United Launch Alliance

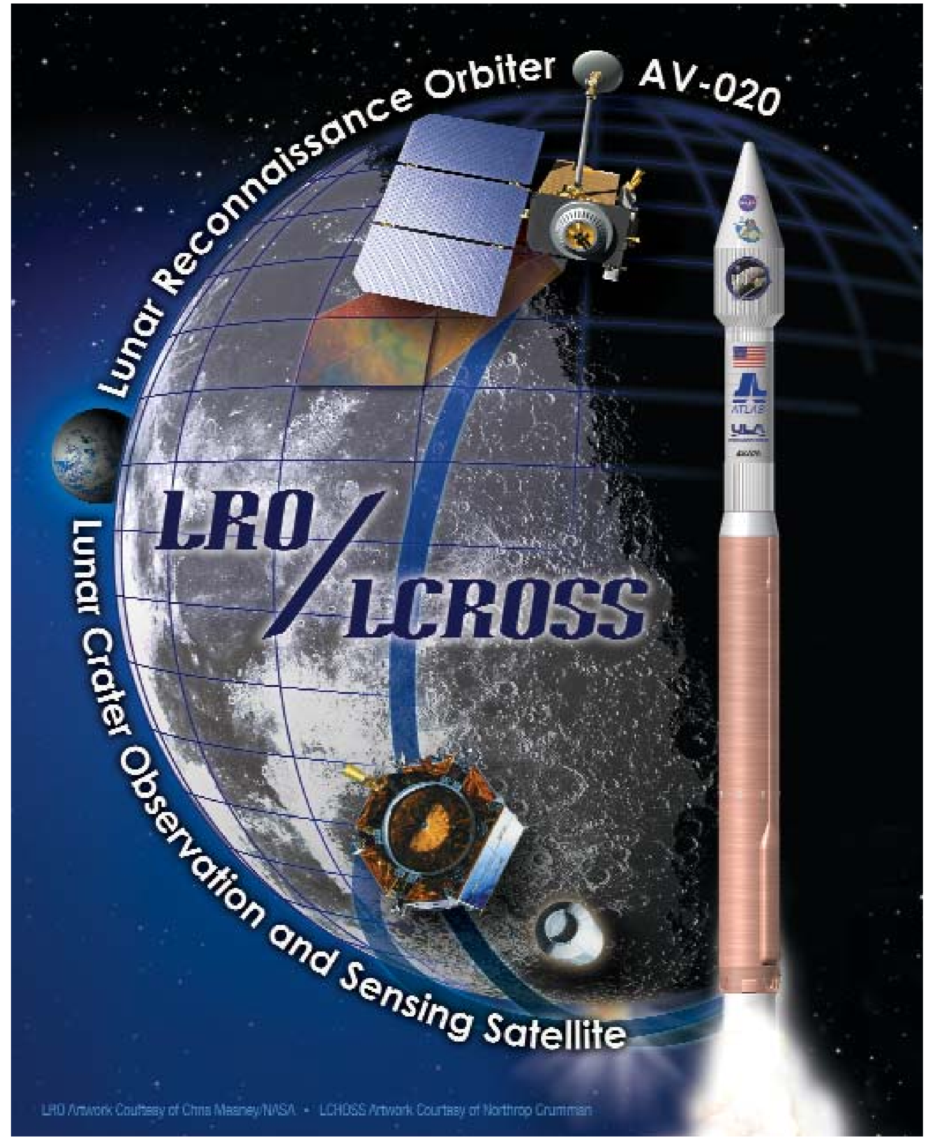
Atlas V Launches LRO/LCROSS

Mission Overview

Atlas V 401

Cape Canaveral Air Force Station, FL

Space Launch Complex-41



ATLAS

AV-020/LRO/LCROSS

United Launch Alliance is proud to be a part of the Lunar Reconnaissance Orbiter (LRO) and the Lunar Crater Observation and Sensing Satellite (LCROSS) mission with the National Aeronautics and Space Administration (NASA). The LRO/LCROSS mission marks the sixteenth Atlas V launch and the seventh flight of an Atlas V 401 configuration.

LRO/LCROSS is a dual-spacecraft (SC) launch. LRO is a lunar orbiter that will investigate resources, landing sites, and the lunar radiation environment in preparation for future human missions to the Moon. LCROSS will search for the presence of water ice that may exist on the permanently shadowed floors of lunar polar craters. The LCROSS mission will use two Lunar Kinetic Impactors, the inert Centaur upper stage and the LCROSS SC itself, to produce debris plumes that may reveal the presence of water ice under spectroscopic analysis.

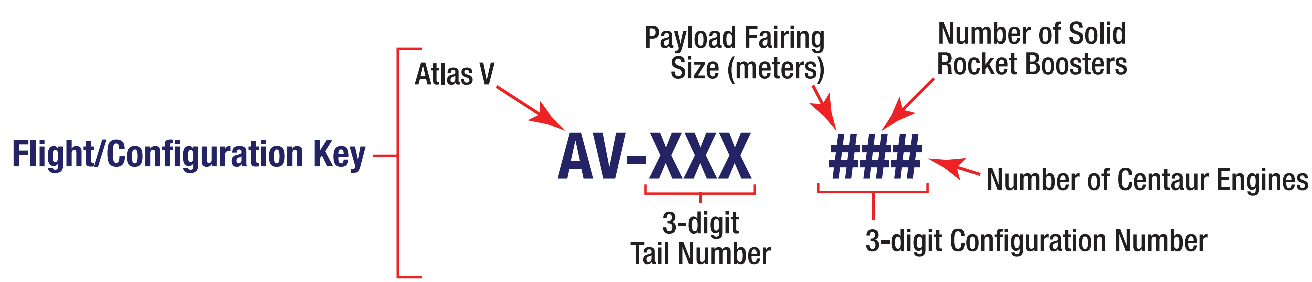
My thanks to the entire Atlas team for its dedication in bringing LRO/LCROSS to launch, and to NASA for selecting Atlas for this ground-breaking mission.

Go Atlas, Go Centaur, Go LRO/LCROSS!

Mark Wilkins
Vice President, Atlas Product Line

Atlas V Launch History

Flight	Config.	Mission	Mission Date
AV-001	401	Eutelsat Hotbird 6	21 Aug 2002
AV-002	401	HellasSat	13 May 2003
AV-003	521	Rainbow 1	17 Jul 2003
AV-005	521	AMC-16	17 Dec 2004
AV-004	431	Inmarsat 4-F1	11 Mar 2005
AV-007	401	Mars Reconnaissance Orbiter	12 Aug 2005
AV-010	551	Pluto New Horizons	19 Jan 2006
AV-008	411	Astra 1KR	20 Apr 2006
AV-013	401	STP-1	08 Mar 2007
AV-009	401	NROL-30	15 Jun 2007
AV-011	421	WGS SV-1	10 Oct 2007
AV-015	401	NROL-24	10 Dec 2007
AV-006	411	NROL-28	13 Mar 2008
AV-014	421	ICO G1	14 Apr 2008
AV-016	421	WGS-2	03 Apr 2009



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LRO Overview

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LRO is the first mission in NASA’s planned return to the Moon. LRO’s objectives include finding safe landing sites, locating potential resources, characterizing the lunar radiation environment, and testing new technologies.

LRO’s mission to the Moon will enable scientific activities that address fundamental questions about the history of Earth, the solar system, and the universe at large. The LRO mission will allow NASA to test technologies, systems, and flight operation and exploration techniques. These new flight operation and exploration techniques are designed to reduce risk and increase the productivity of future missions to the Moon, Mars, and beyond. LRO will also help to expand Earth's economic sphere, enabling NASA to conduct lunar activities with benefits to life on Earth.

