
# Atlas V MSL

Mission Overview
Cape Canaveral Air Force Station, FL

ULA®
United Launch Alliance

ATLAS®

United Launch Alliance (ULA) is proud to be a part of NASA's Mars Science Laboratory (MSL) mission.

Following launch on an Atlas V 541 from Cape Canaveral Air Force Station (CCAFS), MSL will complete a nearly 9-month journey, landing on Mars in August 2012. The MSL rover and its sample acquisition system and suite of scientific instruments will spend at least the next two years analyzing the surface and atmosphere in an effort to determine the red planet's habitability.

MSL is the last of five critical missions ULA is scheduled to launch for NASA in 2011. These missions will address important questions of science — ranging from climate and weather on planet Earth to life on other planets and the origins of the solar system.

The ULA team is focused on attaining Perfect Product Delivery for the MSL mission, which includes a relentless focus on mission success (the perfect product) and also excellence and continuous improvement in meeting all of the needs of our customers (the perfect delivery).

Thank you to the entire ULA team and our mission partners. Your dedication has made this extraordinary mission possible.

Go Atlas, Go Centaur, Go MSL!

**Jim Sponnick**
Vice President,
Mission Operations



## MARS SCIENCE LABORATORY SPACECRAFT | Overview

After landing on Mars in August 2012, the Mars Science Laboratory's prime mission will last one Martian year (nearly two Earth years). Researchers will use the rover's tools to study whether the landing region has had environmental conditions favorable for supporting microbial life.

MSL will rely on new technological innovations including landing a rover on Mars about the size of a small car (approximately 2,000 lbs), precision landing systems that reduce the landing target to a 12.4-mile circle and long-range mobility on the surface of the red planet (3 to 12 miles anticipated for the mission).

The MSL spacecraft consists of:

- Cruise Stage: Configuration for travel between Earth and Mars.
- Entry, Descent, & Landing (EDL) System: Heatshield, aeroshell and control systems for atmospheric entry and landing.
- Curiosity Rover: Six-wheeled mobile chemistry laboratory with 10 science instruments.

The spacecraft is in the cruise configuration from launch through the majority of the approximately 9-month journey to Mars. Upon arrival at Mars the spacecraft will begin the EDL phase. Atmospheric entry begins at an altitude of about 80 miles at a velocity of approximately 13,000 mph. The entire EDL sequence takes approximately five minutes and includes guided hypersonic entry, parachute descent, retrorocket powered descent and finally a soft landing via the sky crane.

Once on the surface, Curiosity has the ability to roll over obstacles up to 29 inches high and travel approximately 150 to 200 feet per hour, depending on power levels, terrain and other variables. Curiosity will carry the biggest, most advanced suite of scientific instruments ever sent to the Martian surface. The rover will gather the soil and rock samples for the onboard laboratory in order to detect chemical building blocks of life on Mars.

NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, built the spacecraft and manages the Mars Science Laboratory Project for NASA's Mars Exploration Program in Washington. Launch management is the responsibility of the NASA Launch Services Program at Kennedy Space Center in Florida.




Images courtesy of NASA/JPL-Caltech



# Atlas V MSL

## ATLAS V 541 LAUNCH VEHICLE | Overview

The Atlas V 541 consists of a single Atlas V booster stage, the Centaur upper stage, four solid rocket boosters (SRB), and a 5-m short payload fairing (PLF).

The Atlas V booster is 12.5 ft in diameter and 106.5 ft in length. The booster's tanks are structurally rigid and constructed of isogrid aluminum barrels, spun-formed aluminum domes, and intertank skirts. Atlas booster propulsion is provided by the RD-180 engine system (a single engine with two thrust chambers). The RD-180 burns RP-1 (Rocket Propellant-1 or highly purified kerosene) and liquid oxygen, and it delivers 860,200 lb of thrust at sea level. The Atlas V booster is controlled by the Centaur avionics system, which provides guidance, flight control, and vehicle sequencing functions during the booster and Centaur phases of flight.

