

# NASA Facts

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## FACT SHEET

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### Engine Cutoff Sensor System

The sensor system is one of several that protect the shuttle's main engines by triggering their shut down in the event fuel - either liquid hydrogen or liquid oxygen - levels in the external tank run unexpectedly low. The ECO sensors operate much like the "gas low" warning light in an automobile. When the fuel level drops below a sensor, that sensor sends a message to the orbiter's computer that it is dry.

Orbiter computers poll these sensors about 8-12 seconds prior to planned Main Engine Cutoff, or MECO, which is about 8.5 minutes after launch.

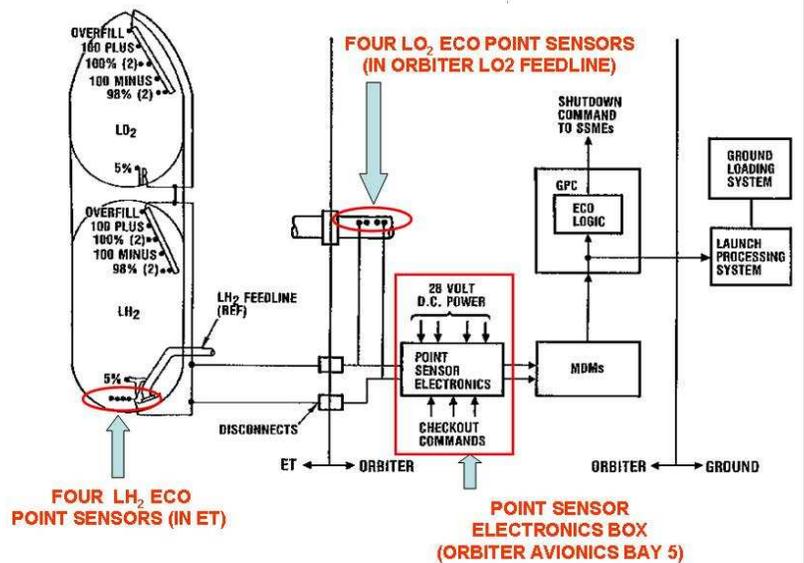
If two of the four ECOs indicate dry, which means the tank is almost empty, the space shuttle main engines will be immediately shut down. If the main engines are shut down prior to normal operating time, it could affect whether or not the shuttle reaches the appropriate orbit. (The Orbital Maneuvering System engines do have the ability to make up for a slightly early main engine cutoff.)

In the history of the Space Shuttle Program, the LH2 ECO system has never initiated an engine shut down. Ascent performance margin and fuel bias provide additional protection against premature fuel depletion. Failure to shut down the engines before depletion could result in catastrophic engine failure and loss of vehicle and crew. NASA requires three of four functioning sensors to launch, although the shuttle has never lifted off without a fully functioning ECO system.

#### Liquid Hydrogen ECO System

The sensors in the LH2 section of the external tank include wiring, harnesses, a series of connectors and point sensor box electronics in the orbiter. The sensors in the tank send electronic signals through wires to the point sensor box in the orbiter, which in turn sends data signals to the orbiter's onboard computer system. The sensor wires lead to a feed through connector in the side of the tank. The external cables run up the external tank vertical strut to the LH2 ET/orbiter interface. The circuit is then routed inside the orbiter to the point sensor electronics box.

There are four ECO sensors in the LH2 tank, mounted on a single, shock isolated carrier plate approximately four feet from the bottom of the tank. There are similar ECO sensors on the liquid oxygen side that are located in the Main Propulsion System LOX feedline inside the orbiter.



#### Launch Day ECO Sensor Testing

Once propellant loading begins, the LH2 ECO sensors will read 'wet,' meaning they are covered with cryogenic propellant. To demonstrate their proper functioning, the sensors are tested during tanking operations. Once we enter the fast fill stage of tanking, we send an electronic command to force the sensors to read 'dry'. This simulated 'dry' command is held until just after we enter the T-9 minute hold, when the command is removed and the sensors are monitored to assure that they are reading 'wet' through the remainder of the count.