A variety of scientific instruments will be used to accomplish these objectives. The Cosmic Ray Telescope for the Effects of Radiation (CRATER) will acquire data allowing NASA to characterize the lunar radiation environment, determine the scope of potential impacts to astronauts and other forms of life, test models of the effects of radiation, and measure radiation absorption by a plastic material similar to human tissue. The results will aid in the development of protective equipment for future lunar explorers.

The Diviner Lunar Radiometer Experiment (DLRE) will measure surface and subsurface temperatures from orbit and identify cold traps, potential ice deposits, rough terrain, and other landing hazards.

The Lyman-Alpha Mapping Project (LAMP) will map the entire lunar surface in the far-ultraviolet spectrum and provide images of permanently shadowed regions illuminated only by starlight. This far-ultraviolet map will aid in the search for surface ice and frost in the polar regions.

LRO Overview (concluded)

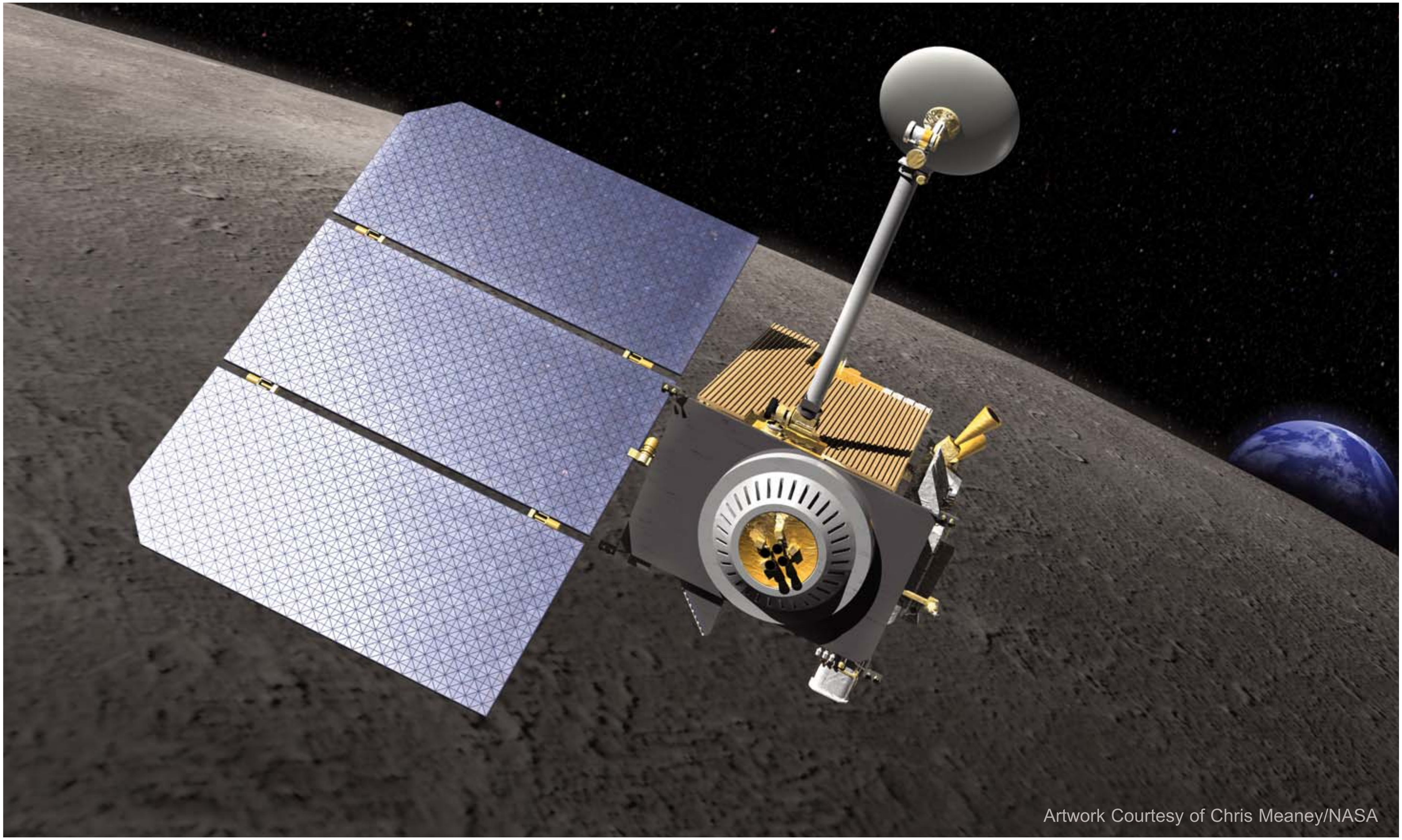
The Lunar Exploration Neutron Detector (LEND) will create high-resolution maps of hydrogen distribution and gather information about the neutron component of lunar radiation. Its data will be analyzed for evidence of water ice near the Moon's surface.

The Lunar Orbiter Laser Altimeter (LOLA) will measure landing site slopes and lunar surface roughness and generate high-resolution, three-dimensional maps of the Moon. The instrument also will measure and analyze the lunar topography to identify both permanently illuminated and shadowed areas.

The Lunar Reconnaissance Orbiter Camera (LROC) will take high-resolution, black-and-white, color, and ultraviolet images of the lunar surface, capturing images of the lunar poles with resolutions down to 1 meter. These images will provide knowledge of polar illumination conditions, identify potential resources and hazards, and enable safe landing site selection.

The Mini-Radio Frequency (RF) technology demonstrator's primary goal is to search for subsurface water ice deposits. It will also take high-resolution images of permanently shadowed regions.

LRO Spacecraft



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LCROSS Overview

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In 1999, NASA's Lunar Prospector detected concentrated hydrogen signatures in permanently shadowed craters at the lunar poles. These readings may indicate lunar water, which has far-reaching implications for human exploration beyond low-Earth orbit. The LCROSS mission seeks a definitive answer.