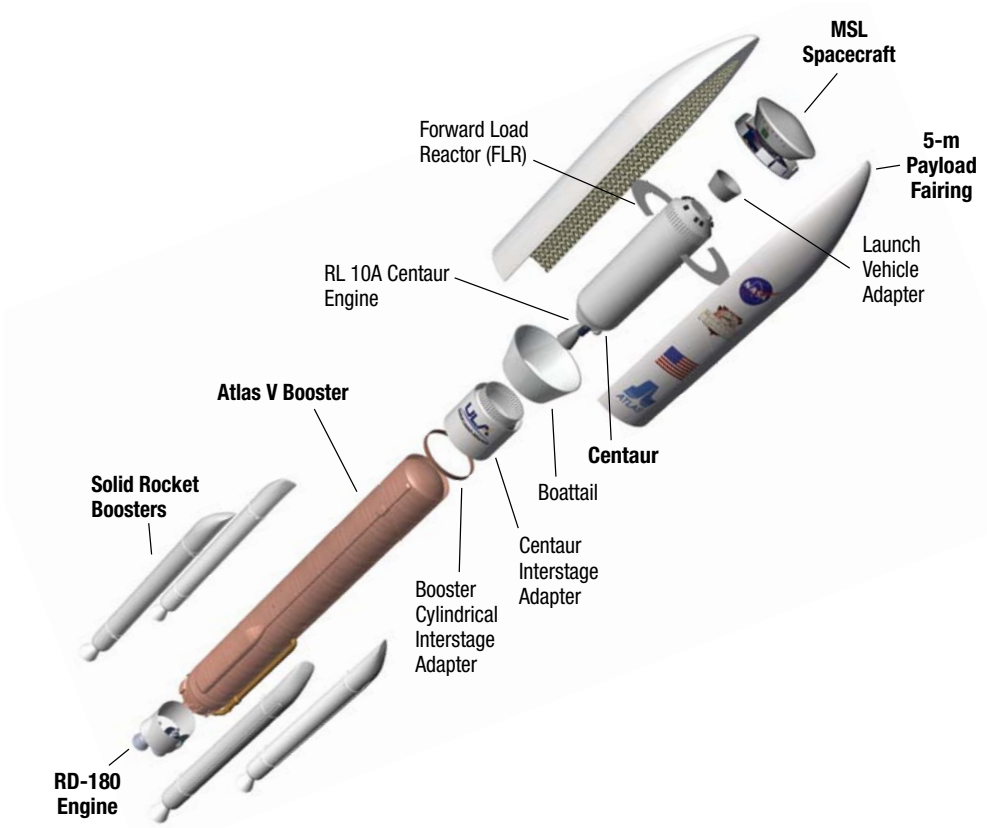
The SRBs are approximately 61 in. in diameter, 67 ft in length, and constructed of a graphite-epoxy composite with the throttle profile designed into the propellant grain. The SRBs are jettisoned by structural thrusters following a 92-second burn.

The Centaur upper stage is 10 ft in diameter and 41.5 ft in length. Its propellant tanks are constructed of pressure-stabilized, corrosion resistant stainless steel. Centaur is a liquid hydrogen/liquid oxygen- (cryogenic-) fueled vehicle. It uses a single RL10A-4-2 engine producing 22,300 lb of thrust. The cryogenic tanks are insulated with a combination of helium-purged insulation blankets, radiation shields, and closed-cell polyvinyl chloride (PVC) insulation. The Centaur forward adapter (CFA) provides the structural mountings for vehicle electronics and the structural and electronic interfaces with the spacecraft.

The MSL spacecraft is encapsulated in the Atlas V 5-meter diameter short PLF. The 5-m PLF is a sandwich composite structure made with a vented aluminum-honeycomb core and graphite-epoxy face sheets. The bisector (two-piece shell) PLF encapsulates both the Centaur and the spacecraft, which separates using a debris-free pyrotechnic actuating system. Payload clearance and vehicle structural stability are enhanced by the all-aluminum forward load reactor (FLR), which centers the PLF around the Centaur upper stage and shares payload shear loading. The vehicle's height with the 5-m short PLF is approximately 197 ft.

