

# Atlas

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## THE ATLAS FAMILY

**MX-774:** Project MX-774 inaugurated by AAF with Consolidated-Vultee to study rocket capabilities with an ICBM as a final objective. Limited funds permitted a few test launches. These rockets demonstrated technologies that would later be applied to the Atlas.

**Atlas A:** First test model of Atlas ICBM. Two booster engines, no sustainer, dummy warhead. Also known as X-11. 50% reliability in 8 flight tests.

**Atlas B:** (1958) Also known as X-12. First all-up version of Atlas ICBM, with jettisonable booster engines and single engine sustainer on core. '1 1/2' stage launch vehicle.

**Atlas Able:** (1959) Atlas with upper stage based on Vanguard second stage.

**Atlas D:** (1959) Also known as LV-3B. First operational version of Atlas ICBM and used as launch vehicle for Project Mercury.

**Atlas Agena A:** (1960) Also known as LV-3A. Agena originally called 'Hustler', based on engine for cancelled rocket-propelled nuclear warhead pod for B-58 Hustler bomber.

**Atlas Agena B:** (1961) Also known as SLV-3. Improved, enlarged Agena upper stage.

**Atlas Centaur C:** (1962) Also known as LV-3C. First test version of Atlas with Centaur upper stage.

**Atlas Agena D:** (1963) Also known as SLV-3A. Further improved and lightened Agena upper stage.

**Atlas Centaur D:** (1963) Also known as SLV-3C; SLV-3D. Fully developed version of Atlas with Centaur upper stage.

**Atlas E/F:** (1966) Final operational versions of Atlas ICBM. Differed in guidance systems. Deployed as missiles from 1960 to 1966. After retirement, the ICBM's were refurbished and used over twenty years as space launch vehicles.

**Atlas G/H/I:** (1983) Atlas-Centaur launch vehicles using stretched, uprated Atlas core. Atlas H flown a few times without Centaur.

**Atlas I:** (1990) Commercial Atlas with upgraded core and Centaur upper stage.

**Atlas II:** (1991) Commercial Atlas using stretched core with uprated boosters and stretched Centaur upper stage. Verniers replaced by hydrazine thruster modules.

**Atlas IIA:** (1992) Enhanced version of Atlas II.

**Atlas IIAS:** (1993) Atlas IIA but with solid rocket motor strap-ons.

**Atlas IIIA:** (2000) Development of Atlas using Russian engines in place of booster/sustainer group used on all previous models. First stage couples unique Atlas balloon tanks and high performance Glushko engines.

**Atlas IIIB:** (2002) Atlas IIIA 1st stage with stretched 1 or 2-engine Centaur upper stage.

**Atlas V:** (2002) Based on the 3.8 m diameter Common Core Booster (CCB) powered by a single RD-180 engine and incorporating a stretched Centaur upper stage. Variants use from 0 to 5 solid rocket motor strap-ons. 400-series uses standard 4.2 m diameter Atlas payload fairing, 500-series uses larger 5.4 m diameter fairing.

### ATLAS CENTAUR FAMILY RECORD

**First launch:** 8-May-1962

**Number launched:** 151 to end-2004

**Launch sites:** Cape Canaveral pads 36A/B; Vandenberg AFB SLC-3E from 1998

**Vehicle success rate:** 91.39% to end-2004

**Success rate, past 25 launches:** 100% to end-2004

## ATLAS I SPECIFICATIONS

**First launch:** 25-Jul-1990

**Last launch:** 25-Apr-1997

**Number launched:** 11

**Launch sites:** Cape Canaveral pad 36B

**Principal uses:** medium-class telecom and metsat payloads into GTO

**Vehicle success rate:** 72.7% to end-2000

### Performance:

LEO (185 km, 28.5°): 5,900 kg medium fairing, 5,700 kg large

GTO (167 x 35,786 km, 27.0°): 2,375 kg medium fairing, 2,255 kg large

Earth escape: 1,520 kg medium fairing, 1,400 kg large

**Availability:** typically four launches/year per pad. Launch typically 24-30 months following contract

**Cost:** about \$60 million with delivery into GTO

**Number of stages:** 2-1/2 (booster engines burn in parallel)

**Overall length:** 42.0 m with medium fairing, 43.9 m with large

**Principal diameter:** 3.05 m

**Launch mass:** 163,900 kg with medium fairing, 164,290 kg with large

**Launch thrust:** 1,953 kN sea level

**Guidance:** Honeywell's Inertial Navigation Unit mounted on Centaur's forward equipment module performs the inertial guidance and attitude control computations for both Atlas & Centaur. Some initial Atlas 1s retained the existing Honeywell inertial unit and Teledyne flight control computer but subsequent vehicles incorporate a Honeywell ring laser gyro INU + Gulton digital data

acquisition unit, saving 36 kg and enhancing reliability.