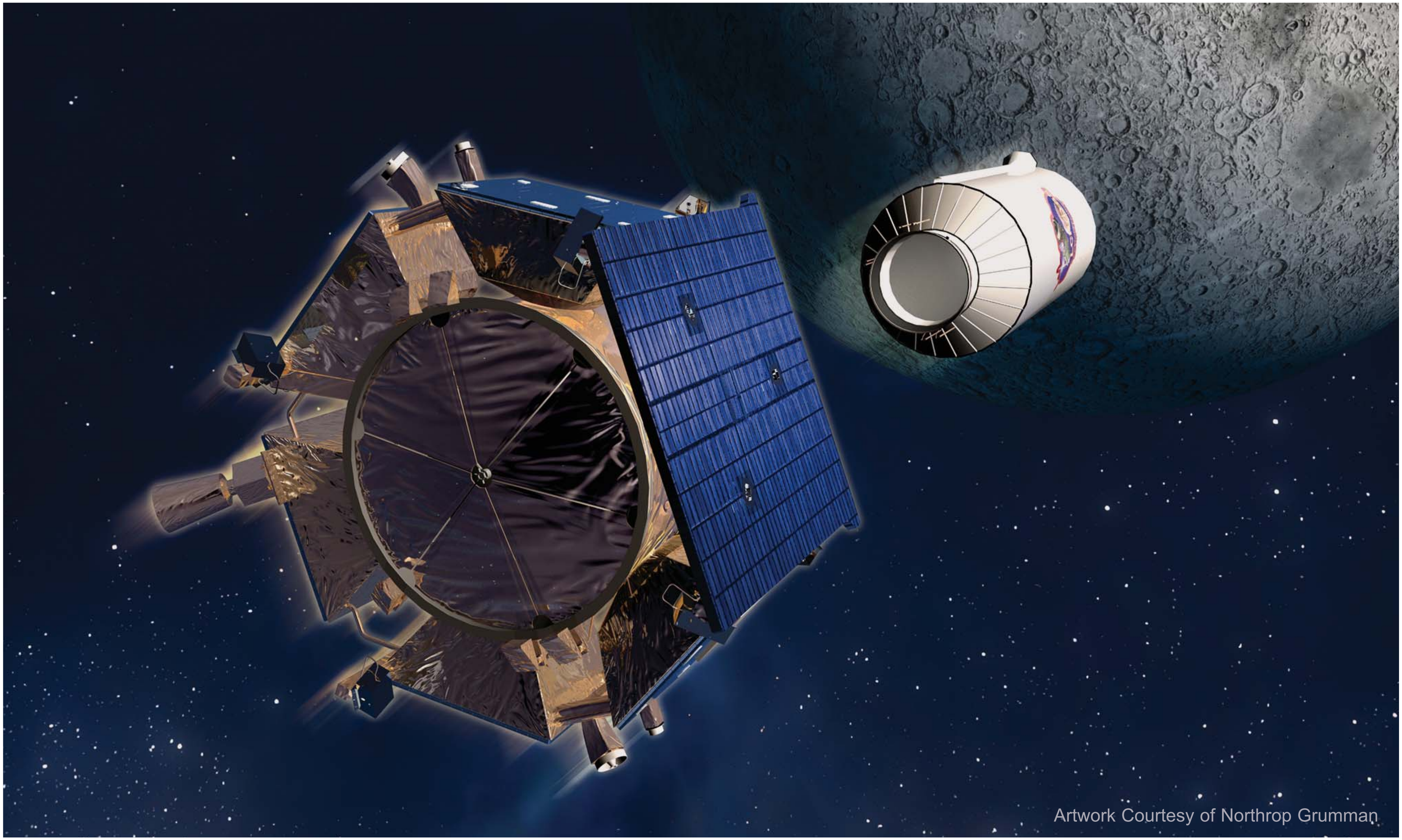
LCROSS is a low-cost, fast-track companion mission to the LRO mission. Its main objective is to confirm the presence or absence of water ice in a permanently shadowed crater near a lunar polar region.

After launch, the LCROSS shepherding SC and the Atlas V's Centaur upper stage will execute a fly-by of the Moon and enter an elongated Earth orbit to position LCROSS for impact on a lunar pole. On final approach, the shepherding SC and Centaur will separate. The Centaur will act as a heavy impactor to create a debris plume that will rise above the lunar surface. Following four minutes behind, the shepherding LCROSS SC will fly through the debris plume, collecting and relaying data back to Earth before itself impacting the lunar surface and creating a second debris plume. Both debris plumes should be visible to the LRO and to Earth- and space-based telescopes with 10- to 12-inch apertures and larger.

LCROSS's science payload consists of two near-infrared spectrometers; a visible-light spectrometer; two mid- and two near-infrared cameras; a visible-light camera; and a visible-light radiometer. These instruments will provide mission scientists with multiple measurements and analyses of the debris plume created by the Centaur impact.

As ejecta rises above the target crater's rim and is exposed to sunlight, any water ice, hydrocarbons, or organic material will vaporize and break down into its basic components. These components will be monitored primarily by the visible and infrared spectrometers. The near- and mid-infrared cameras will determine the total amount and distribution of water in the debris plume. The SC's visible-light camera will track the impact location and the behavior of the debris plume, while the visible radiometer will measure the flash created by the Centaur impact.

LCROSS Spacecraft and Centaur Stage

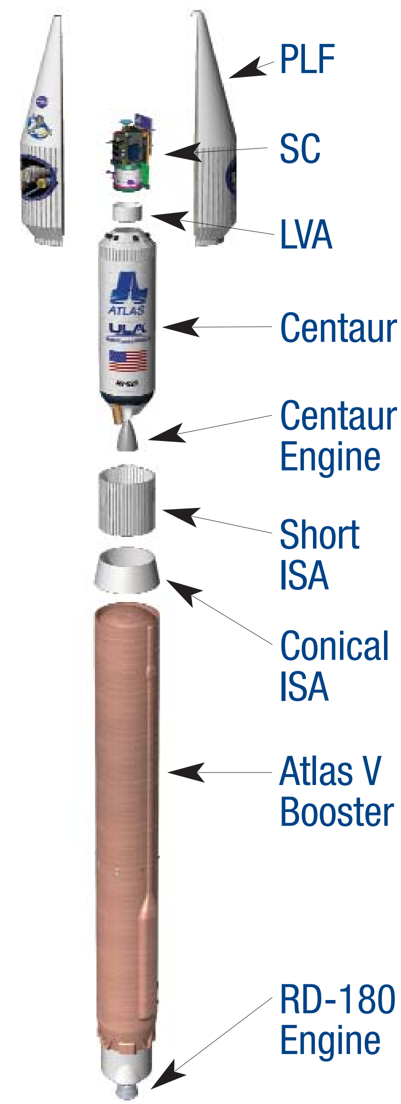


AV-020 Configuration Overview

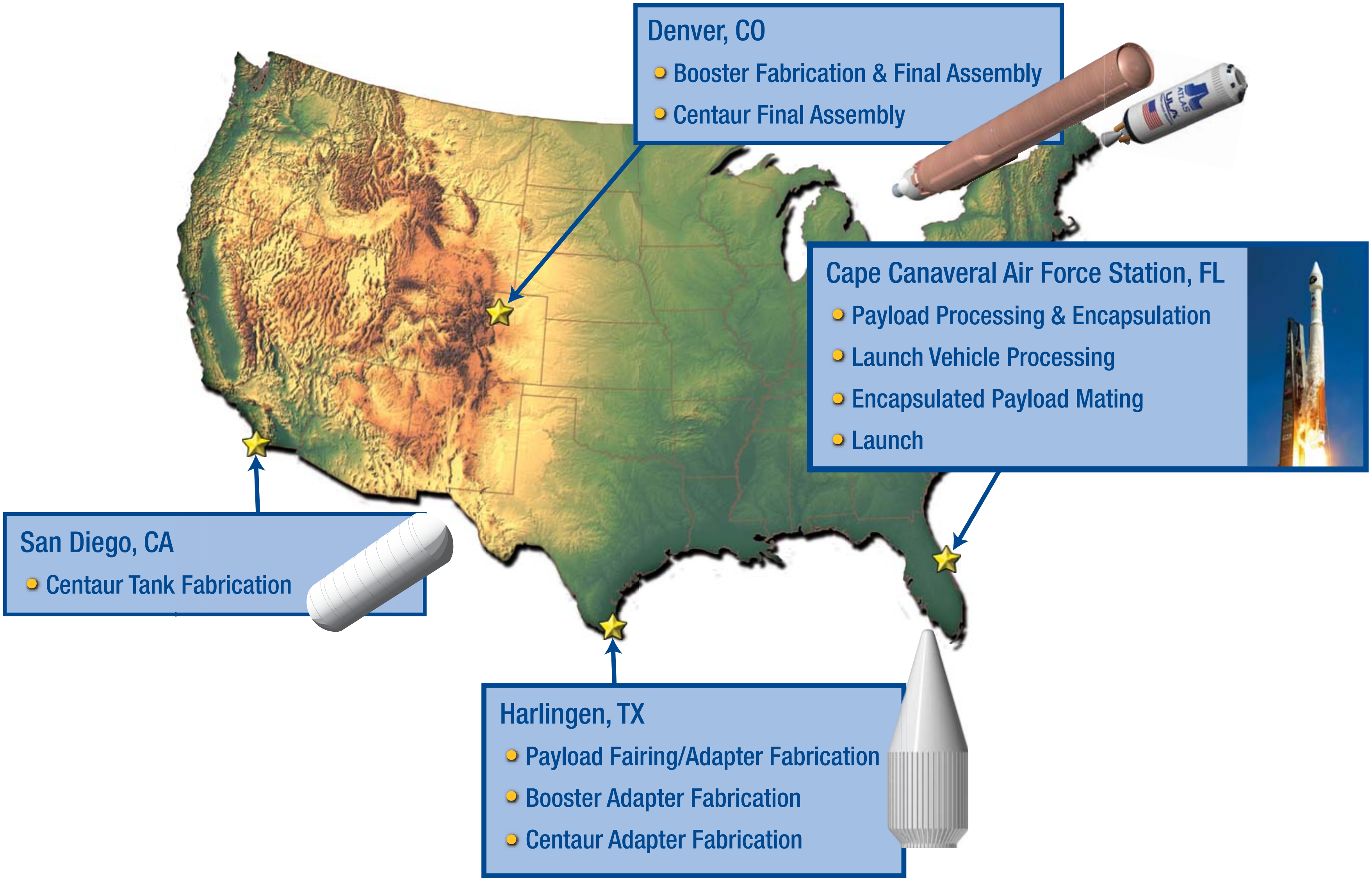
The Atlas V 401 configuration consists of a single Atlas V booster stage and the Centaur upper stage. The Atlas V booster and Centaur are connected by the conical and short interstage adapters (ISAs).