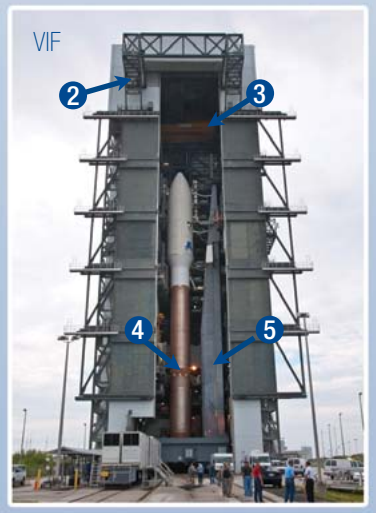


## ATLAS V 541 LAUNCH VEHICLE | Expanded View



## SLC-41 | Overview

1 Vertical Integration Facility (VIF) (See call out at right)
2 Bridge Crane Hammerhead
3 Bridge Crane
4 Launch Vehicle
5 Mobile Launch Platform (MLP)
6 Launch Vehicle
7 Centaur $LO_2$ Storage
8 Gaseous Helium Conversion Plant
9 High Pressure Gas Storage
10 Booster $LO_2$ Storage
11 Pad ECS Shelter
12 Pad Equipment Building (PEB)







# Atlas V MSL

## ATLAS V MARS SCIENCE LABORATORY | Mission Overview

The MSL mission is based on a Atlas V 541 ascent profile to an interplanetary hyperbolic departure trajectory. The mission begins with ignition of the RD-180 engine approximately 2.7 seconds prior to liftoff. The flight begins with a vertical rise of 180 feet, after which the vehicle begins its initial pitch-over phase, a simultaneous roll, pitch, and yaw maneuver to achieve the desired flight azimuth. The vehicle then throttles down and begins a nominal zero-pitch and zero yaw angle-of-attack phase to minimize aerodynamic loads. Following maximum dynamic pressure and SRB burnout, the RD-180 is throttled back up to 100 percent. Zero pitch and yaw angle-of-attack flight continues until closed-loop guidance takes over, at 118.5 seconds into flight.

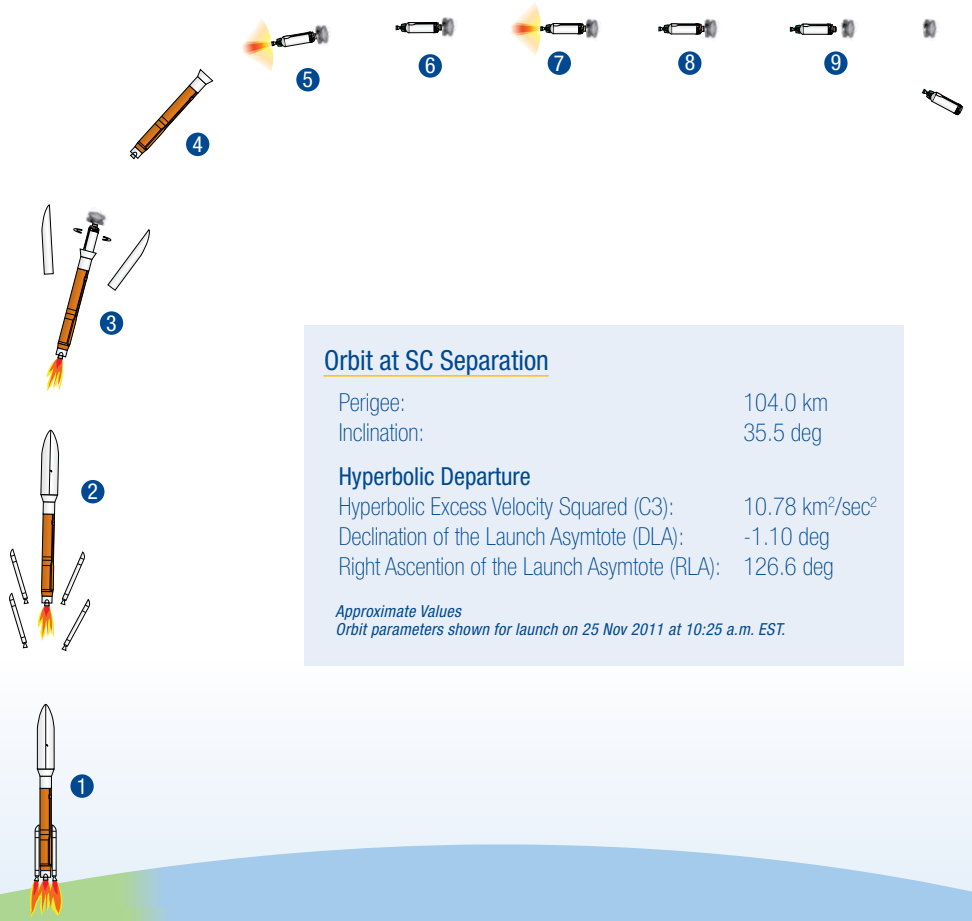
Booster flight continues in this guidance-steered phase until propellant depletion. Jettison of the 5-meter payload fairing occurs at approximately 205 seconds, based on thermal constraints. When the vehicle reaches 4.6 G's the RD-180 engine is throttled to maintain this G-level. The boost phase of flight ends with Atlas/Centaur separation at a nominal time of 6.0 seconds after Booster Engine Cutoff (BECO).

