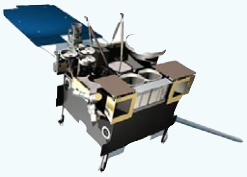
A Close-up Look at Launching GOES-O



... our next weather satellite

Ed Murashie

Do you ever wonder what it takes to get those nightly television weather pictures? What it takes is a satellite in an orbit 22,000 miles away, where it moves at the same speed as the Earth's rotation so it appears stationary. This special orbit is called a geostationary orbit. That orbit lets the satellite take a steady picture of the earth every 15 minutes. The weatherman then animates or shows each picture in sequence so the clouds move but the Earth does not. But wait—we are getting ahead of ourselves! How does the satellite reach orbit? Seeing the rockets and satellites up close is more fascinating than the pictures they transmit.

Let's walk through the process as Brian Bauerlin takes us on a tour of Cape Canaveral Air Force Station's Launch Complex 37B (LC37B) in Florida, where the United Launch Alliance (ULA) *Delta-IV* rocket is launched. The tour will also include the *Astrotech* facility in nearby Titusville Florida, where the GOES-O satellite resides before being placed on top of its *Delta-IV* rocket. Brian is highly qualified in explaining the launch process, from planning stages through lift-off; he is the Mission Integration Manager for GOES-O. Brian led this tour, giving behind-the-scene facts and humourous stories. He is very passionate about his job and for him, every launch is a thrill.

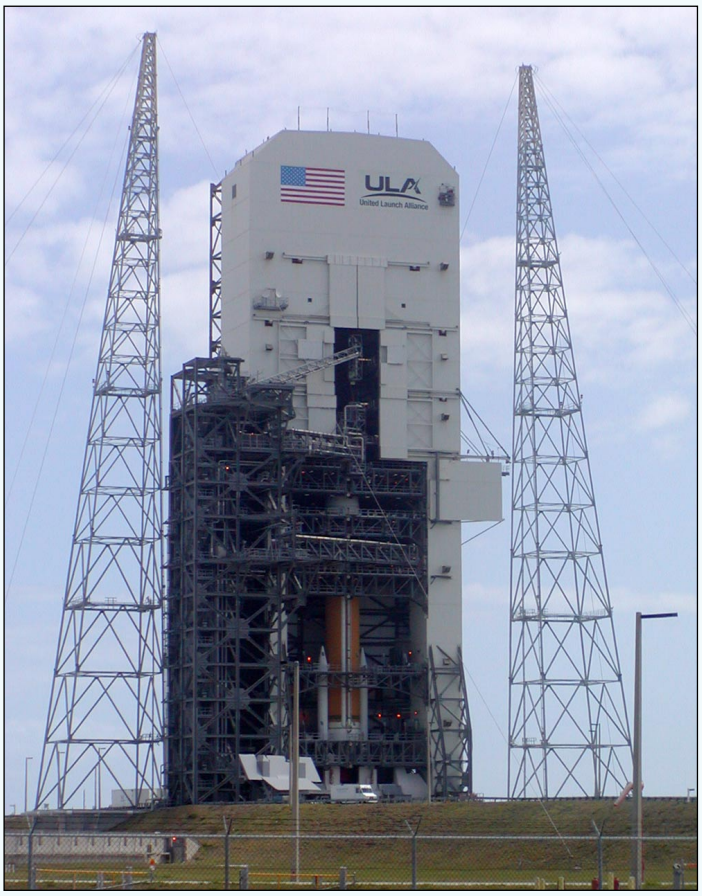
The tour begins at the Horizontal Integration Facility (HIF) which is just south of LC37B. GOES-O will be launched using a ULA *Delta-IV* Medium Plus (4,2). A ULA what? And who is ULA?

