

GEM MOTOR SERIES

RELIABLE, LOW-COST BOOSTERS

The Graphite Epoxy Motor (GEM) series originated with the GEM 40 motor. Northrop Grumman developed the GEM 40 for the Delta II launch vehicle to support both commercial and government launches for The Boeing Company and other users. GEM 40 boosters increased the launch capability of the Delta II. GEMs have demonstrated through qualification and flight that they are the most reliable, lowest cost boosters available. Both ground- and air-start versions with a canted fixed nozzle are available for strap-on applications. In addition, a version with a straight vectorable nozzle has been added for in-line applications.

The GEM 46 is a larger derivative of the highly reliable GEM 40. The second-generation GEM motor has increased length, diameter, and optional vectorable nozzles. This motor has been used on Delta III, and subsequently, Delta II Heavy launch vehicles.

GEM 60 motors were developed commercially for the Delta IV Evolved Expendable Launch Vehicle. This third-generation 70-foot GEM motor provides auxiliary lift-off capability for the Delta IV Medium-Plus (M+) vehicle. It is available in both fixed and vectorable nozzle configurations.

GEM 63 motors were developed commercially with configurations planned for use on United Launch Alliance's Atlas V and Vulcan launch vehicles. These fourth-generation GEMs capitalize on common designs and materials and low-cost manufacturing processes developed during work on previous GEM, Orion, and CASTOR motors.

State-of-the-art automation, robotics, commercial practices, and process controls are used to produce GEMs. Cases are filament wound by computer-controlled winding machines using high-strength graphite fiber and durable epoxy resin. Northrop Grumman is the largest producer of filament wound rocket motors in the world. Critical processes (e.g., case bond application, propellant mixing, motor casting) are performed using an extensive network of computerized and robotic facilities ensuring accurate control of manufacturing. The delivered products are consistent, reliable, repeatable, high quality, competitively priced, and delivered on time.

The GEM family of motors includes:

- GEM 40, multiple configurations
- GEM 46, multiple configurations
- GEM 60, multiple configurations
- GEM 63, multiple configurations

Inquiries regarding our GEM motor products should be directed to our business development representatives at psbdev@ngc.com.

GEM 40 (GROUND IGNITED)



FIXED NOZZLE, GROUND-IGNITED

The 40-inch-diameter graphite epoxy motor (GEM 40) is a strap-on booster system developed to provide thrust augmentation for the Delta II launch vehicle. The GEM 40 features an IM7/55A graphite epoxy motor case, an aramid-filled EPDM insulator, and a 10-degree canted, fixed nozzle assembly. The nozzle has a high-performance 3-D carbon-carbon throat and carbon phenolic insulators. Ignition is accomplished with a forward-mounted pyrogen igniter. The GEM 40 motor also includes a raceway assembly, forward interstage, and aft attach ball interfaces. GEM 40 strap-on boosters began launching Delta II vehicles in 1990, with final flight in September 2018, ending a successful 28-year, 1,003-motor era.

MOTOR DIMENSIONS

Motor diameter, in.....40.4
 Overall motor length (including nozzle), in.435
 Nozzle exit cone diameter, in.....32.17

MOTOR PERFORMANCE (73°F NOMINAL)

Burn time, sec.....63.3
 Maximum thrust, lbf144,740
 Specific impulse, lbf-sec/lbm274.0
 Total impulse, lbf-sec.....7,107,800
 Burn time average thrust, lbf112,200