#### ATLAS I STAGE 1

**Engines:** Rocketdyne MA-5 propulsion system of two booster, one sustainer and two vernier single-start liquid bipropellant engines

**Length:** 22.16 m

**Diameter:** 3.05 m

**Dry mass:** 7,882 kg (including 3,646 kg booster section)

**Oxidizer:** liquid oxygen

**Fuel:** RP-1 hydrocarbon

**Propellant mass:** 137,530 kg

**Thrust:** 1,953 kN SL

**Burn time:** 156 s boosters, 266 s sustainer

**Attitude control:** engines are gimballed hydraulically to provide 3-axis control during burn

**Separation:** Atlas uniquely incorporates two booster engines fired in parallel with the central sustainer until the base section is jettisoned by the release of pneumatically-actuated latches at about T+156 s/5.5 g longitudinal acceleration. Separation is ensured by eight solid propellant retros around the base firing angled at 40° to the vertical to prevent spacecraft contamination.

#### INTERSTAGE ADAPTER

The 477 kg, 3.96 m long, 3.05 m diameter ISA supports the Centaur until separation at about 268 s is effected by a flexible linear shaped charge around the forward circumference. Construction is an aluminum skin/stringer and frame.

#### CENTAUR (ATLAS VERSION)

**Engines:** two P&W RL10A-3-3A cryogenic multiple start engines

**Length:** 9.15 m

**Diameter:** 3.05 m

**Dry mass:** 1,700 kg

**Oxidizer:** liquid oxygen

**Fuel:** liquid hydrogen

**Propellant mass:** 13,790 kg

**Thrust:** 146.8 kN vac

**Burn time:** 408 s for single burn direct ascent, or 312 + 93 s for dual-burn parking orbit ascent

**Attitude control:** Engines are gimballed for 3-axis control during burn; 12 x 27 N hydrazine thrusters provide 3-axis control during coast, spin-up for payload separation and collision avoidance maneuver.

#### FAIRING/PAYLOAD ACCOMODATION

Two fairing designs are available for spacecraft protection during ascent: 4.19 m diameter, 12.22 m long, 2,005 kg; or 3.30 m diameter, 10.36 m long, 1,375 kg mass. Usable diameters are 3.65 m and 2.92 m, respectively. Both employ an aluminum skin/stringer/frame structure and non-contaminating pyro separation bolts for jettison in halves at about 205 s prior to sustainer engine cutoff when heating rate has reduced to 1,135 W/m<sup>2</sup>. On the pad, air conditioning can provide a 15-25°C environment around the spacecraft.

**Acceleration load:** 5.5 g maximum longitudinal, 0.4 g lateral

**Acoustic load:** maximum 138.9 dB overall

## ATLAS II SPECIFICATIONS

**First launch:** 7-Jul-1991

**Last launch:** 16-Mar-1998

**Number launched:** 10

**Launch sites:** Cape Canaveral pads 36A/B, Vandenberg AFB SLC-3E from 1998 for access to Sun-synchronous polar and 63.4° orbits for military and Earth observation satellites

**Principal uses:** delivery of DSCS-3 satellites into GTO; future: high inclination missions

**Vehicle success rate:** 100% to end-2000

#### Performance:

LEO (185 km, 27.0° Canaveral): 6,780 kg medium fairing, 6,580 kg large

LEO (185 km, 90.0° VAFB): 5,510 kg large

GTO (160 x 35,786 km, 28.5°): 2,950 kg medium fairing, 2,810 kg large

Earth escape: 2,000 kg large fairing

**Number of stages:** 2-1/2 (booster engines burn in parallel)

**Overall length:** 46.8 m with medium fairing, 47.4 m with large

**Principal diameter:** 3.05 m

**Launch mass:** 187,170 kg with medium fairing, 187,560 kg with large

**Launch thrust:** 2,159 kN sea level

**Guidance:** as Atlas I

#### ATLAS II STAGE 1

**Engines:** Rocketdyne MA-5A single-start liquid bipropellant consisting of two booster engines and one sustainer

**Length:** 24.9 m

**Diameter:** 3.05 m

**Dry mass:** 10,282 kg (including 4,187 kg booster section)

**Oxidizer:** liquid oxygen

**Fuel:** RP-1 hydrocarbon  
**Propellant mass:** 156,260 kg  
**Thrust:** 2,159 kN SL  
**Burn time:** 169 s boosters, 277 s sustainer

#### INTERSTAGE ADAPTER

The ISA is similar to that on Atlas I but two hydrazine thruster modules similar to those on Centaur provide roll control; mass is 545 kg.