United Launch Alliance [1] is a joint venture, formed in December 2006, between *Lockheed Martin* and *Boeing*. In order to compete with Russia, Europe, China and others in the world satellite launch market, Lockheed Martin (with their *Atlas* rockets) and Boeing (with their *Delta* rockets) combined their Space Divisions to form ULA. Since the capabilities of the *Delta* and *Atlas* overlap, what determines which rocket is used? Heavy payloads are launched on Delta-IVs and the rest are decided by customer requirements and preferences.

Boeing developed the *Delta-II*, *Delta-III* and *Delta-IV* rockets, each one more capable than its predecessor in lifting heavier loads into higher orbits. The *Delta-II* is used to launch the polar orbiting NOAA weather satellites into lower orbits. The *Delta III* was discontinued in favour of the *Delta-IV*, which comes in *Medium*, *Medium-Plus* and *Heavy* versions. The *Delta-II* and *Delta-IV* rockets will be around for the foreseeable future.

All *Delta-IV*s [2] start with a Common Booster Core (CBC) first stage. The *Medium-Plus* adds two or four solid fuel strap-on rockets—like the Space Shuttle—and either a 4 meter or 5 meter second stage and fairing. So a *Delta IV Medium-Plus (4,2)* has one CBC first stage, a 4 meter diameter second stage and fairing plus two solid rocket strap-on motors. Simple!

All ULA rockets, including the *Delta IV*, are manufactured at the Decatur, Alabama factory, in a building so large that 'you can fit approximately 18 *Wal-Mart* stores' into the factory; and 'if you stretched all of the runs end-to-end you would be looking along about 22 miles', explains Brian. The factory can process five complete rockets at one time, up to



The GOES-O Delta-IV on its Launchpad

40 CBCs per year and employs approximately 700 people. It starts the build process for a launch five or six years in advance. When complete, It takes 14 days to float the CBC, payload attach fitting, and fairing down the Tennessee River, through the Gulf of Mexico, around the Florida peninsula to Cape Canaveral. A one-of-a-kind ship named the *Delta Mariner* [3,4] is up to the task. It has a draft of only eight feet to navigate the waterways and then fills its ballast tanks with water, increasing its draft to fourteen feet for stability in the ocean. It has the capacity to carry three CBCs and a crew of fourteen (including one outstanding chef). It takes from 24-28 days to go though the Panama Canal and reach Vandenberg Air Force Base in California where *Deltas* are also launched.

Once the rocket and other components arrive at the dock they are moved to the *Horizontal Integration Facility* (HIF). Some rockets are stacked vertically, one stage after another, at the launch pad, like the *Delta-II*. Not so the *Delta-IV*. It is assembled horizontally in the HIF building, trucked to the launch pad then rotated into place. 'The floor you are standing on is North America's levelest floor', explains Brian. It requires this level of precision to join and laser-align the stages. Without the second stage being perfectly aligned to the interstage and the interstage being perfectly aligned to the first stage, the second stage would oscillate too much during separation. An excellent video onboard a *Delta-IV Heavy*, showing the staging, can be found on *YouTube* [5].

The HIF building contains offices and three bays for processing the rockets. It is temperature-controlled and has been designed to withstand hurricane strength winds of 140 mph. The doors are made of strong durable fabric so that they give with the wind better than metal doors and can be replaced easier. At the time of this tour, GPS rocket GPS2F1 and the WGS3 rocket are being processed. These rockets are huge, from the RS68 single engine, the engine compartment, up through the orange long hydrogen tank, the white interstage with the equipment shelf and avionics and past the orange oxygen tank, the interstage and second stage. The CBC alone is 5 metres in diameter and 40.8 meters long. It takes the team up to 60 days to complete the mating and testing. Part of the launch pad, the Launch Mate Unit, LMU, is also attached using bolts and frangible nuts in the HIF building. NASA images inside the HIF are available [6].