Following Atlas/Centaur separation, the Centaur stage ignites its main engine or Main Engine Start 1 (MES1). The 412-second Centaur first burn concludes with Main Engine Cutoff 1 (MECO1), injecting the vehicle into a nearly circular parking orbit.

The mission profile varies following the first Centaur burn dependent on launch day and time. The Centaur and spacecraft enter a coast period between 13 to 31 minutes. Based on a guidance-calculated start time, the Centaur is re-started (MES2) then steered into the desired hyperbolic departure orbit. The second Centaur burn duration is between 450 and 515 seconds and concludes with Main Engine Cutoff (MECO2), initiated by guidance command once the targeted orbital parameters are achieved. Between MECO2 and spacecraft separation the vehicle turns to the separation attitude and initiates a 2.5 rpm spin for spacecraft stability. Spacecraft separation is initiated 223 seconds after MECO2.

Depending on launch day and time, spacecraft separation will occur 37 to 56 minutes after liftoff.

## FLIGHT PROFILE | Liftoff to Spacecraft Separation




### Orbit at SC Separation

| | |
|---|---|
| Perigee: | 104.0 km |
| Inclination: | 35.5 deg |

**Hyperbolic Departure**

| | |
|---|---|
| Hyperbolic Excess Velocity Squared (C3): | 10.78 $km^2/sec^2$ |
| Declination of the Launch Asymtote (DLA): | -1.10 deg |
| Right Ascention of the Launch Asymtote (RLA): | 126.6 deg |

*Approximate Values*
*Orbit parameters shown for launch on 25 Nov 2011 at 10:25 a.m. EST.*

## SEQUENCE OF EVENTS | Liftoff to Spacecraft Separation

| | Event | Time (seconds) | Time (hr:min:sec) |
|---|---|---|---|
| 1 | RD-180 Engine Ignition | -2.7 | -0:00:02.7 |
| | T=0 (Engine Ready) | 0.0 | 0:00:00 |
| | Liftoff (Thrust to Weight > 1) | 1.1 | 0:00:01.1 |
| | Full Thrust | 2.1 | 0:00:02.1 |
| | Begin Pitch/Yaw/Roll Maneuver | 5.2 | 0:00:05.2 |
| | Mach 1 | 34.6 | 0:00:34.6 |
| | Maximum Dynamic Pressure | 46.3 | 0:00:46.3 |
| 2 | Solid Rocket Booster Jettison | 112.5 | 0:01:52.5 |
| 3 | Payload Fairing Jettison | 204.9 | 0:03:24.9 |
| | Begin 4.6 G-Limiting | 227.0 | 0:03:47.0 |
| 4 | Atlas Booster Engine Cutoff (BECO) | 261.5 | 0:04:21.5 |
| | Atlas Booster/Centaur Separation | 267.5 | 0:04:27.5 |
| 5 | Centaur First Main Engine Start (MES1) | 277.4 | 0:04:37.4 |
| 6 | Centaur First Main Engine Cutoff (MECO1) | 689.8 | 0:11:29.8 |
| 7 | Centaur Second Main Engine Start (MES2)* | 1,864.6 | 0:31:04.6 |
| 8 | Centaur Second Main Engine Cutoff (MECO2)* | 2,345.0 | 0:39:05.0 |
| 9 | Spacecraft Separation* | 2,567.7 | 0:42:47.7 |

**Timing for events 7,8 and 9 vary depending on launch day and time.*
*Event times shown for launch on 25 Nov 2011 at 10:25 a.m. EST.*