#### ATLAS II STAGE 2

**Engines:** as Atlas I  
**Length:** 10.1 m  
**Diameter:** 3.05 m  
**Dry mass:** 2,053 kg  
**Oxidizer:** liquid oxygen  
**Fuel:** liquid hydrogen  
**Propellant mass:** 16,780 kg  
**Thrust:** 146.8 kN vac  
**Burn time:** typically as Atlas I

#### FAIRING/PAYLOAD ACCOMODATION

As Atlas 1

## ATLAS IIA

Atlas IIA was a commercial derivative of the Atlas II developed for the US Air Force. Higher performance RL10A-4-1 engines replaced the Atlas II's RL10A-3-3A engines. RL10A-4-1 engines are offered with or without extendable nozzles, which increase the engine's specific impulse providing additional performance if required. The upgraded second stage increased LEO capacity to 7,280 kg (185 km, 28.5°), and GTO performance to 3,039 kg. 23 Atlas IIA's were launched with a 100% success rate; first launch was 10-Jun-1992, last launch 4-Dec-2002.

#### ATLAS IIA STAGE 2

**Engines:** two P&W RL10A-4-1 cryogenic multiple start engines  
**Length:** 10.1 m  
**Diameter:** 3.05 m  
**Dry mass:** 1,840 kg  
**Oxidizer:** liquid oxygen  
**Fuel:** liquid hydrogen  
**Propellant mass:** 16,930 kg  
**Thrust:** 198.4 kN vac  
**Burn time:** 370 s

## ATLAS IIAS

The Atlas IIAS solid thrust augmented version enhances the IIA's performance by adding four Castor 4A strap-ons. The strap-ons increase LEO capacity to 8,618 kg (185 km, 28.5°), and GTO performance to 3,719 kg (167 x 35,786 km, 27.0°). To end-2004, 30 Atlas IIAS's have been launched with a 100% success rate; first launch was 15-Dec-2002.

#### ATLAS IIAS STRAP-ONS

**Length:** 11.16 m  
**Diameter:** 1.02 m  
**Mass at ignition:** each 11,600 kg  
**Propellant:** TP-H8299 HTPB polymer, 20% aluminum  
**Propellant mass:** each 10,100 kg  
**Thrust:** each 433.7 kN SL average  
**Specific impulse:** 237.8 s SL  
**Burn time:** 55 s  
**Burn sequence:** one pair of strap-ons ignite at launch, burnout at 54.7 s, and are jettisoned at 77.1 s. The second pair is air-lit at 60 s, burnout at 115.3 s, and are jettisoned at 117.2 s.

## ATLAS III SPECIFICATIONS

The Atlas III consists of two versions, the IIIA and IIIB. Both versions are based on a first stage incorporating 3.05 m diameter Atlas balloon tanks and a single RD-180 engine. The IIIA uses a Centaur upper stage with a single RL10A-4-1 engine. The IIIB uses a stretched Centaur upper stage for enhanced performance powered by either one (SEC) or two (DEC) RL10A-4-1 engines. The specifications given below apply to the Atlas IIIA; where the Atlas IIIB's characteristics differ they are included in parentheses.

**First launch:** 24-May-2000  
**Number launched:** 6 to Feb-2005  
**Launch sites:** Cape Canaveral pad 36  
**Principal uses:** delivery of single payloads to LEO or GTO

**Vehicle success rate:** 100% to Feb-2005

**Performance:**

LEO (185 km, 28.5°): 8,686 kg (10,759 kg) with LPF, 8,641 kg (10,718 kg) with EPF

GTO (167 x 35,786 km, 27.0°): 4,060 kg (4,500 kg) with LPF, 4,037 kg (4,477 kg) with EPF