The Atlas V booster is 12.5 ft in diameter and 106.5 ft long. 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—highly purified kerosene) and liquid oxygen; and 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 boost phase of flight ends 6 seconds after propellant-depletion-commanded booster engine cutoff (BECO), when the separation charge attached to the forward ISA is fired and eight retrorockets push the spent Atlas booster stage away from the Centaur upper stage.

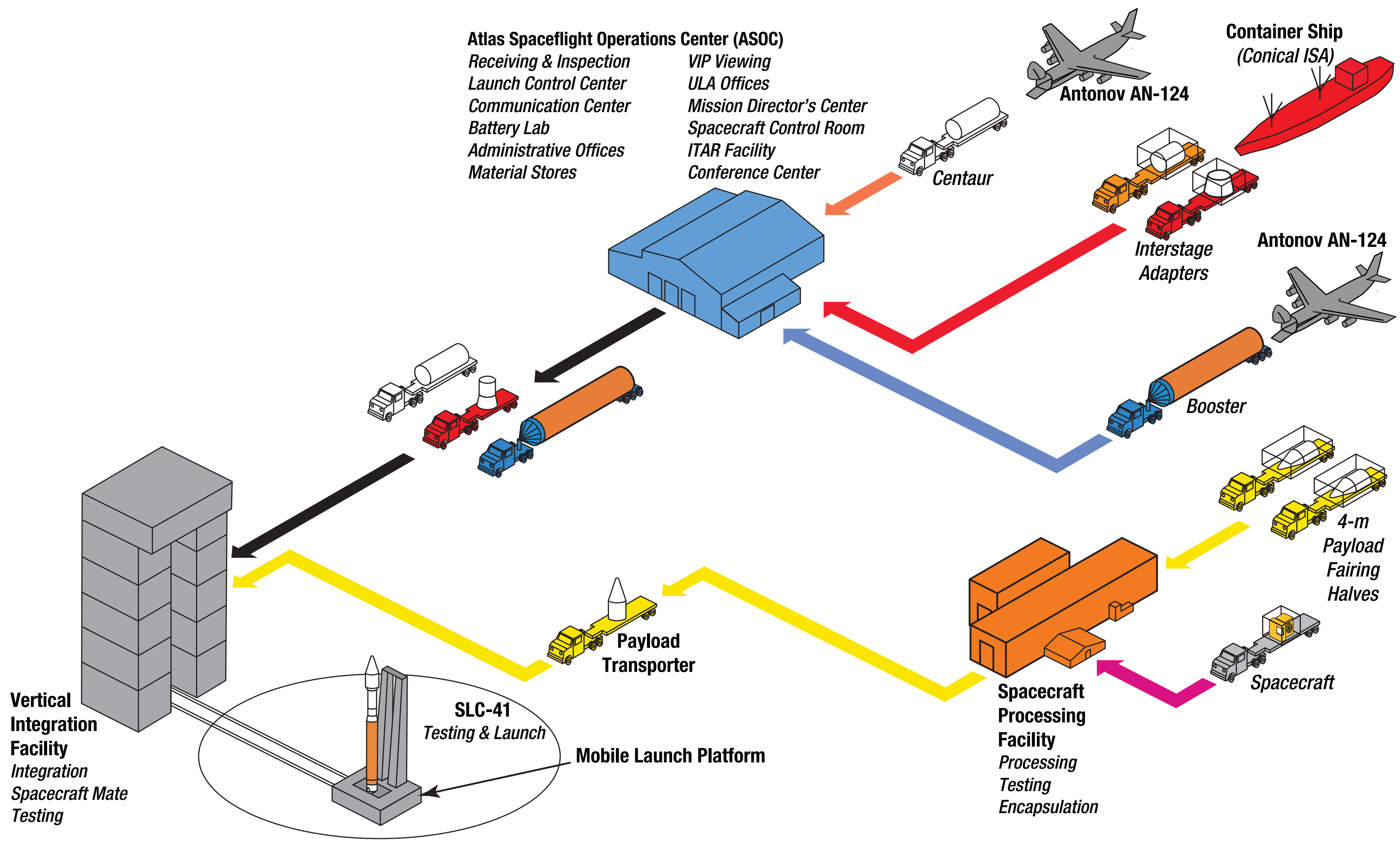
The Centaur upper stage is 10 ft in diameter and 41.5 ft long. Its propellant tanks are constructed of pressure-stabilized, corrosion-resistant stainless steel. Centaur is a liquid hydrogen/liquid oxygen-(cryogenic) fueled vehicle. It uses a single RL10A-4-2 engine that produces 22,300 lb of thrust. 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 SC. The LRO/LCROSS mission uses the 4 m- (14 ft-) diameter large payload fairing (PLF). The PLF is a bisector (two-piece shell) fairing consisting of aluminum skin/stringer construction with vertical split-line longerons. The vehicle's height with the PLF is approximately 189 ft.



