Launch Commentator: Go for main engine start. We have main engine start. 2, 1, booster ignition and the final liftoff of Discovery.

Bob Cabana, Four-Time Shuttle Astronaut: The two solid rocket motors, that's a pretty rough ride, but you can feel the thrust tail off right before they separate and you get an indication, PC less than 50 and you know you're going to be there, two minutes, five seconds or so. They separate away. There's a huge flash in the front window, a big bang, you can hear those sep motors push away and then it's just as smooth as can be on those main engines. They're phenomenal pieces of machinery.

NARRATOR: The space shuttle main engines have been one of the brightest success stories of the space shuttle's 30-year career. Powered by a combination of fuel and oxygen, a single SSME, as the engines are called, produces about 500,000 pounds of thrust. Working with the two solid rocket boosters for the first two minutes of launch, three main engines push a shuttle up to Mach 25 and into orbit in eight and a half minutes.

Daniel Hausman, Pratt & Whitney Rocketdyne: We call the SSME an extreme machine and
it's extreme because on the inlet you've got liquid oxygen and liquid hydrogen and

liquid hydrogen is minus 420 degrees Fahrenheit. So it's extremely cold propellant

that we're putting through the turbo machinery and then we're burning it in the main

combustion chamber at 6,000 degrees Fahrenheit, so that's hot enough to melt iron.

NARRATOR: It can do that without melting because the engine pumps the cryogenic

hydrogen through a series of 1,040 tubes lining the nozzle. The super-cold fuel keeps

the flames from touching the sides of the nozzle.

NARRATOR: There also are a pair of turbopumps that move the propellants through the

machinery and into the combustion chamber quickly. The turbopumps alone produce more

power than a locomotive, even though they would fit on a desk.

NARRATOR: Providing that amount of power safely calls for extensive testing and

inspections of each engine and their turbopumps. A main engine gets examined from

the time the shuttle lands until liftoff. Highly trained technicians use long,

flexible lenses called borescopes to look at each engine's insides for
cracks or other defects.

HERRIDGE: A skilled technician engineer can perform a real good borescope inspection of bearings, seals and actually the turbine blades, nozzle veins,

pump blades and diffusers.

NARRATOR: The engines' success did not come easy. Engineers began testing engine designs in 1975, at NASA's Stennis Space Center in Mississippi.

Just getting the start-up sequence right took months and months of complex work.

PLOWDEN: Well, of course the first test of a space shuttle main engine on the A1 test stand was like 20 milliseconds. I mean, it took a long time to develop the start sequence of the engine and it was 20 milliseconds, finally 40. They worked their way up to one and half seconds, which is a critical time period in the thrust build up of the start sequence and then it just went on from there.

It took a long time to actually finally get to main stage.

NARRATOR: The shuttle's main engines made their first flight test on April 12, 1981,
along with the rest of the space shuttle system. Although the engines had been fired
on test stands, no crew flew with them until Commander John Young and Pilot Bob Crippen rode them into orbit on STS-1.

HAUSMAN: When that whole vehicle got together we put the crew in and we counted down and we saw engine ignition and all three engines come up, it is just an extremely rewarding experience to see that and see the SRBs fire and see that whole orbiter take off and fly was, it was hard to describe. Because of all the activities I know led up to that, and the people involved in it, to see that as a successful mission because we didn't have an opportunity to fly it unmanned before we flew it manned.

So that's the first time this country really did an experiment with people on board.

And it all worked.

NARRATOR: Though the shuttle engines are smaller than the mammoth F-1s that powered the Saturn V's first stage, they had to be far more efficient.

DANIEL HAUSMAN: This was the first time we had to design an engine that would operate for eight-and-a-half minutes. In the Apollo program, the first stage engines would
operate for about 200 seconds. It basically gets you up to about 50,000 feet or

higher through the heavy atmosphere and then the first stage is spent and the second

stage takes over. In this case the SSME was designed to start on the ground,

have the ability to health check it before the solid rocket motors ignited and then

commit to launch and then stay running all the way through orbital injection

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

we'd built previously.

Along with the brawn of hundreds of thousands of pounds of thrust,

the engines carry very delicate brains that take constant measurements of the systems

dozens of times every second.

HAUSMAN: This is the first engine we built that had an active, onboard computer

and the computer has a program in it that runs through a full cycle in 20 milliseconds.

Fifty times a second it's out reading valve positions, sensor data and we have

algorithms in there that allow that engine to have what we call health monitoring.
So we have active flight red lines that in the event that temperature should exceed
the limits, that engine will automatically shut itself down to prevent a catastrophic failure.

NARRATOR: No mission ever failed because of a space shuttle main engine,
but a couple saw close calls during launch.

In 1985, one of the engines on space shuttle Challenger picked up a problem.

HAUSMAN: They actually shut that engine down at 18,000 feet per second and let the
other two engines run the vehicle until it actually reached the velocity required to
make orbit. So it was a successful mission and it just showed that the redundancy
built into the engines really paid off.

NARRATOR: The space shuttle's main engines also had a requirement no other engine
faced before. They had to be reusable.

HAUSMAN: Reusability created issues with hardware embrittlement. It was hydrogen
molecules embedding themselves in the material causing embrittlement later on.

So that created life cycle uses and we were always talking about, what's the remaining
life in the hardware.

NARRATOR: The SSMEs produce nothing but steam when they fire, another departure from previous rocket engines.

Natural sound of liftoff

HAUSMAN: Oxygen and hydrogen, when it combines and creates water, it's very clean. A lot different from the Apollo days when you had liquid oxygen and kerosene. Well, this engine's extremely clean and people are amazed when they look at the engines in the shop that have flown 10 times or more, they look brand new.

NARRATOR: The shuttle main engines have proven to be extremely reliable machines with a record of reusability and success without parallel in rocketry.

PLOWDEN: SSME's in a class all by itself. The reliability that we get of the SSME, the reliability and performance is what allows the shuttle to fly.

HERRIDGE: As far as the extreme temperatures, the pressure they operate, the fact that they have
been reusable, that they have been so reliable since STS-1 to STS-135 I still rate the main engines at the top.