# ATLAS V PRODUCTION & LAUNCH | Overview

**Sacramento, CA**
- Solid Rocket Booster Fabrication at Aerojet

**Denver, CO**
- ULA Headquarters & Design Center Engineering

**Decatur, AL**
- Booster Fabrication & Final Assembly
- Centaur Final Assembly

**West Palm Beach, FL**
- RL10 Engine Fabrication at Pratt & Whitney

**San Diego, CA**
- Centaur Tank Fabrication

**Cape Canaveral Air Force Station, FL**
- Payload Processing & Encapsulation
- Launch Vehicle Processing
- Encapsulated Payload Mating
- Launch

**Harlingen, TX**
- Payload Adapter Fabrication
- Booster Adapter Fabrication
- Centaur Adapter Fabrication

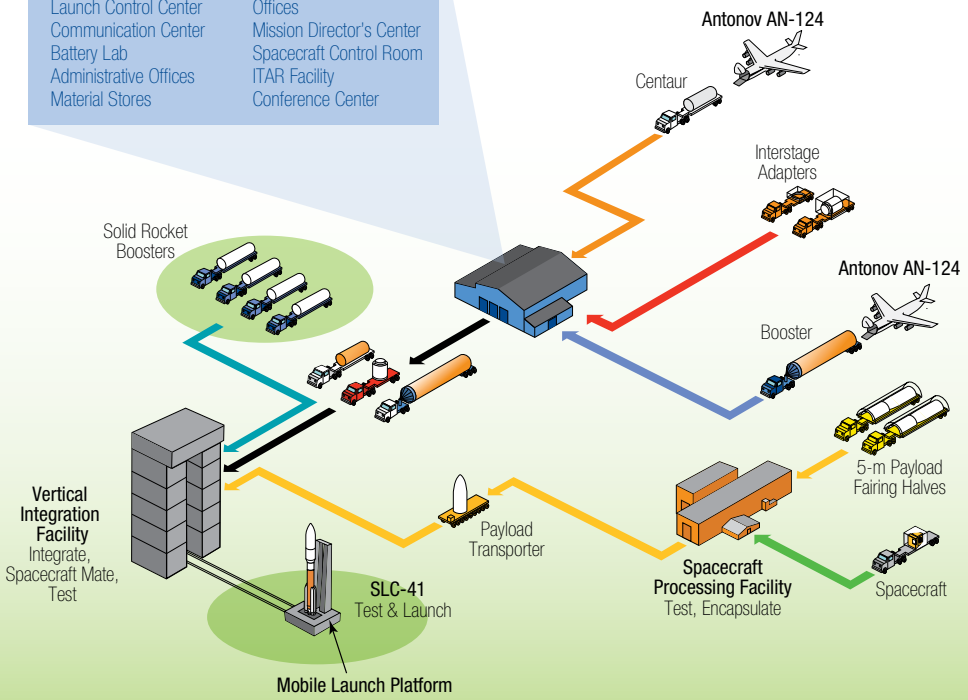
**Zurich, Switzerland**
- 5-meter Payload Fairing Fabrication at RUAG Space