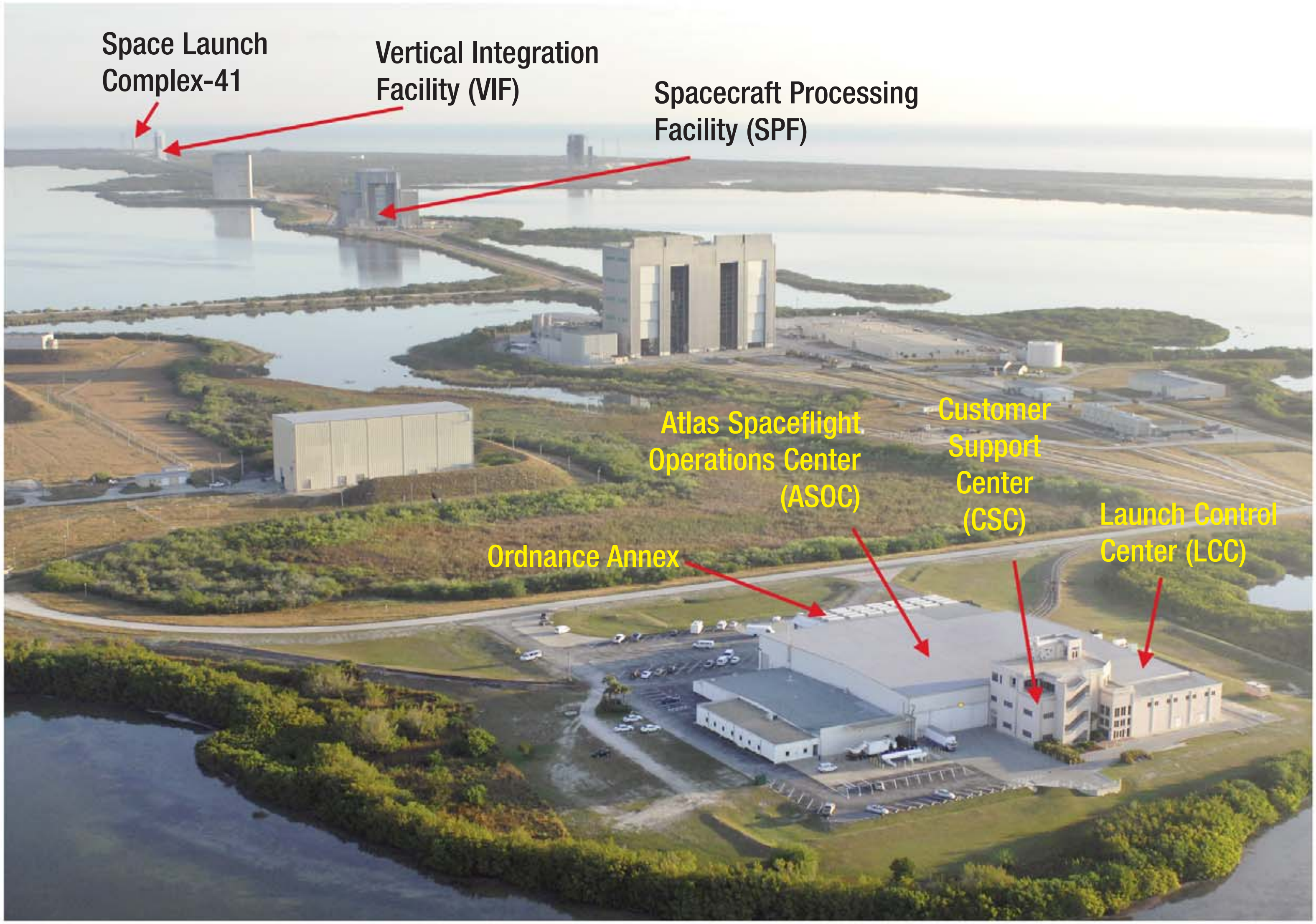
Atlas V Processing Overview



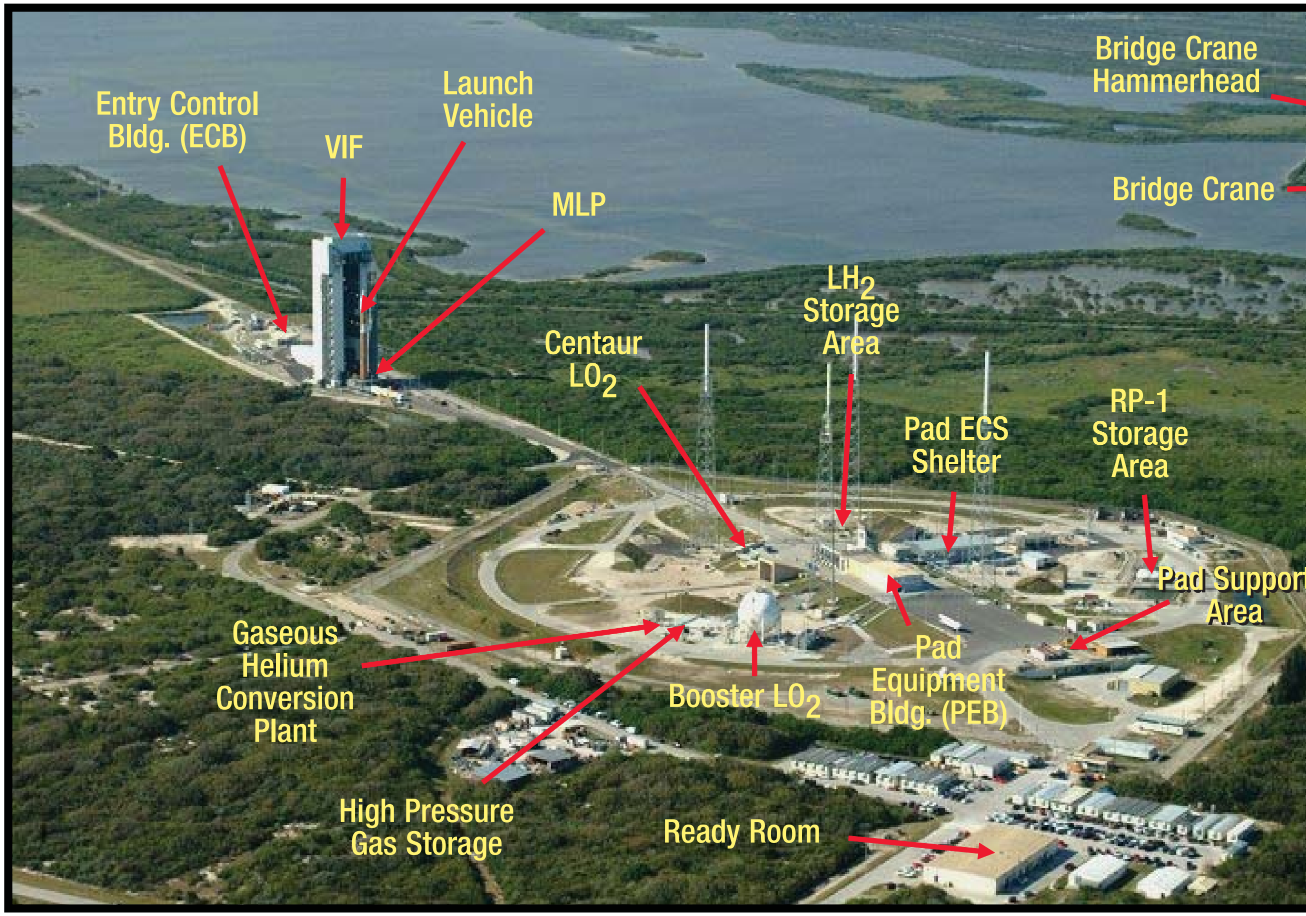
Launch Site Processing Overview



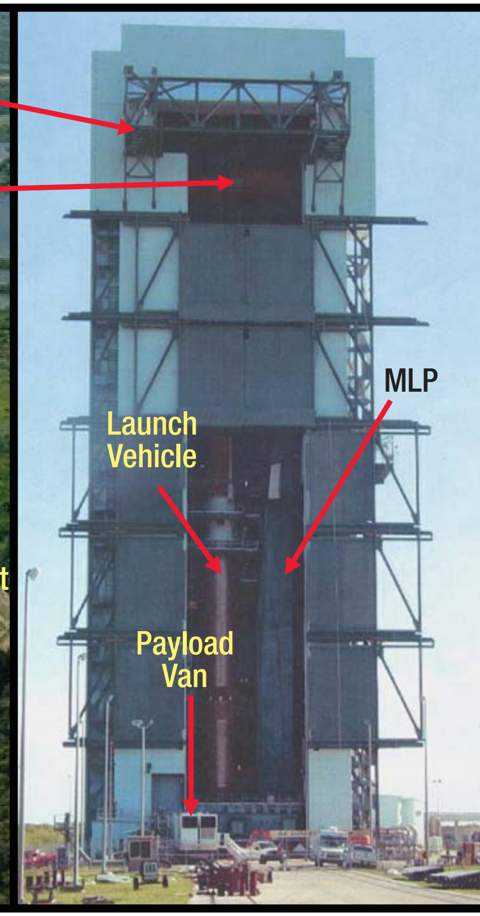
Launch Site Overview



SLC-41 Overview

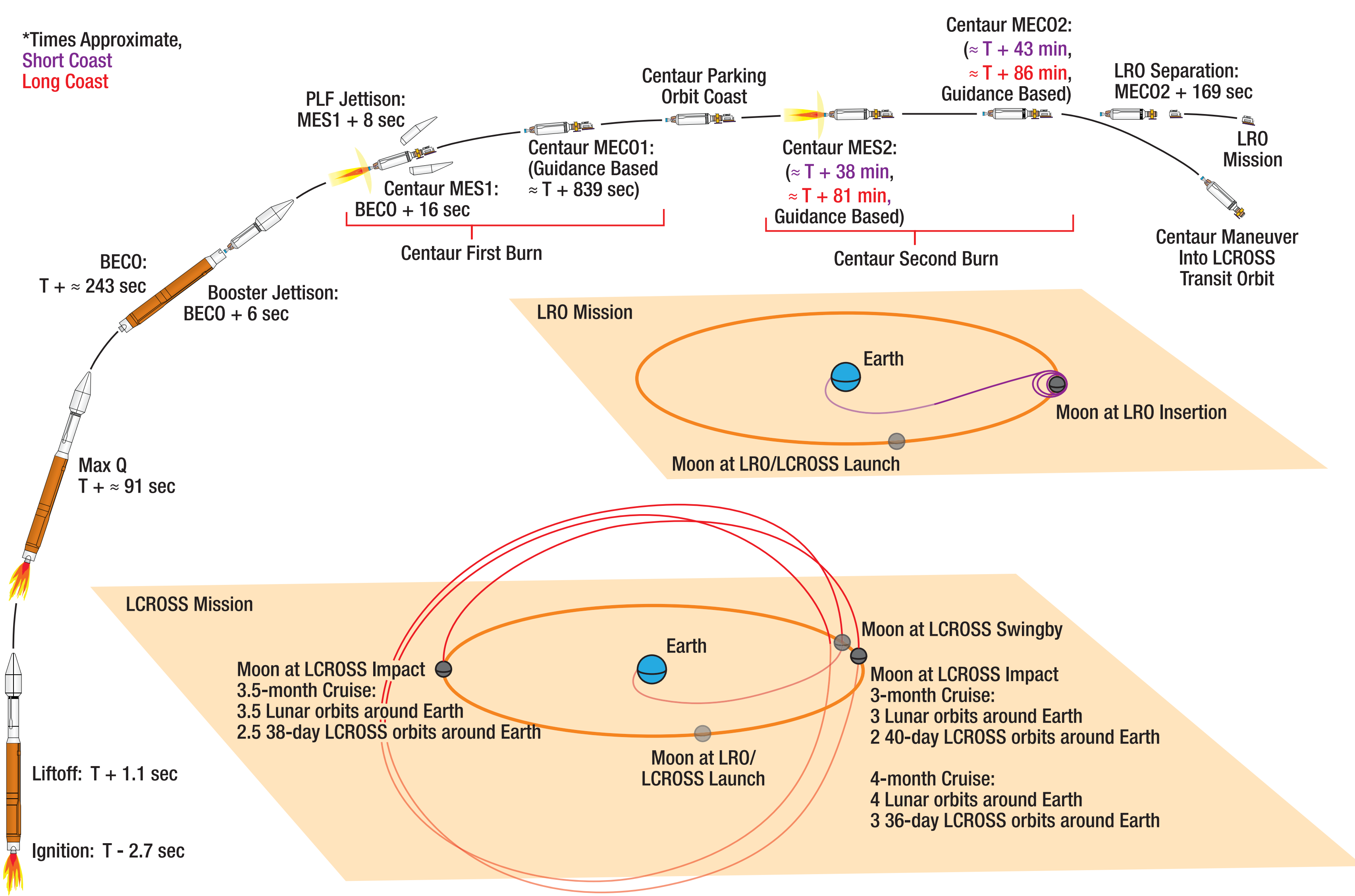


Southwest View of Space Launch Complex-41 (SLC-41)



South View of the Vertical Integration Facility (VIF)

Mission Profile



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Mission Overview

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The LRO/LCROSS mission will fly from Space Launch Complex-41 at Cape Canaveral Air Force Station on an Atlas V 401 configuration vehicle (tail number AV-020) with a single-engine Centaur. The payload will be encapsulated in a 4-m diameter large PLF and integrated to the Centaur upper stage using two modified C22 payload adapters (PLAs) and a ULA-provided spacecraft launch vehicle adapter (SCLVA), separation system, and electrical harness.

The LRO/LCROSS payload consists of two lunar exploration satellites. The mission will fly an easterly trajectory from SLC-41. The first SC separation event will release the LRO spacecraft into a lunar direct-insertion trajectory, which will reach the Moon in approximately four days. At the Moon, LRO's on-board propulsion will first insert LRO into an elliptical "commissioning" orbit from which it will move into its final orbit, a circular polar orbit approximately 50 km (a little over 30 miles) above the Moon's surface.

LCROSS will remain attached to the inert Centaur and shepherd it to the Moon in about 5 days using its own on-orbit resources. Passing the Moon, LCROSS/Centaur's orbit will change to an approximately 38-day geocentric elliptical polar configuration (36 to 40 days, depending on mission-specific guidance). LCROSS will guide Centaur through 2 to 4 Earth orbits (depending on the choice of a north- or south-polar impact site), direct Centaur to impact, and separate from Centaur. LCROSS and Centaur will then impact in permanently shadowed craters at approximately 2.5 km/s, with LCROSS passing though Centaur's debris cloud before impact.