WEIGHTS, LBM

Total motor.....28,577
 Propellant25,940
 Burnout.....2,429

PROPELLANT DESIGNATION

..... QDL-1, HTPB POLYMER, 19% ALUMINUM

HAZARDS CLASSIFICATION... 1.3

RACEWAY YES

ORDNANCE NO

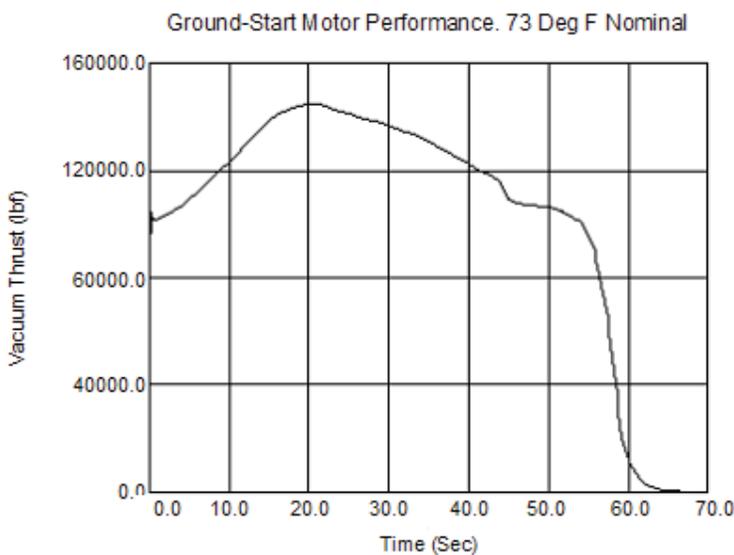
TVA NO

TEMPERATURE LIMITS

Operation.....+30°-100°F
 Storage.....+30°-100°F

PRODUCTION STATUS

..... FLIGHT-PROVEN, INACTIVE PRODUCTION



For more information, contact:

psbdev@ngc.com

northropgrumman.com

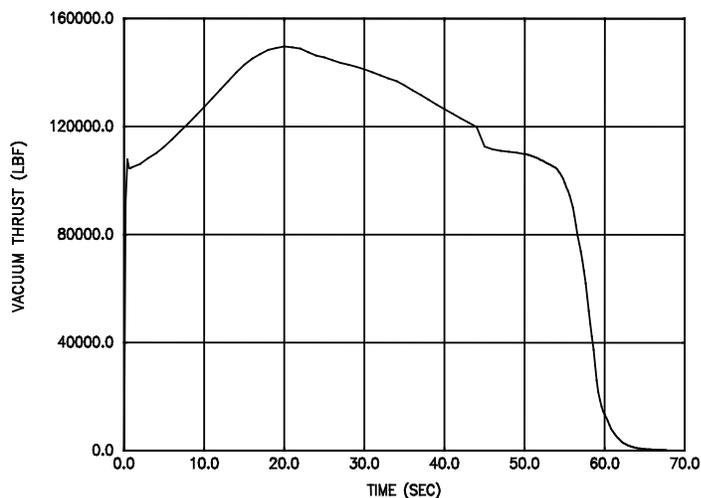
GEM 40 (AIR IGNITED)



FIXED NOZZLE, AIR-IGNITED

The 40-inch-diameter graphite epoxy motor (GEM 40) is a strap-on booster system developed to provide thrust augmentation for the Delta II launch vehicle. The GEM 40 features an IM7/55A graphite composite motor case, an aramid-filled EPDM insulator, and a 10-degree canted, fixed nozzle assembly. For the Delta II nine-motor configuration, six motors are ignited on the ground and three in the air. The air-start (altitude-ignited) GEM 40 motor configuration has a lengthened nozzle exit cone with higher expansion ratio, exit-plane-mounted nozzle closure system that is ejected at air-start motor ignition, and a different external insulation scheme. The GEM 40 has flown on Delta II vehicles since 1991. GEM 40 strap-on boosters began launching Delta II vehicles in 1990, with final flight in September 2018, ending a successful 28-year, 1,003-motor era.