**Number of stages:** 2

**Overall length:** 51.9 m (53.6 m) with LPF, 52.8 m (54.5 m) with EPF

**Principal diameter:** 3.05 m

**Launch mass:** 218,127 kg to 218,295 kg (222,237 kg to 222,585 kg), + payload

**Launch thrust:** 3,827 kN sea level

**Guidance:** inertial, from Centaur upper stage

**ATLAS III STAGE 1**

**Engines:** P&W/NPO Energomash RD-180 with two gimbaled chambers

**Length:** 28.91 m

**Diameter:** 3.05 m

**Dry mass:** 13,725 kg

**Oxidizer:** liquid oxygen

**Fuel:** RP-1 hydrocarbon

**Propellant mass:** 183,200 kg

**Thrust:** 3,827 kN SL

**Burn time:** 184 s (182 s)

**INTERSTAGE ADAPTER**

The 465 kg, 4.45 m long, 3.05 m diameter ISA supports the Centaur until separation is effected by a flexible linear shaped charge around the forward circumference. Construction is an aluminum-lithium skin/stringer and frame.

**ATLAS III STAGE 2**

**Engines:** P&W RL10A-4-1 cryogenic multiple start engine (2 engines for DEC)

**Length:** 10.06 m (11.74 m)

**Diameter:** 3.05 m

**Dry mass:** 1,720 kg (1,930 kg SEC, 2,110 kg DEC)

**Oxidizer:** liquid oxygen

**Fuel:** liquid hydrogen

**Propellant mass:** 16,930 kg (20,830 kg)

**Thrust:** 99.2 kN vac (198.4 kN vac DEC)

**Burn time:** 739 s (907 s SEC, 454 s DEC)

**PAYLOAD FAIRING**

The payload fairing consists of a boattail, cylindrical section, conical section, and spherical cap. Construction is an aluminum skin/stringer and frame with vertical, split-line longerons that allow the fairing to separate into bisectors for jettison. Separation is by pyro bolts and spring thrusters. Large payload fairing (LPF) is 2,087 kg, 12.2 m long, and 4.2 m diameter; extended payload fairing (EPF) is 2,255 kg, 13.1 m long, and 4.2 m diameter.

## ATLAS V SPECIFICATIONS

The Atlas V launch system is based on the 3.8 m diameter Common Core Booster (CCB) powered by a single RD-180 engine and incorporating a stretched Centaur upper stage with either one (SEC) or two (DEC) RL10A-4-2 engines. Variants use from 0 to 5 strap-on solid rocket boosters, and either a 4.2-m or 5.4-m diameter payload fairing. Each Atlas V has a 3-digit vehicle naming designator; the first digit indicates the usable fairing diameter (4-m or 5-m), the second digit indicates the number of strap-on SRBs (0 to 5), and the last digit indicates the number of Centaur engines (1 or 2).

**First launch:** 21-Aug-2002

**Number launched:** 6 to Aug-2005

**Launch sites:** Cape Canaveral pad 41

**Principal uses:** delivery of single or double payloads to LEO or GTO

**Vehicle success rate:** 100% to Aug-2005

**Performance:**

LEO (185 km, 28.5°): 12,500 kg (402), 10,300 kg (502), 12,590 kg (512), 15,080 kg (522), 17,250 (532), 18,955 kg (542), 20,520 kg (552)

GTO (167 x 35,786 km, 27.0°): 4,950 kg (401), 5,950 kg (411), 6,830 kg (421), 7,640 kg (431), 3,970 kg (501), 5,270 kg (511), 6,285 kg (521), 7,200 kg (531), 7,980 kg (541), 8,670 kg (551)

(Quoted performance is with EPF for 400-series and short PLF for 500-series)

**Number of stages:** 2 + 0 to 5 strap-ons

**Overall length:** 400-series: 57.4 m w/LPF, 58.3 m w/EPF; 500-series: 59.7 m w/short PLF, 62.4 m w/medium PLF

**Principal diameter:** 3.81 m

**Launch mass:** 330,625 kg (401) to 470,107 kg (431) with EPF; 333,205 kg (501) to 566,297 (552) w/short PLF

**Launch thrust:** from 3,827 kN SL with 0 SRBs, to 10,632 kN SL with 5 SRBs

**Guidance:** inertial, from Centaur upper stage

**ATLAS V SOLID ROCKET BOOSTERS (SRB)**

**Number used:** 400-series: 0 to 3; 500-series: 0 to 5

**Length:** 19.5 m

**Diameter:** 1.55 m  
**Mass at ignition:** each 46,494 kg  
**Propellant:** HTPB solid  
**Propellant mass:** each 42,630 kg  
**Thrust:** each 1,245 kN vac average, 1,361 kN at ignition  
**Specific impulse:** 275 s vac  
**Burn time:** 94 s  
**Burn sequence:** SRBs are ignited at launch; first three are jettisoned at 99 s followed by the next two at 100 s.