**Khimki, Russia**
- RD-180 Engine Fabrication at NPO Energomash

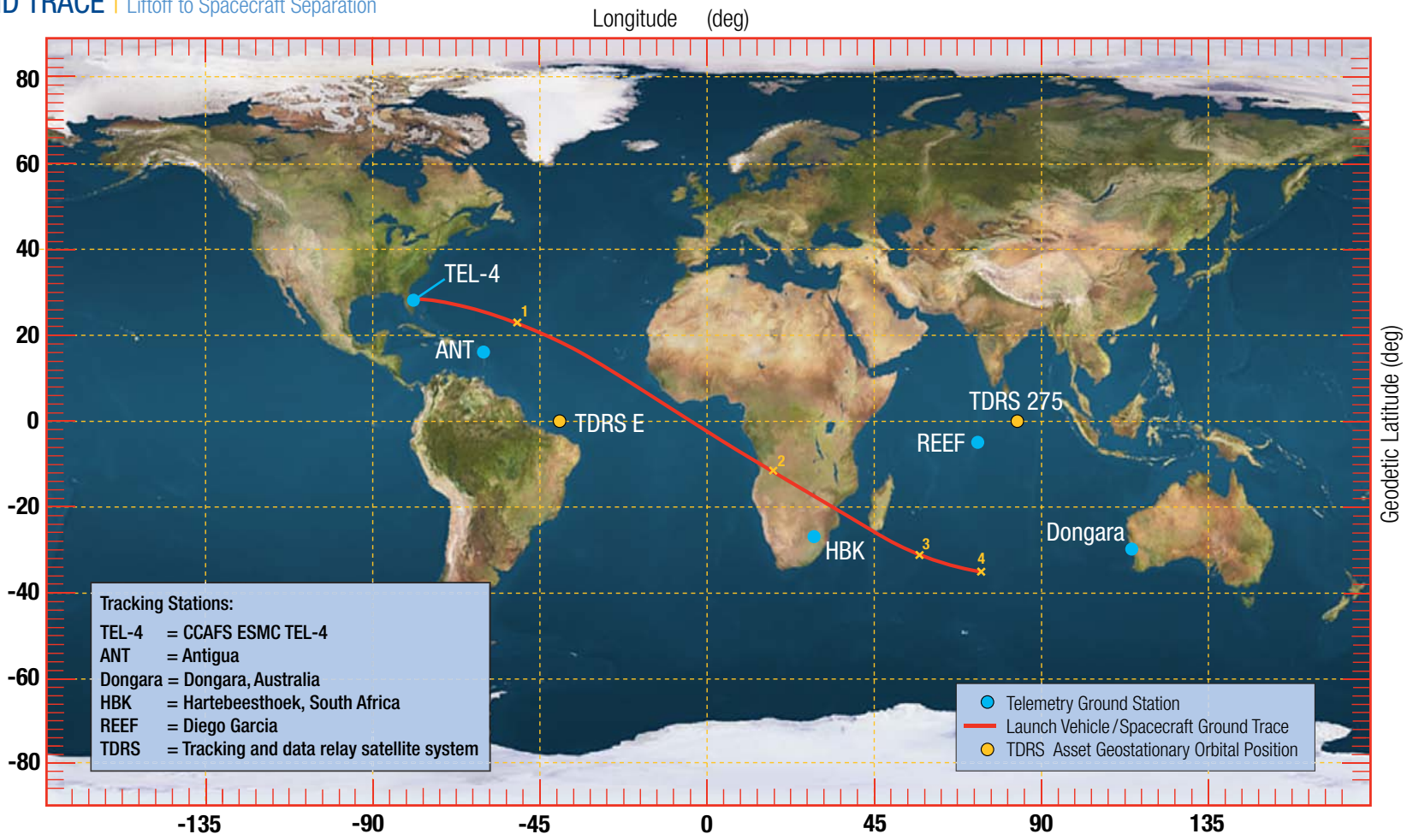
# ATLAS V PROCESSING | Cape Canaveral

**Atlas Spaceflight Operations Center (ASOC)**

| | |
|---|---|
| Receiving & Inspection | VIP Viewing |
| Launch Control Center | Offices |
| Communication Center | Mission Director's Center |
| Battery Lab | Spacecraft Control Room |
| Administrative Offices | ITAR Facility |
| Material Stores | Conference Center |