Air – Start Motor Performance, 73 Deg F Nominal



MOTOR DIMENSIONS

Motor diameter, in.....40.4
 Overall motor length (including nozzle), in.449.1
 Nozzle exit cone diameter, in.....38.80

MOTOR PERFORMANCE (73°F NOMINAL)

Burn time, sec.....63.3
 Maximum thrust, lbf.....149,660
 Effective specific impulse, lbf-sec/lbm283.4
 Total impulse, lbf-sec.....7,351,000
 Burn time average thrust, lbf116,050

WEIGHTS, LBM

Total motor.....28,883
 Propellant25,940
 Burnout.....2,649

PROPELLANT DESIGNATION

..... QDL-1, HTPB POLYMER, 19% ALUMINUM

HAZARDS CLASSIFICATION..... 1.3

RACEWAY..... YES

ORDNANCE..... NO

TVA..... NO

TEMPERATURE LIMITS

Operation.....+30°-100°F
 Storage.....+30°-100°F

PRODUCTION STATUS

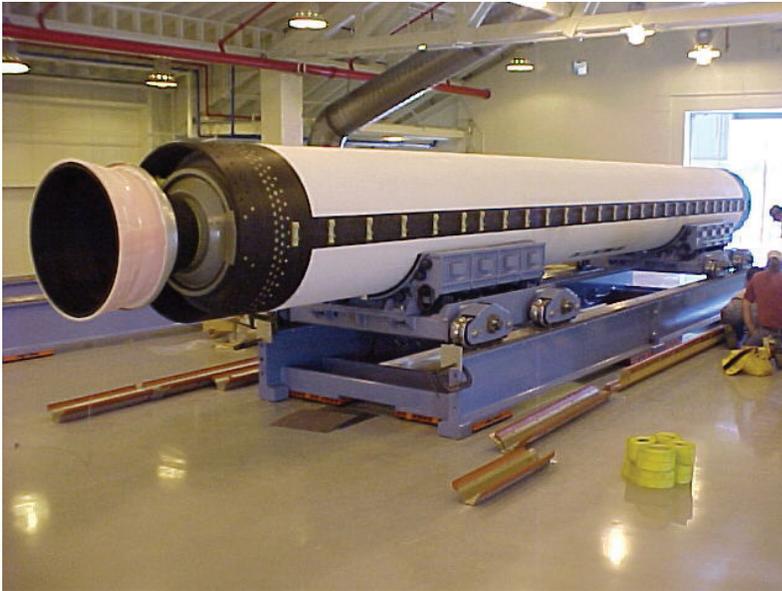
..... FLIGHT PROVEN, INACTIVE PRODUCTION

For more information, contact:

psbdev@ngc.com

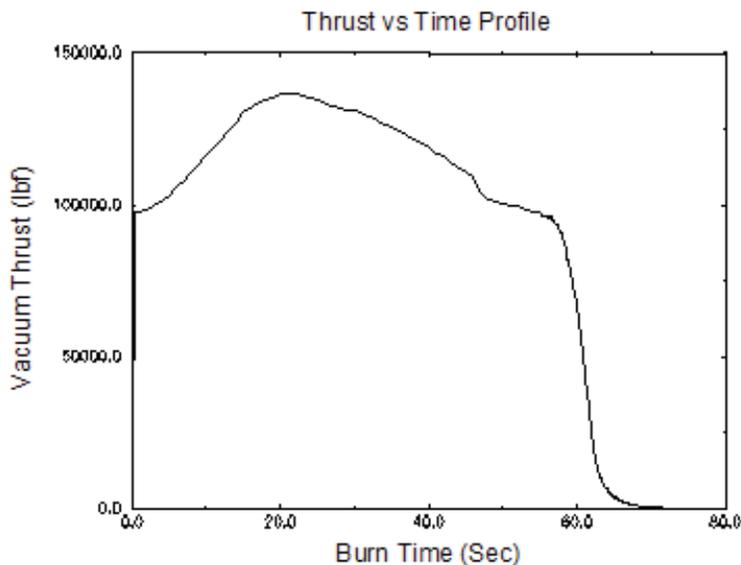
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GEM 40VN