A frangible nut is a nut that has two explosive charges on each side. When the rocket is up to 100% thrust and all readings are good, the computer gives the command and the explosives split the nut in two: the bolt slips down and the rocket is released. The nuts and bolts are in heavy metal boxes so that none of the flying metal pieces penetrate the rocket. A video and pictures of a Space Shuttle frangible nut are available [7].

Mating the GOES-O Delta-IV 2nd stage to CBC
Image: NASA

The elevating platform transporter (EPT), built by the German company *Kamag*, carries the Delta rocket to the launch pad. This is the same vehicle that transported the CBC from the dock to the HIF and will also convey the payload from *Astrotech* to the launch pad. The EPT has a push pull cab, independent wheel axial control, sensors and hydraulics. The hydraulics keep the rocket aligned vertically, horizontally and axially. Brian pointed out how all of the road signs between the HIF and the launch pad are short. 'When you run a *Heavy* up there it hangs over the road and you can't have any signs there. It was a design item', jokes Brian, 'We had to stop, pick up the signs, and take them down'.

The rocket is moved into place where the LMU engages the *Launch Table* and *Fixed Pad Erector* and then two hydraulic cylinders rotate the rocket into place in twenty minutes. Next, two 60-inch solid rocket GEM-60 motors, manufactured by *Alliant Techsystems*, are delivered to the launch pad. They are hoisted on the side opposite the rocket, moved over the second stage, lowered into place and secured. Pictures of GOES-O's *Delta-IV* being transported to the pad and the *Fixed Pad Erector* can be viewed [8].

The author (left), pictured with Brian Bauerlin in front of the Astrotech Building

The launch pad's two largest components are the stationary gray *Fixed Umbilical Tower* (FUT) with its three swing arms and the moveable white *Mobile Service Tower* (MST). The MST is over 330 feet high and weighs over 4000 tonnes just before launch. 160 mph hurricane rated locks release, the tower lifts up 3 to 4 inches and then rolls back 300 yards on rails. 'This is one of the largest moveable structures in the world!', exclaims Brian. Next to the launch pad are two lightning towers to protect the pad and workers. Before lightning towers were installed, everyone had to stop working during a Phase-1 alert, which is when lightning is expected within 5 nautical miles in approximately 30 minutes. Today they can work through a Phase-1 alert and only have to stop lifting and ordinance operations during a Phase-2, when lightning is imminent or occurring within 5 nm, saving time.

Riding the elevator to the 8th floor and stepping out, puts you at eye level with the top of the second stage and a removable protective dome. This is where the satellite payload will be mated to the second stage. The view is incredible with plenty of room around the rocket to work. There is so much work-space that a temporary clean room can be installed next to the payload to allow the access panels to be removed and work on the satellite to be performed. Each level has platforms that drop down allowing technicians to work around the entire rocket and satellite. Just before launch these platforms lift, allowing the tower to roll back. Floors 8, 9 and 10 are air temperature controlled. Brian points out the tape running down the second stage and explains that there are shaped charges on the rocket that are part of the range protection system. If the rocket veers off course, a command is sent to detonate the charges causing the rocket to explode. NASA won't settle for less than a high reliability factor when it comes to range safety, especially since this *Delta-IV* is more powerful than the *Saturn-1B* rockets formerly launched from the previous launch pad at this same site. That is why even the *Saturn-1B* blockhouse next to the pad is no longer manned during a launch—in case of an explosion.

When the satellite is brought to the launch pad, it will be raised by a 50 tonne crane from the side of the MST tower opposite the rocket. It is raised above the 8th level and lowered on to the second stage, leaving the top of the GOES rocket at the 11th floor. Brian takes us to the best view on the entire cape. Down one floor and through a red door marked '*NOT AN EXIT*', is a 15 foot long 6 foot wide observation gantry with nothing but the floor grating between you and the ground seven floors down. From there we see the beach, the *Atlas V* launch pad, the two space shuttle pads, *Vertical Assembly Building* and surrounding area for miles around. Looking down we see remnants of the original *Saturn-1B* launch pad, the hydrogen and oxygen spheres used to fuel the rockets and the theodolite building. What's a theodolite you might ask? It is an instrument to precisely measure the rocket's location on the Earth and is used in the rocket's trajectory calculations.