#### ATLAS V COMMON CORE BOOSTER (CCB)

**Engines:** P&W/NPO Energomash RD-180 with two gimbaled chambers  
**Length:** 32.46 m  
**Diameter:** 3.81 m  
**Dry mass:** 20,743 kg (21,173 kg for 55X configuration)  
**Oxidizer:** liquid oxygen  
**Fuel:** RP-1 hydrocarbon  
**Propellant mass:** 284,089 kg  
**Thrust:** 3,827 kN SL  
**Burn time:** 236 s to 252 s

#### INTERSTAGE ADAPTER

The 400-series combines a conical CCB ISA and a short Centaur ISA. The total mass is 794 kg, overall length is 4.78 m, and the diameter is 3.83 m at the bottom by 3.05 m at the top. The 500-series combines a cylindrical CCB ISA and a large Centaur ISA. The total mass is 1,544 kg, overall length is 4.13 m, and the diameter is 3.83 m.

#### ATLAS V STAGE 2

**Engines:** one or two P&W RL10A-4-2 cryogenic multiple start engines  
**Length:** 12.68 m  
**Diameter:** 3.05 m  
**Dry mass:** 1,914 kg SEC, 2,106 kg DEC  
**Oxidizer:** liquid oxygen  
**Fuel:** liquid hydrogen  
**Propellant mass:** 20,830 kg  
**Thrust:** 99.2 kN vac SEC, 198.4 kN vac DEC  
**Burn time:** 900 s SEC, 450 s DEC

#### PAYLOAD FAIRING

The 400-series utilizes the same payload fairings as the Atlas III. The 500-series uses 5-m short and medium payload fairings. The bisector fairings consist of sandwich construction with graphite epoxy face sheets and an aluminum honeycomb core. The fixed boattail is composite sandwich construction. Vertical separation is by a linear piston and cylinder activated by a pyrotechnic cord; horizontal separation is by an expanding tube shearing a notched frame, activated by a pyrotechnic cord. Short payload fairing (standard) is 4,085 kg, 20.7 m long, and 5.4 m diameter; medium payload fairing is 4,649 kg, 23.4 m long, and 5.4 m diameter. Air conditioning on the pad can provide 15-25°C.

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## ROCKETDYNE / MA-5

The MA-5 propulsion system comprises a YLR89-NA-7 dual-chamber liquid propellant booster engine, a YLR105-NA-7 single-chamber liquid sustainer and two YLR101-NA-15 verniers to control vehicle roll and provide final velocity and directional control following sustainer burnout. The single-start main engines are fed from the same propellant tanks but Atlas uniquely separates the two outer boosters some 172 s into flight, leaving the altitude configured sustainer to provide propulsion to near-orbital velocity.

**Application:** Atlas I propulsion system  
**First flown:** 18-Nov-1961  
**Number flown:** 215 MA-5, 152 MA-3, 118 MA-2 to end-1995  
**Dry mass:** 1,423 kg for both boosters, 470 kg sustainer  
**Length:** 3.40 m booster, 2.69 m sustainer (with aspirator)  
**Maximum diameter:** 1.19 m booster, 1.17 m sustainer  
**Mounting:** all thrust chambers are gimbaled  
**Engine cycle:** gas generator  
**Oxidizer:** liquid oxygen, delivered at 458 kg/s for booster, 89 kg/s for sustainer  
**Fuel:** RP-1, delivered at 203 kg/s for booster, 39 kg/s for sustainer  
**Mixture ratio:** 2.25 booster, 2.27 sustainer  
**Oxidizer turbopump:** each 6,732 rpm, 1,678 kW, 68 atm discharge pressure for boosters; 10,568 rpm, 846 kW, 73 atm discharge pressure for sustainer  
**Fuel turbopump:** each 1,116 kW, 68 atm discharge pressure for boosters; 508 kW, 73 atm discharge pressure for sustainer  
**Thrust:** 1,882 kN for booster pair vac/1,681 kN SL; 374 kN sustainer vac/269 kN SL; verniers are 2,975 N each  
**Specific impulse:** 292 s vac/259 s SL for boosters; 309 s vac/220 s SL for sustainer  
**Time to full thrust:** 2.0 s  
**Expansion ratio:** 8:1 boosters, 25:1 sustainer  
**Combustion chamber pressure:** 44 atm booster/50 atm sustainer  
**Combustion chamber temperature:** 3,316°C both booster/sustainer  
**Burn time:** 167 s max booster, 368 s max sustainer