VECTORABLE NOZZLE, GROUND-IGNITED, IN-LINE MOTOR

The GEM 40VN booster is derived from the successful GEM 40 booster. The GEM 40VN maintains the same loaded motor configuration as the GEM 40 with a design modification to the nozzle assembly to provide ± 6 -degree thrust vector capability. Air-ignition with extended length nozzle can also be readily provided. The GEM 40VN can be used in both in-line and strap-on booster applications. A version of this motor has been developed and was qualified for use on the Boost Vehicle/Boost Vehicle Plus (BV/BV+) configuration for the Ground-based Midcourse Defense missile interceptor program.



MOTOR DIMENSIONS

Motor diameter, in.....40.4
 Overall motor length (including nozzle), in.....425.1
 Nozzle exit cone diameter, in.....32.3

MOTOR PERFORMANCE (73°F NOMINAL)

Burn time, sec.....64.6
 Maximum thrust.....139,036
 Effective specific impulse, lbf-sec/lbm.....265.3
 Total impulse, lbf-sec.....6,950,000
 Burn time average thrust, lbf.....107,625

WEIGHTS, LBM

Total motor.....28,886
 Propellant.....25,940
 Burnout.....2,607

PROPELLANT DESIGNATION

.....QDL-1, HTPB POLYMER, 19% ALUMINUM

RACEWAY.....YES

ORDNANCE.....NO

TVA.....YES

TEMPERATURE LIMITS

Operation.....+30°-100°F
 Storage.....+30°-100°F

PRODUCTION STATUS

.....FLIGHT PROVEN, INACTIVE PRODUCTION

For more information, contact:

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northropgrumman.com

GEM 46 (FIXED, GROUND-IGNITED)



FIXED NOZZLE, GROUND-IGNITED

The larger diameter, extended length graphite epoxy motor (GEM 46) is a strap-on booster system originally developed to increase the payload-to-orbit capability of the Delta III launch vehicle. The GEM 46 features an IM7/55A graphite composite motor case, an aramid-filled EPDM insulator, and a 10-degree canted, fixed nozzle assembly. The nozzle has a high performance 3-D carbon-carbon throat and carbon phenolic insulators. Ignition is accomplished with a forward-mounted pyrogen igniter. The GEM 46 booster includes raceway assembly, forward interstage, and aft attach ball interfaces. GEM 46 motors have been used on both the Delta II Heavy and Delta III launch vehicles.

MOTOR DIMENSIONS

Motor diameter, in.....45.1
 Overall motor length (including nozzle), in.495.8
 Nozzle exit cone diameter, in.....39.93

MOTOR PERFORMANCE (73°F NOMINAL, VACUUM)

Burn time, sec.....75.9
 Maximum thrust.....198,800
 Specific impulse, lbf-sec/lbm277.8
 Total impulse, lbf-sec.....10,425,000
 Burn time average thrust, lbf137,300

WEIGHTS, LBM

Total motor.....41,590
 Propellant37,180
 Burnout.....4,050

PROPELLANT DESIGNATION

..... QEM, HTPB POLYMER, 19% ALUMINUM

HAZARDS CLASSIFICATION..... 1.3

RACEWAY YES

ORDNANCE NO

TVA NO

TEMPERATURE LIMITS

Operation.....+30°-100°F
 Storage.....+30°-100°F

PRODUCTION STATUS

..... FLIGHT-PROVEN, INACTIVE PRODUCTION

For more information, contact:

psbdev@ngc.com

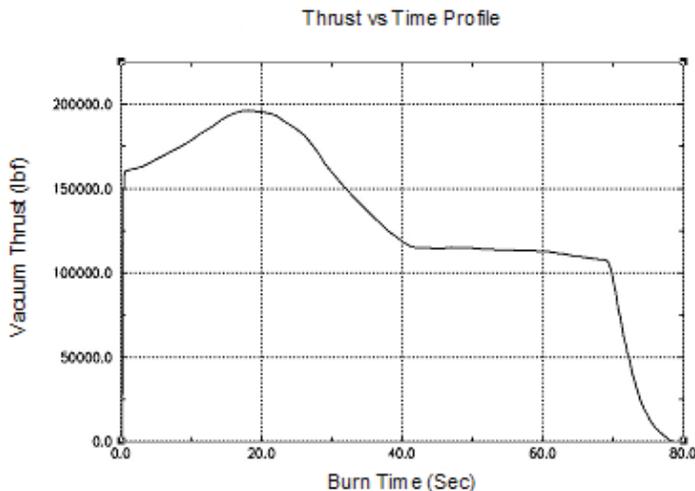
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GEM 46 (VECTORABLE, GROUND-IGNITED)



VECTORABLE NOZZLE, GROUND-IGNITED

The larger diameter, extended length graphite epoxy motor (GEM 46) is a strap-on booster system originally developed to increase the payload-to-orbit capability of the Delta III launch vehicle. The GEM 46 features an IM7/55A graphite composite motor case and an aramid-filled EPDM insulator. This configuration has a 5-degree canted, ±5-degree moveable nozzle assembly with a high-performance 3-D carbon-carbon throat and carbon phenolic insulators. Ignition is accomplished with a forward mounted pyrogen igniter. This GEM 46 booster includes thrust vector actuation, raceway assembly, forward interstage, and aft attach ball interfaces. Three of these vectorable-nozzle ground-ignited motors were used on each Delta III.



MOTOR DIMENSIONS

Motor diameter, in.....	45.1
Overall motor length (including nozzle), in.....	491.5
Nozzle exit cone diameter, in.....	36.93

MOTOR PERFORMANCE (73°F NOMINAL, VACUUM)

Burn time, sec.....	76.9
Maximum thrust, lbf.....	196,600
Specific impulse, lbf-sec/lbm.....	279.8
Total impulse, lbf-sec.....	10,400,000
Burn time average thrust, lbf.....	135,200

WEIGHTS, LBM

Total motor.....	42,196
Propellant.....	37,180
Burnout.....	4,656

PROPELLANT DESIGNATION

..... QEM, HTPB POLYMER, 19% ALUMINUM

HAZARDS CLASSIFICATION..... 1.3

RACEWAY..... YES

ORDNANCE..... NO

TVA..... YES

TEMPERATURE LIMITS

Operation.....	+30°-100°F
Storage.....	+30°-100°F

PRODUCTION STATUS

..... FLIGHT-PROVEN, INACTIVE PRODUCTION

For more information, contact:

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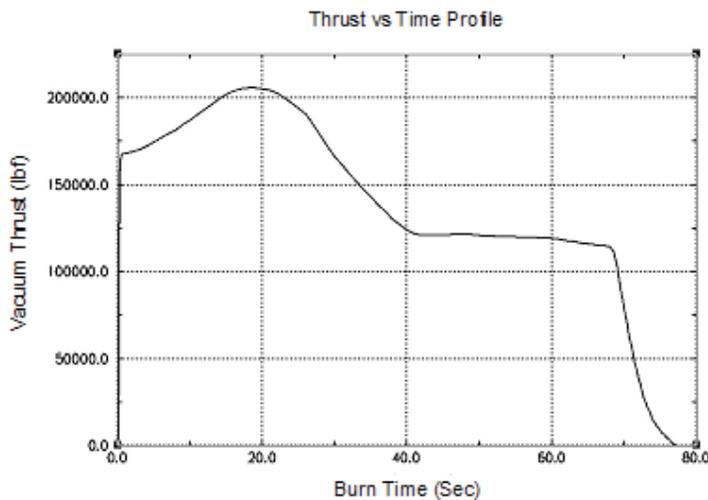
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GEM 46 (FIXED, AIR-IGNITED)