Not only does this tour take us from the top of the second stage, to beneath the first stage engine, it takes us below

Lifting the GOES-O Delta-IV onto the launch pad
Image: NASA

the launch pad. Below the launch pad is the flame duct, which is flooded with fresh water during the launch for pad protection. Another layer of protection is the ablative material which coats the concrete walls of the flame duct and is repaired after each launch. The flame duct is so large that, if the middle supporting wall were removed, a 767 airplane could be parked in it. 'It would make for a great skateboard area' remarks Brian. During the *Titan* years there was a ritual where workers would line up Barney, Teletubby and other stuffed dolls at the edge of the flame duct and try to find them after the launch. You can view an outstanding movie of the launch pad and photos of the GOES-O and *Delta-IV* [9] as well as photos of the launch pad [10].

As we leave the pad we're looking for a non-official member of the launch team, Henry. Henry is the nine-foot alligator that sometimes roams the area. To keep Henry out of certain areas, the chain-link fences are curved at the top because alligators can climb regular chain link fences.

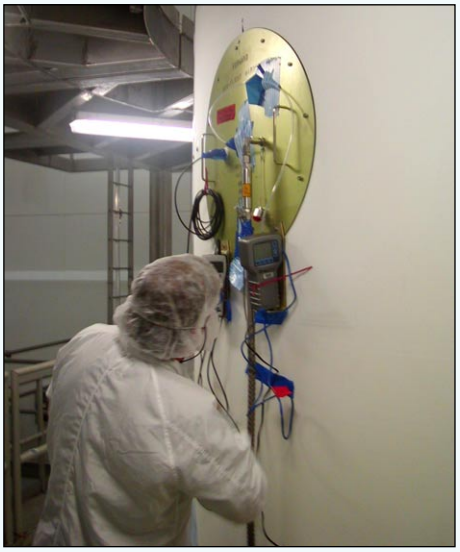
It takes as few as thirteen days on the launch pad to prepare the rocket and satellite for a launch. It can then stay on the pad with little support. If limited life items that have calibration or use-by dates are close to expiring, ULA will try to get a waiver. If a waiver is not granted, then the component must be replaced.

The 8th level on PAD37 with the solid rocket and the top of the 2nd stage visible
Credit: NASA

Approximately six hours before launch, the pad is cleared and no one is allowed closer than the Delta Operations Centre (DOC) where our tour takes us next. The DOC is where the second stage is processed before moving it to the HIF building. On the 4*th* floor is the Mission Directors Centre (MDC). The back row of the MDC is where the broadcast commentator sits. ULA, the launch director, flight director, flight operations director and chief engineer sit in the next row, closer to the large

Encapsulating GOES-O
Image: NASA

screen monitors and clocks; the NOAA satellite customer and NASA sit in the front row. This is the room where all main milestones and events are observed. Off to the right is a large window with a view of the launch pad. Not only is this room used during launch day, but also during wet dress rehearsals. This room is also used during inter-crew exercises (ICE). The full crew is brought in and run through simulated launches with anomalous events. One of Brian's former jobs as a Rehearsal Director, was to create those anomalies and gauge the customer's response. This could even be the customer's first



Brian inspecting the temperature and humidity readings inside the fairing.

launch, yet they need to know how to respond to the anomaly.

The Launch Conductor and all of the propellant, hydraulic, electrical, mechanical, and other engineers and technicians sit in the Launch Control Centre (LCC) located on the 3rd floor. It's the Launch Conductor you hear calling out the entire launch steps. The engineers who show up 10-12 hours prior to launch are looking at large DLPS computer monitors displaying all of the rocket and satellite sensor readings, which are colour coded to quickly point out the out-of-limit readings. As the countdown progresses, the computer takes over at T-1.5 seconds. So at T-10 seconds you might as well look out the LCC room window because there is nothing you can do; only the computer is quick enough to review all sensor readings and either launch or scrub.