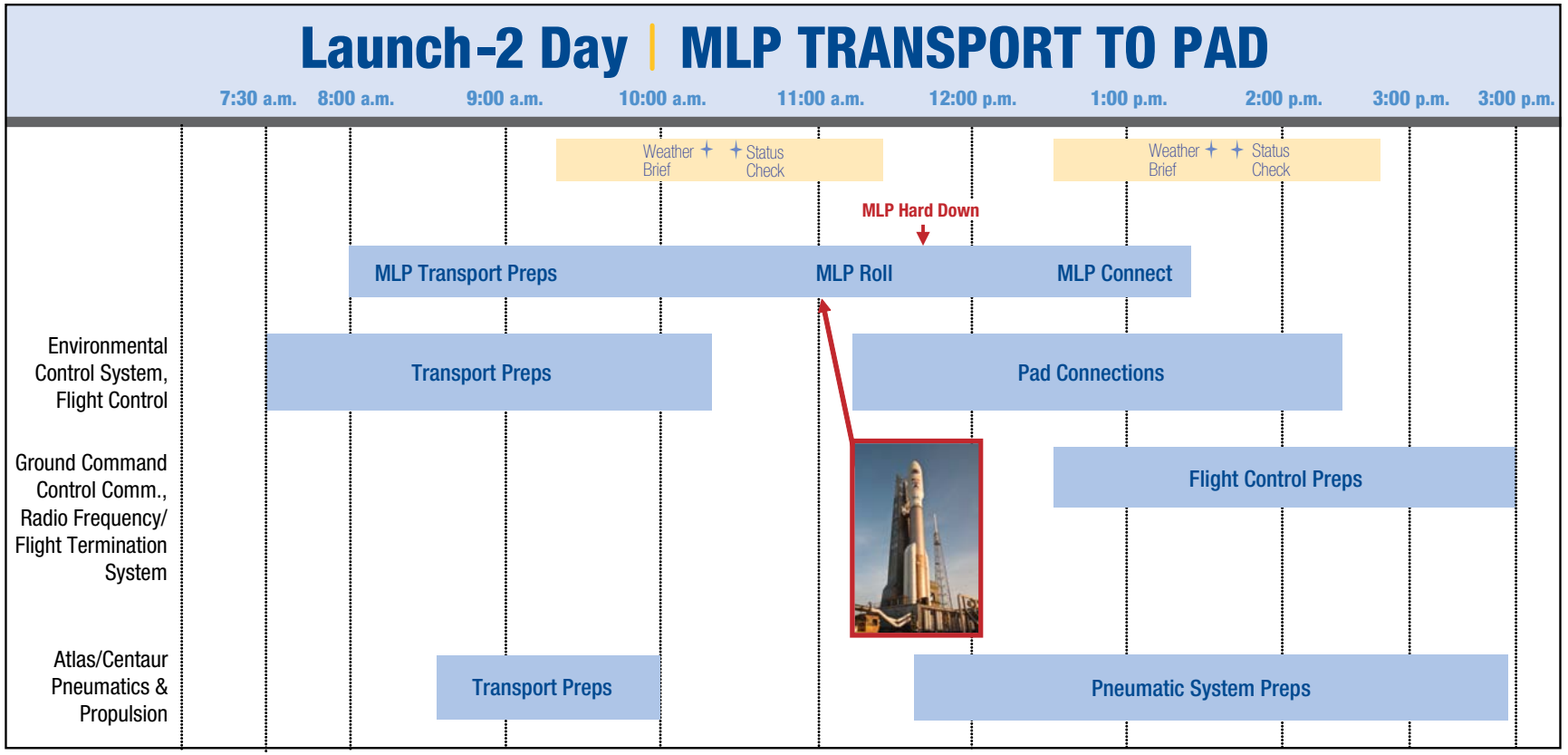
## GROUND TRACE | Liftoff to Spacecraft Separation