FIXED NOZZLE, AIR-IGNITED

The larger diameter, extended length graphite epoxy motor (GEM 46) is a strap-on booster system originally developed to increase the payload-to-orbit capability of the Delta III launch vehicle. The GEM 46 features an IM7/55A graphite composite motor case, an aramid-filled EPDM insulator, and a 10-degree canted, fixed nozzle assembly. The nozzle has a high-performance 3-D carbon-carbon throat and carbon phenolic insulators. This air-start (altitude-ignited) GEM 46 motor configuration has a lengthened nozzle exit cone with a higher expansion ratio. Ignition is accomplished with a forward-mounted pyrogen igniter. The GEM 46 booster includes raceway assembly, forward interstage, and aft attach ball interfaces. This GEM 46 motor has been used on both the Delta II Heavy and Delta III launch vehicles.



MOTOR DIMENSIONS

Motor diameter, in.....	45.1
Overall motor length (including nozzle), in.	508.6
Nozzle exit cone diameter, in.....	49.25

MOTOR PERFORMANCE (73°F NOMINAL, VACUUM)

Burn time, sec.....	75.9
Maximum thrust, lbf.....	206,000
Specific impulse, lbf-sec/lbm.....	290.7
Total impulse, lbf-sec.....	10,803,000
Burn time average thrust, lbf.....	142,300

WEIGHTS, LBM

Total motor.....	42,039
Propellant.....	37,180
Burnout.....	4,397

PROPELLANT DESIGNATION

..... QEM, HTPB POLYMER, 19% ALUMINUM

HAZARDS CLASSIFICATION.... 1.3

RACEWAY YES

ORDNANCE NO

TVA NO

TEMPERATURE LIMITS

Operation.....	+30°-100°F
Storage.....	+30°-100°F

PRODUCTION STATUS

..... FLIGHT-PROVEN, INACTIVE PRODUCTION

For more information, contact:

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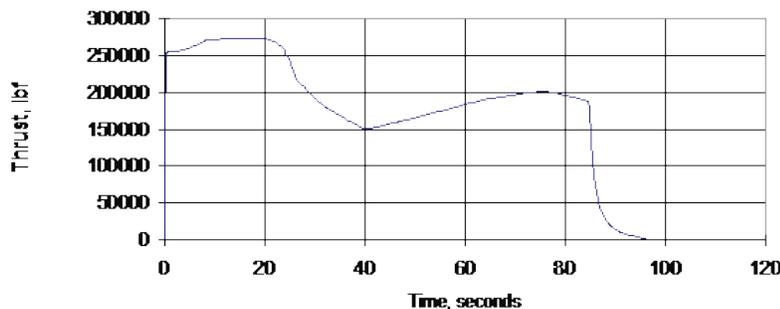
GEM 60 (VECTORABLE)



VECTORABLE NOZZLE

The 60-inch-diameter graphite epoxy motor (GEM 60) is a strap-on booster system developed to increase the payload-to-orbit capability of the Delta IV Medium-Plus (M+) launch vehicles. Two and four strap-on motor configurations of the GEM 60 can be flown on the Delta IV M+ vehicles. The GEM 60 features an IM7R/CLRF-100 graphite composite motor case and aramid-filled EPDM insulator. This configuration has a 5-degree canted, ± 5 -degree moveable nozzle assembly. The nozzle has a high-performance 3-D carbon-carbon throat, EPDM, and carbon phenolic insulators. Ignition is accomplished with a forward-mounted pyrogen igniter. The GEM 60 booster includes a raceway assembly, forward interstage, aft attach ball interfaces, nosecone, customer-furnished material ordnance/cabling, and closeout hardware. This motor's first flight occurred in November 2002 and was the first flight of the Air Force's Evolved Expendable Launch Vehicle program; final flight was on Delta IV in August 2019.