What will Brian be doing during the launch? He will be acting as the

The author in the Astrotech Encapulation Bay next to the encapsulated GOES-O satellite.

Spacecraft Coordinator and will be monitoring the temperature and humidity readings in the payload fairing. He needs to ensure the temperature is 18-19°C, optimal for batteries and other components, and the relative humidity lies between 35-55%, optimal to prevent static electricity and dew point issues. Brian is also the coordinator between ULA and the customer. If any issues arise it is his job to communicate between the two. The next room contained the computers to monitor and launch the rocket. 'The old Saturn had four such rooms', mentions Brian. The next room was for the customer, ECS and HVAC engineers.

The final stop of the tour is at the *Astrotech Corporation* in Titusville Florida, just outside the Kennedy Spaceflight Centre which is just north of the Air Force Station. *Astrotech* [11] is a commercial space company founded in 1984 with a history dating back to *Northrop Grumman. Astrotech* is the first private company formed to meet the growing demand for commercial satellite processing; they provide the facilities commodities,

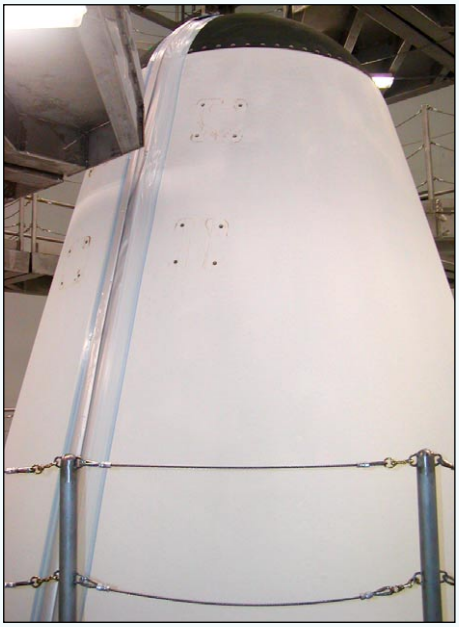
processing support and safety officers to oversee the hazardous operations. Operations like final assembly, testing, fuelling and encapsulation are performed by the contracting customer at *Astrotech's* facility. There are four satellite processing buildings on the 62 acres with Building 9 currently storing GOES-O. It also housed *Kepler* (the recently launched NASA Space Telescope mission to discover Earth-like planets) before it was launched. *Astrotech* is also currently processing or storing LCROSS, WGS3 and GPS2F1.

After getting through several levels of security, we enter the changing room, clean our shoes and don our clean-room attire. We pass through the air scrubber which cleans and removes static electricity and can finally enter the encapsulation bay where GOES-O is stored. The first two things we notice are that the satellite is surrounded by a scaffold, and the completely white room with black ruler markings, in feet, on the walling.

The GOES-O satellite is encapsulated in the fairing and sitting on the Payload Adapter Fitting (PAF) which is supported on an air bearing platform that can be moved easily. Around the fairing are two eight-level scaffolds, pushed together to allow access to the 47 foot tall fairing in a room large enough to accommodate an 86 foot fairing. There is a line exit through the bottom of the platform for battery charging; an access cover with ports which connect to nitrogen purge lines, relative humidity and temperature probes; and a dedicated nitrogen fly-away purge line attached to the internal spatial orientation navigation unit. The current temperature inside the fairing is 18°C at 3% relative humidity. A cross-hair with the letters 'RF' on the fairing marks an RF window which allows communications through an external loop Yagi.