Launch begins with RD-180 engine ignition, approximately 2.7 seconds before liftoff (T-2.7 seconds). Liftoff occurs at T+1.1 sec., after telemetry indication of healthy RD-180 startup. Shortly after the vehicle clears the pad, it performs its pitch/yaw/roll program. Maximum dynamic pressure occurs at approximately 91 seconds. BECO occurs at approximately 243 seconds, based on booster fuel or LO_2 depletion detection.

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Mission Overview (concluded)

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Telemetry data are gathered by TEL-4 (Merritt Island, FL), Jonathan Dickinson Missile Tracking Annex (JDMTA-Jupiter, FL), Antigua, and Guam tracking stations. The TDRSS constellation will also participate in gathering telemetry during the LRO/LCROSS mission.

Centaur separation is 6 seconds after BECO. The first Centaur main engine start (MES1) occurs 10 seconds after the separation event. Payload fairing jettison takes place at 8 seconds after MES1. At approximately 14 minutes into the mission, main engine cutoff 1 (MECO1) occurs and Centaur has achieved its parking orbit.

After reaching the guidance-determined optimum position for injection, Centaur reorients itself for MES2. The second Centaur engine burn lasts a little less than 5 minutes, at which point the second Centaur main engine cutoff number two (MECO2) occurs. After MECO2, Centaur reorients its attitude for the LRO separation event.

The LRO SC separates about 2.8 minutes after MECO2. Following LRO separation, Centaur maneuvers into the LCROSS transit orbit. This manuever uses directed impulse from blowdown of the main propellant system, followed by a guidance-determined manuever using the Reaction Control System's hydrazine-powered settling motors. Following the transit-orbit-injection manuever, remaining propellants are blowndown before handing off guidance to the LCROSS SC.