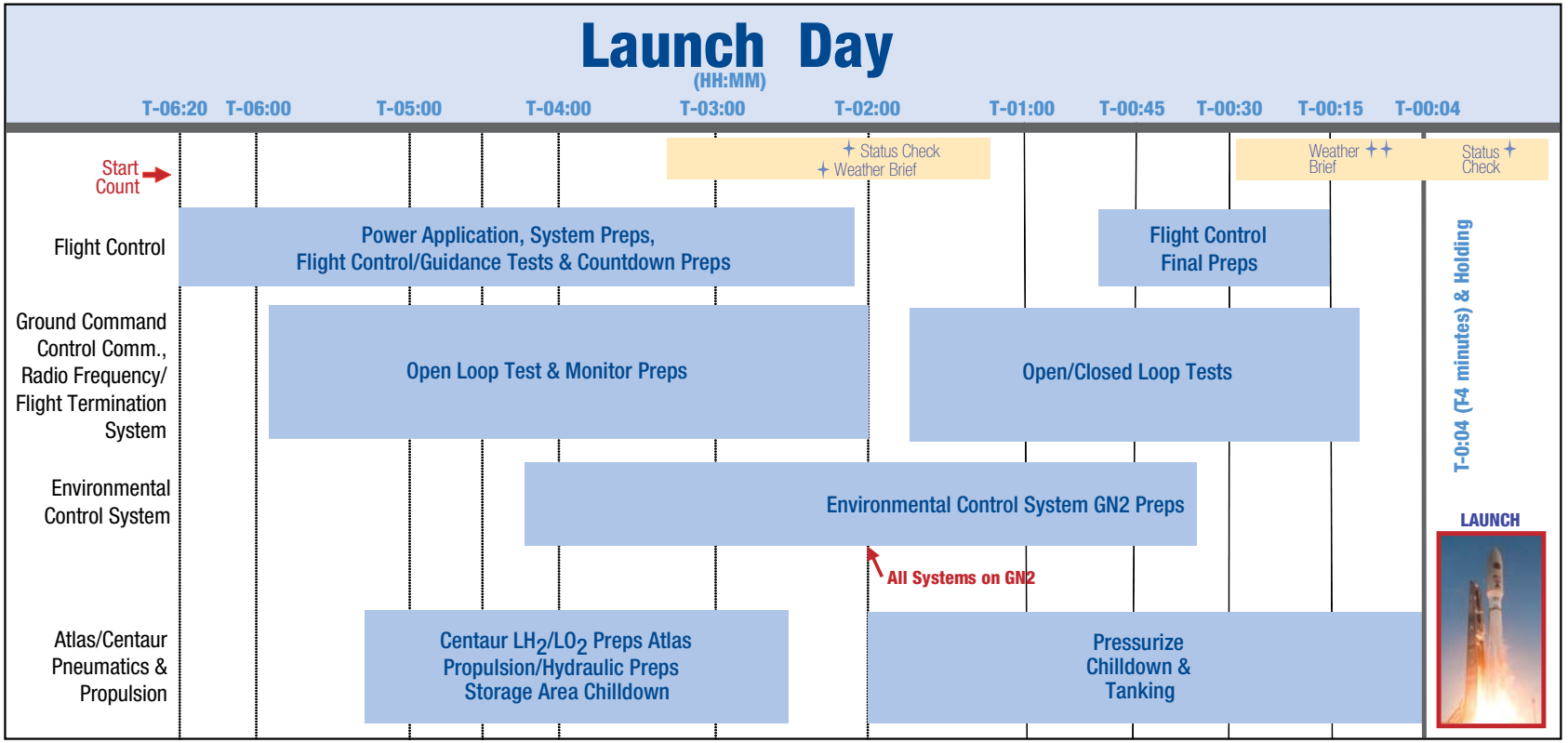



**1 =** MECO1 (0:11:29.8 ) | **2 =** MES2 (0:31:04.6) **3 =** MECO2 (0:39:05.0) | **4 =** Spacecraft Separation (0:42:47.7)

**Timing for events 2,3 and 4 vary depending on launch day and time.*

*Event times and ground trace shown for launch on 25 Nov 2011 at 10:25 a.m. EST.*


Launch-2 Day | MLP TRANSPORT TO PAD
7:30 a.m.
8:00 a.m.
9:00 a.m.
10:00 a.m.
11:00 a.m.
12:00 p.m.
1:00 p.m.
2:00 p.m.
3:00 p.m.
3:00 p.m.
Weather Brief
Status Check
Weather Brief
Status Check
MLP Hard Down
MLP Transport Preps
MLP Roll
MLP Connect
Environmental Control System, Flight Control
Transport Preps
Pad Connections
Ground Command Control Comm., Radio Frequency/ Flight Termination System
Flight Control Preps
Atlas/Centaur Pneumatics & Propulsion
Transport Preps
Pneumatic System Preps


Launch Day
(HH:MM)
T-06:20
T-06:00
T-05:00
T-04:00
T-03:00
T-02:00
T-01:00
T-00:45
T-00:30
T-00:15
T-00:04
Start Count
Status Check
Weather Brief
Weather Brief
Status Check
Flight Control
Power Application, System Preps, Flight Control/Guidance Tests & Countdown Preps
Flight Control Final Preps
Ground Command Control Comm., Radio Frequency/ Flight Termination System
Open Loop Test & Monitor Preps
Open/Closed Loop Tests
Environmental Control System
Environmental Control System GN2 Preps
All Systems on GN2
Atlas/Centaur Pneumatics & Propulsion
Centaur LH2/LO2 Preps Atlas Propulsion/Hydraulic Preps Storage Area Chilldown
Pressurize Chilldown & Tanking
T-0:04 (T-4 minutes) & Holding
LAUNCH


United Launch Alliance | P.O. Box 3778 Centennial, CO 80155-3788 | www.ulalaunch.com