## TROUBLESHOOTING THE ECO SENSOR SYSTEM

### History of ECO Sensor Problems

- **STS-114, (ET-121), July 2005** – During tanking, an ECO sensor showed abnormal readings and caused a two-week postponement. An exhaustive engineering analysis was performed, which led to a safety of flight rationale that three of the four sensors reading normal would be okay for launch. Launch occurred on July 26, 2005, and no ECO sensor issue like what occurred during the July 13 launch attempt reoccurred.
- **STS-121 (ET-119), July 2006** -- An ECO sensor showed an abnormal reading on sensor 3 at NASA's Michoud Assembly Facility before shipment. No action was taken because it was determined that if change-out was required, the work could be done at NASA's Kennedy Space Center in Florida in the check-out cell to provide better access. A decision was made to replace all four sensors, postponing launch from March to July.
- **STS-115 (ET-118), Sept 2006** -- ECO sensors aboard STS-115 were replaced in June 2006 at Kennedy after a potential issue was identified with a lot manufactured in 1996. There was a one day delay. The shuttle launched on Sept. 9.

### Space Shuttle Atlantis' STS-122 Mission

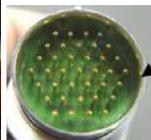
The launch of shuttle Atlantis on STS-122 was delayed in December 2007 after failures occurred in the fuel sensor system while Atlantis' external tank was being filled.

- The Dec. 6 launch attempt was postponed after two of the four LH2 tank ECO sensors gave false readings. NASA's launch commit criteria required three of four functioning sensors to lift off. A third sensor failed after the tank was drained of fuel. Within several hours of the tanking operation, all four ECO circuits returned correct readings.
- On Dec. 9, one of the four ECO sensors inside the LH2 section of the tank gave a false reading, causing the launch to be postponed for the second time. NASA modified its launch commit criteria for this attempt to require that all four sensors function properly.

### Going Forward Plan

A tanking, or fueling, test at Kennedy on Dec. 18, 2007, revealed that open circuits in the external tank's external electrical feed through connector were the most likely cause of false readings in the ECO sensor system during launch attempts on Dec. 6 and Dec. 9. NASA formed a combined troubleshooting team involving multiple NASA centers to find the root cause and develop plans to fix the system. A parallel team also was established to develop a forward plan of action to support the earliest possible launches STS-122 and STS-123.

After removing a layer of external tank foam insulation at the launch pad, the external plug and feed through connector were removed from the tank and shipped to Marshall Space Flight Center in Alabama to determine whether the failure could be recreated in a test facility using focused and limited nondestructive and destructive physical tests. The tests were configured to replicate tank chill down temperatures, loading pressures and environmental conditions during the two launch attempts.



Feed Through Connector  
(1.25" dia. x 2.25" length)



Chad Bryant, ET project manager at Marshall, and Greg Vinyard of Lockheed Martin, prepare to install ET-125's feed through connector in a pressure vessel. The ECO sensor connector is undergoing testing to determine if it was the cause of the false sensor readings.

All circuit anomalies experienced during testing were able to be repeated as seen during the two launch attempts and tanking test. Open circuits in the part that connects wires from the interior to the exterior of the liquid hydrogen tank, commonly known as the feed through plate, were identified as the culprit that caused false readings during two launch attempts and a tanking test in December 2007.

A modified connector was designed with the pins and sockets soldered together. A similar, but slightly redesigned connector was to be used. Both the original and modified connector configurations were subjected to temperature, pressure and vibration environments identical to those experienced during a shuttle launch. The tests verified the adequacy of the new configuration.



At a lab at Kennedy, Bob Arp, United Launch Alliance technician, solders a pin to the socket of the replacement feed-through connector