Emergency breathing bottles remind you that the satellite is fuelled with station-keeping gas. Brian points out the light gray tape running from the top to the bottom on two sides of the fairing. Under this tape are rivets and a linear explosive assembly that, at approximately 2 minutes and 42 seconds into flight, will detonate, separating the fairing instantaneously. Every four days the satellite gets a health check and *Boeing Space and Intelligence Systems*, the satellite manufacturer, has stated that the satellite can stay in the fairing, with periodic charging of the GOES-O flight batteries, until August. As we leave the encapsulation room, we notice a mascot, Wall-E, a security camera on a roll-around stand.

Wall-E, the security camera/mascot



The fairing, showing tape running down its side. Explosive charges to release the fairing lie beneath this tape.

The next room is the air-lock separating the outside world from the East and West Processing Bays. GOES-O arrived from the Boeing manufacturing plant in El Segundo California on a C-17 military transport plane on March 3, 2009 and passed through this air lock. It was in the East Processing Bay where GOES-O was processed, fuelled and had the PAF attached before being moved into the Encapsulation Bay. The Processing Bays are large clean-rooms, capable of 10,000 class—which means that there can be no more than 10,000 air particles per cubic foot (compared with room air, which contains about a million air particles per cubic foot). The adjacent room is the Payload Faring Processing Bay where the fairings are first cleaned and have the logos applied before being moved into the Encapsulation Bay.

After the *Delta-IV* rocket is ready and passes all tests, and approximately thirteen days prior to launch, the payload will be moved from the *Astrotech* facility on the EPT transporter. The EPT maintains a level environment during its 5 mph, 8 hour drive to the launch pad. The drive starts around 8 pm, to prevent a traffic jam, and arrives at the pad between 5 am and 6 am. When the new shift arrives at 7 am, the payload is loaded on top of the *Delta-IV* second stage, similar to the solid rocket motors.

GOES-O is the second in the new generation of Geostationary Operational Environmental Satellites. The first, GOES-N as it was called prior to a successful on-orbit checkout, is now called GOES-13 and is in standby mode at 105° west longitude. It may soon replace GOES-12 (which has a leaking thruster), or a major failure of GOES-11. GOES-11 is the active satellite covering the western portion of the United States at 134° west longitude and GOES-12 is the active satellite covering the eastern portion of the United States at 75° west longitude. GOES-O will probably be checked out at 90°W and, if successful, will be renamed GOES-14 and become an on-orbit spare. GOES-P has been manufactured and is in storage at at the *Boeing Space and Intelligence Systems* facility in California.

Timeline	
T-5 hr 15 min	Terminal count starts
T-5 hr	Start loading 1st stage oxygen
T-4 hr	Start loading 1st stage hydrogen
T-3 hr 20 min	Start loading 2nd stage oxygen
T-3 hr 10 min	Start loading 2nd stage hydrogen
T-1 hr 40 min	All fuel loading complete
T-1 hr	Engine slewing test started
T-15 min	Switch satellite to internal batteries
T-4 min	Switch *Delta-IV* to internal batteries
T-5.5 sec	1st stage solid engine start
T-0	Launch!
T+1 min 40 sec	Jettison the solid engines
T+4 min 27 sec	Main engine cutoff and jettison
T+4 min 47 sec	2nd stage engine ignition
T+4 min 57 sec	Fairing jettison
T+23 min 05 sec	2nd stage engine cutoff
T+27 min 08 sec	2nd stage engine ignition
T+4 hr 10 min 01 sec	2nd stage engine ignition
T+4 hr 10 min 57 sec	2nd stage engine cutoff
T+4 hr 21 min 27 sec	Satellite separation into a 41 555 km x 13 000 km orbit
Apogee motor burns	Five more burns to insert into a 42 175 km geostationary orbit

Acknowledgements

I want to thank Brian Bauerlin for the outstanding tour, Tom Coussens, GOES OP Launch IPT Lead and Raymond McGlynn, NASA GOES-O/P Launch Services Manager, for both making the tour possible, and the Cape Canaveral Air Force Station.

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