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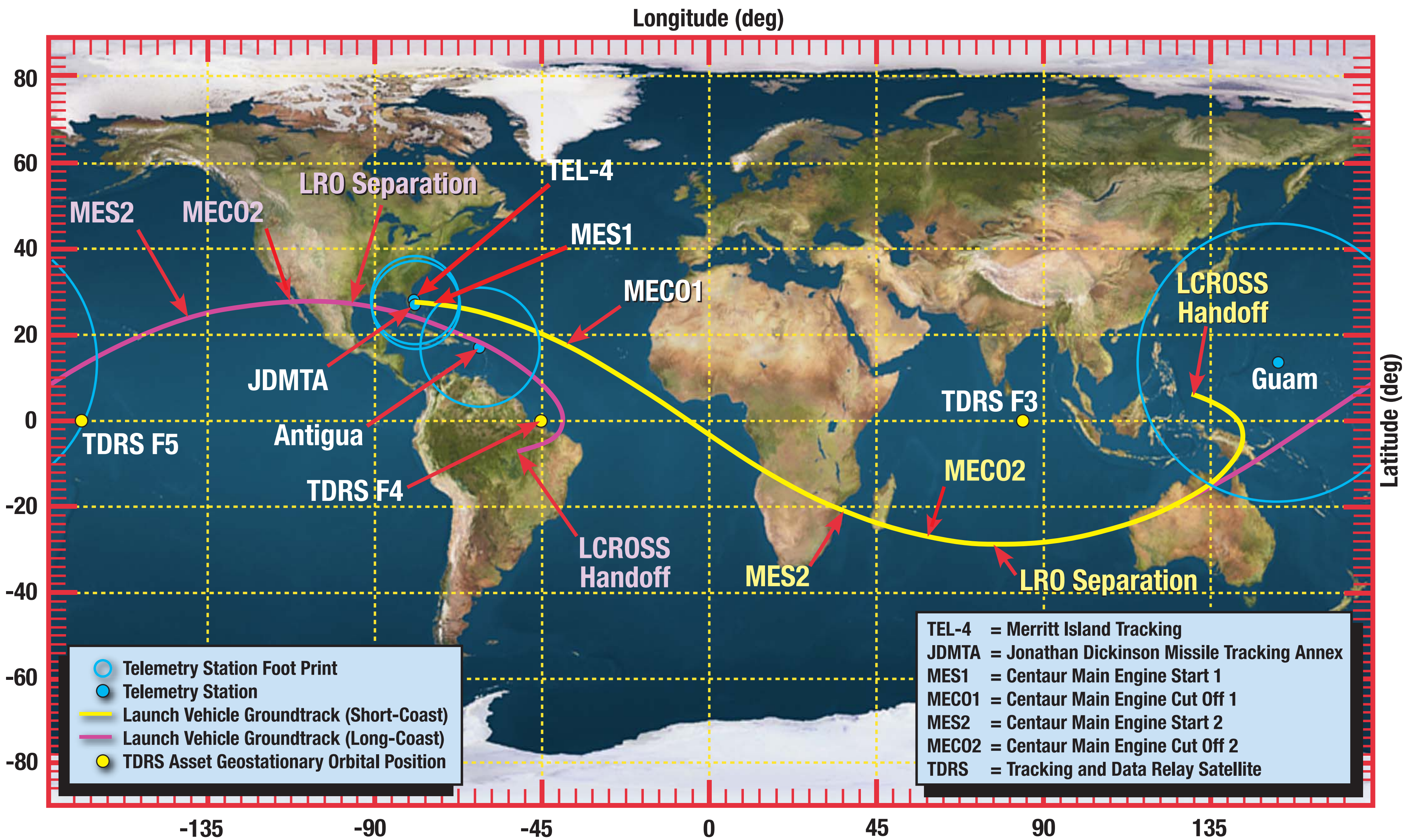
Mission Ground Trace

