:31,820 --> 00:04:37,620
operate for about 200 seconds. It basically gets you up to about 50,000 feet or

59
00:04:37,620 --> 00:04:41,630
higher through the heavy atmosphere and then the first stage is spent and the second

60
00:04:41,630 --> 00:04:48,760
stage takes over. In this case the SSME was designed to start on the ground,

61
00:04:48,760 --> 00:04:54,270
have the ability to health check it before the solid rocket motors ignited and then

62
00:04:54,270 --> 00:04:59,710
commit to launch and then stay running all the way through orbital injection

63
00:04:59,710 --> 00:05:04,770

velocity, so that meant eight-and-a-half minutes. So that was different from engines

64
00:05:04,770 --> 00:05:06,980
we'd built previously.

65
00:05:06,980 --> 00:05:10,680
NARRATOR: Along with the brawn of hundreds of thousands of pounds of thrust,

66
00:05:10,680 --> 00:05:15,040
the engines carry very delicate brains that take constant measurements of the systems

67
00:05:15,040 --> 00:05:17,790
dozens of times every second.

68
00:05:17,790 --> 00:05:22,870
HAUSMAN: This is the first engine we built that had an active, onboard computer

69
00:05:22,870 --> 00:05:27,810
and the computer has a program in it that runs through a full cycle in 20 milliseconds.

70
00:05:27,810 --> 00:05:33,440
Fifty times a second it's out reading valve positions, sensor data and we have

71
00:05:33,440 --> 00:05:38,530
algorithms in there that allow that engine to have what we call health monitoring.

72
00:05:38,530 --> 00:05:43,440
So we have active flight red lines that in the event that temperature should exceed

73
00:05:43,440 --> 00:05:50,030
the limits, that engine will automatically shut itself down to prevent a catastrophic failure.

74
00:05:50,030 --> 00:05:53,460
NARRATOR: No mission ever failed because of a space shuttle main engine,

75
00:05:53,460 --> 00:05:57,420
but a couple saw close calls during launch.

76
00:05:57,420 --> 00:06:02,880
In 1985, one of the engines on space shuttle Challenger picked up a problem.

77
00:06:02,880 --> 00:06:07,500
HAUSMAN: They actually shut that engine down at 18,000 feet per second and let the

78
00:06:07,500 --> 00:06:12,870
other two engines run the vehicle until it actually reached the velocity required to

79
00:06:12,870 --> 00:06:17,840
make orbit. So it was a successful mission and it just showed that the redundancy

80
00:06:17,840 --> 00:06:21,730
built into the engines really paid off.

81
00:06:21,730 --> 00:06:25,420
NARRATOR: The space shuttle's main engines also had a requirement no other engine

82
00:06:25,420 --> 00:06:29,350
faced before. They had to be reusable.

83
00:06:29,350 --> 00:06:33,820
HAUSMAN: Reusability created issues with hardware embrittlement. It was hydrogen

84
00:06:33,820 --> 00:06:39,520
molecules embedding themselves in the material causing embrittlement later on.

85
00:06:39,520 --> 00:06:44,630
So that created life cycle uses and we were always talking about, what's the remaining

86
00:06:44,630 --> 00:06:46,620
life in the hardware.

87
00:06:46,620 --> 00:06:52,200
NARRATOR: The SSMEs produce nothing but steam when they fire, another departure from

88
00:06:52,200 --> 00:06:52,950

previous rocket engines.

89
00:06:52,950 --> 00:06:57,500
Natural sound of liftoff

90
00:06:57,500 --> 00:07:00,920
HAUSMAN: Oxygen and hydrogen, when it combines and creates water,

91
00:07:00,920 --> 00:07:06,530
it's very clean. A lot different from the Apollo days when you had liquid oxygen and

92
00:07:06,530 --> 00:07:08,980
kerosene. Well, this engine's extremely

93
00:07:08,980 --> 00:07:13,490
clean and people are amazed when they look at the engines in the shop that have

94
00:07:13,490 --> 00:07:16,210
flown 10 times or more, they look brand new.

95
00:07:16,210 --> 00:07:20,350
NARRATOR: The shuttle main engines have proven to be extremely reliable machines

96
00:07:20,350 --> 00:07:25,110
with a record of reusability and success without parallel in rocketry.

97
00:07:25,110 --> 00:07:32,950
PLOWDEN: SSME's in a class all by itself. The reliability that we get of the SSME,

98
00:07:32,950 --> 00:07:38,480
the reliability and performance is what allows the shuttle to fly.