**Verniers:** each 24.1 kg mass, 2.24/2.97 kN SL/vac thrust, 172/231 s SL/vac Isp, 1.8 mixture ratio, 5.66 expansion ratio (exit diameter 9.65 cm), 391 s burn time

## ROCKETDYNE / MA-5A

The MA-5 system was uprated for Atlas 2 by replacing the booster engines, now designated RS-56A, with Rocketdyne's RS-27. The side-mounted verniers were deleted; their roll control and final adjustment functions were assumed by thruster modules on the vehicle's interstage. Sustainer engine (RS-56SA) specifications are as for the MA-5 except that total oxidizer/fuel flow rates are 90/38 kg/s, respectively; only booster engine specifications are given below.

**Application:** Atlas II propulsion system

**First flown:** 7-Nov-1991

**Number flown:** 20 to end-1995

**Dry mass:** 1,610 kg

**Length:** 3.43 m

**Maximum diameter:** 1.19 m

**Mounting:** all thrust chambers are gimballed

**Engine cycle:** gas generator

**Oxidizer:** liquid oxygen, delivered at 505 kg/s

**Fuel:** RP-1, delivered at 224 kg/s

**Mixture ratio:** 2.25

**Oxidizer turbopump:** each 1,903 kW, 6,730 rpm, 70 atm discharge pressure

**Fuel turbopump:** each 1,362 kW, 75 atm discharge pressure

**Thrust:** total 2,100 kN vac, 1,890 kN SL

**Specific impulse:** 295 s vac, 263 s SL

**Time to full thrust:** 2.0 s

**Expansion ratio:** 8:1

**Combustion chamber pressure:** 48 atm

**Combustion chamber temperature:** 3,316°C

**Burn time:** 167 s max

## P&W / RL10A-3-3A

**Application:** Centaur stage of Atlas & Titan

**First flown:** Nov-1963 (3-3A first flight Jun-1984)

**Number flown:** 246 to end-1995

**Dry mass:** 138 kg

**Length:** 1.78 m

**Maximum diameter:** 1.02 m

**Mounting:** gimballed  $\pm 4^\circ$  for pitch/yaw control

**Engine cycle:** expander

**Oxidizer:** liquid oxygen, delivered at 14.0 kg/s

**Fuel:** liquid hydrogen, delivered at 2.79 kg/s

**Mixture ratio:** 5.0

**Oxidizer turbopump:** 11.3 kg mass, 13,100 rpm, 88 kW, 45.6 atm discharge pressure

**Fuel turbopump:** 34 kg mass, 32,800 rpm, 76.2 atm discharge pressure

**Thrust:** 73.4 kN vac

**Specific impulse:** 444.4 s vac

**Time to full thrust:** typically 2.15 s

**Expansion ratio:** 61:1

**Combustion chamber pressure:** 32.2 atm

**Combustion chamber temperature:** 3,340°C

**Burn time:** about 600 s required on Titan 4 Centaur, engine qualified to 4,000 s

## P&W / RL10A-4-1, RL10A-4-2

**Application:** Centaur stage of Atlas IIA & III (RL10A-4-1), and Atlas V (RL10A-4-2)

**Dry mass:** 168 kg

**Maximum diameter:** 1.53 m

**Oxidizer:** liquid oxygen, delivered at 19.0 kg/s

**Fuel:** liquid hydrogen, delivered at 3.45 kg/s

**Mixture ratio:** 5.5

**Thrust:** 99.2 kN vac

**Specific impulse:** 450.5 s vac

**Expansion ratio:** 84:1

**Combustion chamber pressure:** 39.0 atm

## P&W-NPO ENERGOMASH / RD-180

**Configuration:** two gimballed chambers

**Application:** Atlas III and Atlas V stage 1

**First flown:** 1999

**Dry mass:** 5,480 kg

**Length:** 3.56 m

**Maximum diameter:** 3.15 m

**Engine cycle:** staged combustion  
**Oxidizer:** liquid oxygen, delivered at 916.5 kg/s  
**Fuel:** kerosene, delivered at 337 kg/s  
**Mixture ratio:** 2.72  
**Feed method:** High-pressure turbopump assembly feeds both chambers  
**Thrust:** 3,827 kN SL, 4,152 kN vac, throttleable 47-100%  
**Specific impulse:** 311.3 s SL, 337.8 s vac  
**Expansion ratio:** 36.4:1  
**Combustion chamber pressure:** 253 atm  
**Burn time:** 150 s

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