ATLAS



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Countdown Timeline

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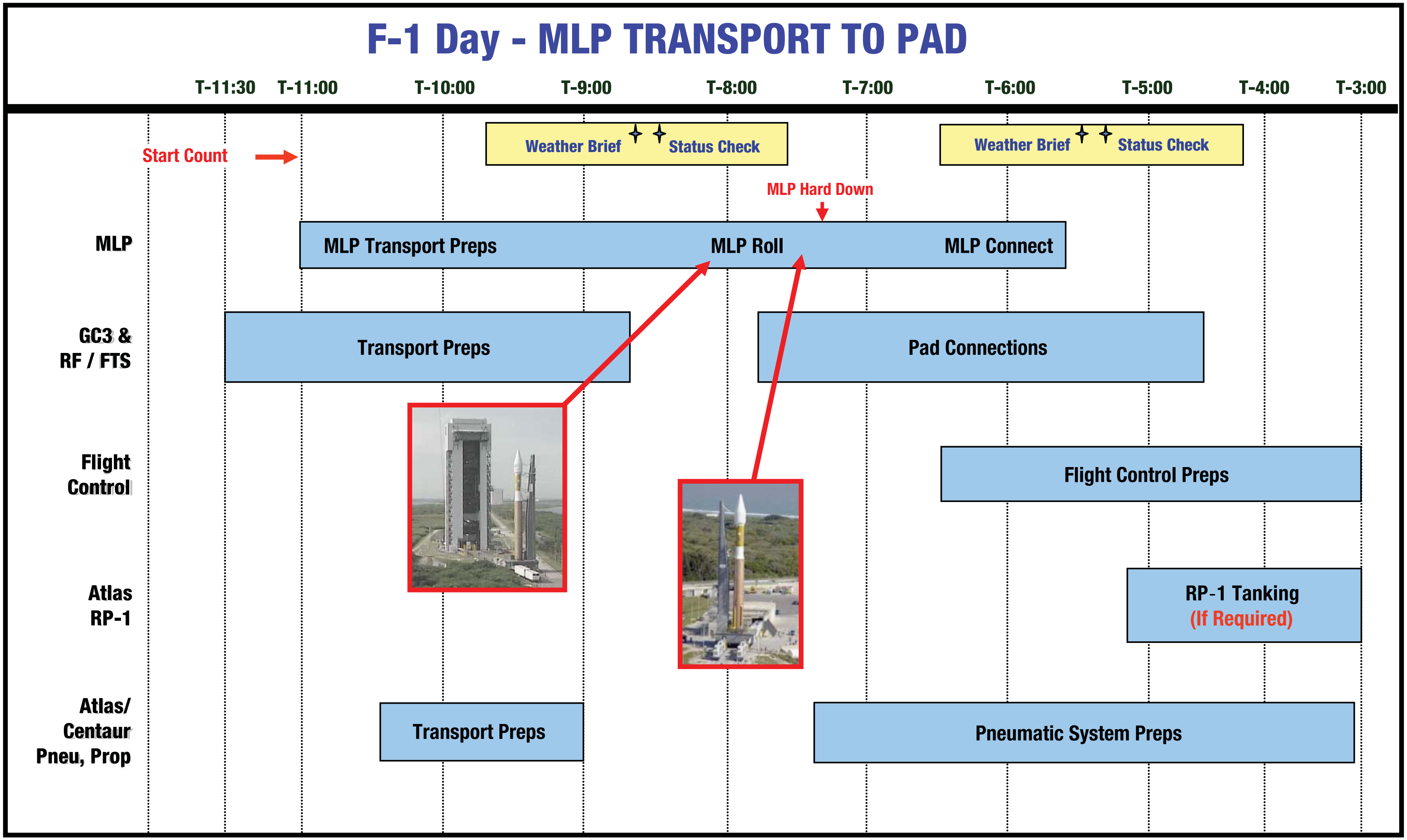
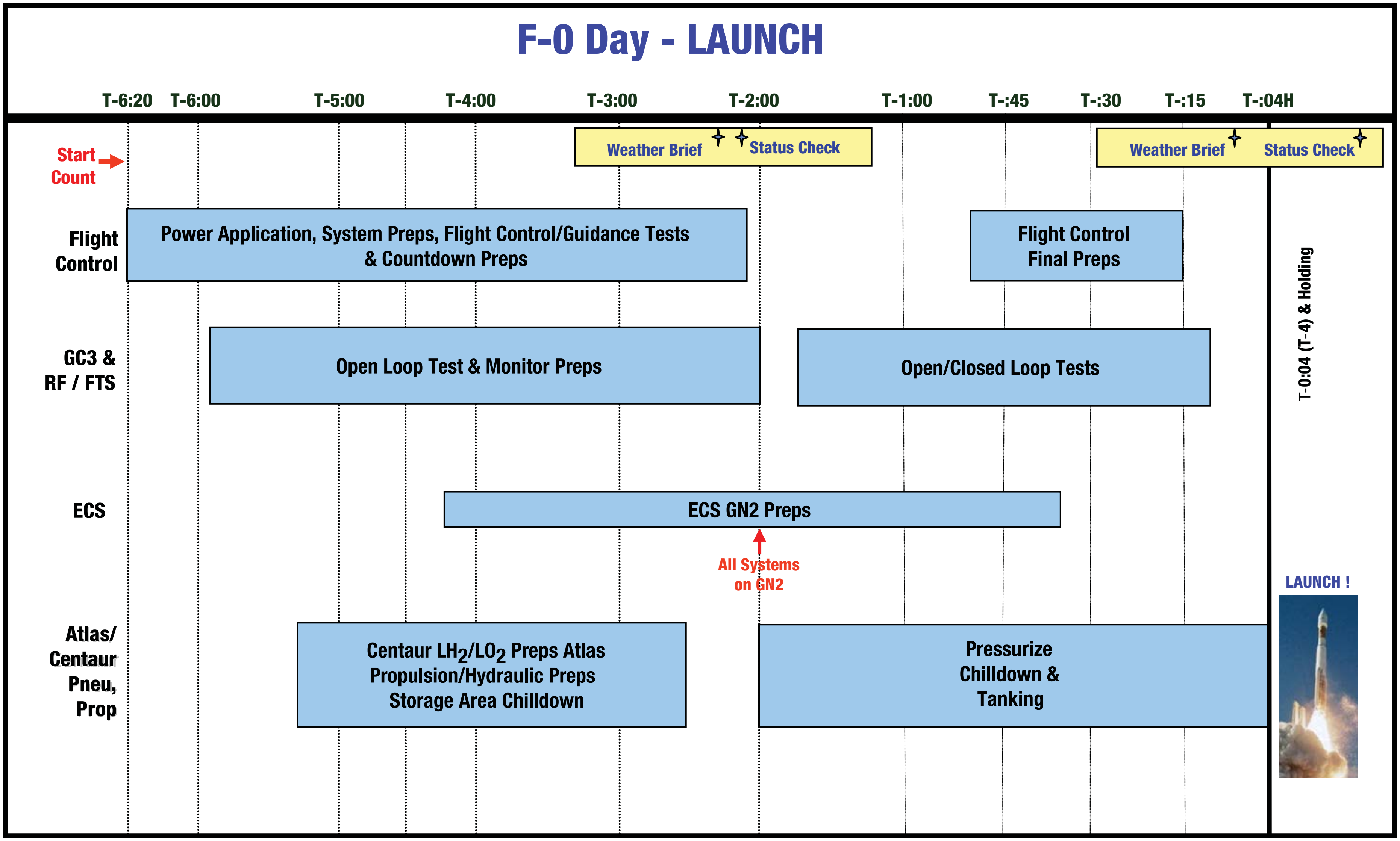


Countdown Timeline (concluded)



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Plus Count Key Events

ATLAS

MET (hh:mm:ss)		Action
Short-Coast	Long-Coast	
-00:00:03	-00:00:03	RD-180 Engine Ignition
00:00:00	00:00:00	T=0 (Engine Ready)
00:00:01	00:00:01	Liftoff (Thrust to Weight > 1)
00:00:18	00:00:18	Start Pitchover
00:00:51	00:00:51	Begin Zero Angle of Attack Flight
00:01:44	00:01:44	Maximum Dynamic Pressure
00:04:03	00:04:03	Atlas Booster Engine Cutoff (BECO)
00:04:09	00:04:09	Atlas Booster/Centaur Separation
00:04:19	00:04:19	Centaur First Main Engine Start (MES1)
00:04:27	00:04:27	Payload Fairing Jettison
00:13:59	00:13:59	Centaur First Main Engine Cutoff (MECO1)
00:38:28	01:20:58	Centaur Second Main Engine Start (MES2)
00:43:25	01:25:53	Centaur Second Main Engine Cutoff (MECO2)
00:46:14	01:28:42	LRO Spacecraft Separation (LRO SEP)
00:46:18	01:28:46	LCROSS Sequence
01:11:14	01:53:42	Begin Impulsive Blowdown
01:15:11	01:57:54	End Impulsive Blowdown (Guidance Computed)
01:18:11	02:00:54	Begin Non-impulsive Blowdown
02:04:34	02:47:02	End Non-impulsive Blowdown
02:07:54	02:50:22	Begin Guided Hydrazine Burn
02:13:04	03:02:44	End Guided Hydrazine Burn
03:11:14	04:00:55	Begin Nominal Hydrazine Depletion
03:17:07	04:05:11	End Nominal Hydrazine Depletion
04:01:14	04:34:15	Centaur Handoff to LCROSS Spacecraft
04:34:34	05:07:35	Centaur End of Mission (EOM)

*Values Approximate

Abbreviations & Acronyms

ASOC	Atlas Spaceflight Operations Center
BECO	Booster Engine Cut Off
CFA	Centaur Forward Adapter
CSC	Customer Support Center
ECB	Entry Control Building
ECS	Environmental Control System
GTS	Guam Transmitter Station
ISA	Interstage Adapter
JDMTA	Jonathan Dickinson Missile Tracking Annex
km	kilometer
LC	Launch Complex
LCC	Launch Control Center
LCROSS	Lunar CRater Observing and Sensing Satellite
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
LPF	Large Payload Fairing
LRO	Lunar Reconnaissance Orbiter
LVA	Launch Vehicle Adapter
Max Q	Maximum Dynamic Pressure
MECO	Main Engine Cut Off
MES	Main Engine Start (Centaur)
MLP	Mobile Launch Platform
MET	Mission Elapsed Time
NASA	National Aeronautics and Space Administration
PEB	Pad Equipment Building
PLA	Payload Adapter
PLF	Payload Fairing
Pneu	Pneumatics
Prop	Propulsion
PVC	Polyvinyl Chloride
RF	Radio Frequency
RP-1	Rocket Propellant – 1 (Kerosene)
SC	Spacecraft
SCLVA	Spacecraft Launch Vehicle Adapter
SMARF	Solid Motor Assembly and Readiness Facility
SPF	Spacecraft Processing Facility
SRMU	Solid Rocket Motor Upgrade
SVC	Space Vehicle Contractor
Tel-4	Easter Range Telemetry Station (Merritt Island)
TDRS(S)	Tracking & Data Relay Satellite (System)
ULA	United Launch Alliance
VIB	Vertical Integration Building
VIF	Vertical/Vehicle Integration Facility
VIP	Very Important Person

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Notes

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