Vectorable Nozzle



MOTOR DIMENSIONS

Motor diameter, in.....	60
Overall motor length (including nozzle), in.....	518
Nozzle exit cone diameter, in.....	43.12

MOTOR PERFORMANCE (73°F NOMINAL, VACUUM)

Burn time, sec.....	90.8
Maximum thrust.....	277,852
Specific impulse, lbf-sec/lbm.....	274
Total impulse, lbf-sec.....	17,928,000
Burn time average thrust, lbf.....	199,403

WEIGHTS, LBM

Total motor.....	74,185
Propellant.....	65,472
Burnout.....	8,203

PROPELLANT DESIGNATION

.....QEY, HTPB POLYMER, 19% ALUMINUM

HAZARDS CLASSIFICATION.....

1.3

RACEWAY.....

YES

ORDNANCE.....

YES

TVA.....

YES

TEMPERATURE LIMITS

Operation.....+30°-100°F

Storage.....+30°-100°F

PRODUCTION STATUS

.....FLIGHT-PROVEN, INACTIVE PRODUCTION

For more information, contact:

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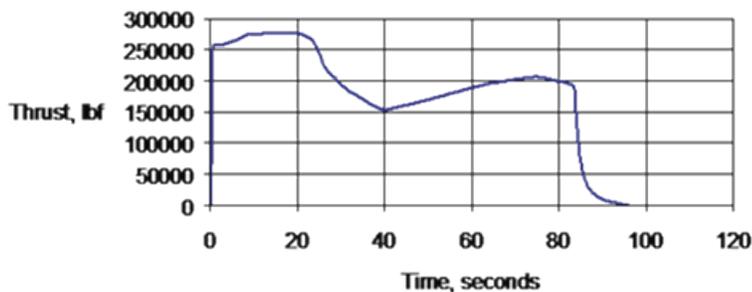
GEM 60 (FIXED)



FIXED NOZZLE

The 60-inch-diameter graphite epoxy motor (GEM 60) is a strap-on booster system developed to increase the payload-to-orbit capability of the Delta IV Medium-Plus (M+) launch vehicles. Two and four strap-on motor configurations of the GEM 60 can be flown on the Delta IV M+ vehicles. The GEM 60 features an IM7R/CLRF-100 graphite composite motor case and an aramid-filled EPDM insulator. This configuration has a 10-degree canted, fixed nozzle assembly. The nozzle has a high performance 3-D carbon-carbon throat, EPDM, and carbon phenolic insulators. Ignition is accomplished with a forward-mounted pyrogen igniter. The GEM 60 booster includes a raceway assembly, forward interstage, aft attach ball interfaces, nosecone, customer-furnished material ordnance/cabling, and closeout hardware. This motor's first flight occurred in December 2009, with final flight on Delta IV in August 2019.

Fixed Nozzle



MOTOR DIMENSIONS

Motor diameter, in.....	60
Overall motor length (including nozzle), in.....	518
Nozzle exit cone diameter, in.....	43.12

MOTOR PERFORMANCE (73°F NOMINAL, VACUUM)

Burn time, sec.....	90.8
Maximum thrust.....	280,767
Specific impulse, lbf-sec/lbm.....	275
Total impulse, lbf-sec.....	17,965,776
Burn time average thrust, lbf.....	201,260

WEIGHTS, LBM

Total motor.....	73,156
Propellant.....	65,472
Burnout.....	7,207

PROPELLANT DESIGNATION

.....QEY, HTPB POLYMER, 19% ALUMINUM

HAZARDS CLASSIFICATION..... 1.3

RACEWAY..... YES

ORDNANCE..... YES

TVA..... NO

TEMPERATURE LIMITS

Operation.....	+30°-100°F
Storage.....	+30°-100°F

PRODUCTION STATUS

..... FLIGHT-PROVEN, INACTIVE PRODUCTION

For more information, contact:

psbdev@ngc.com

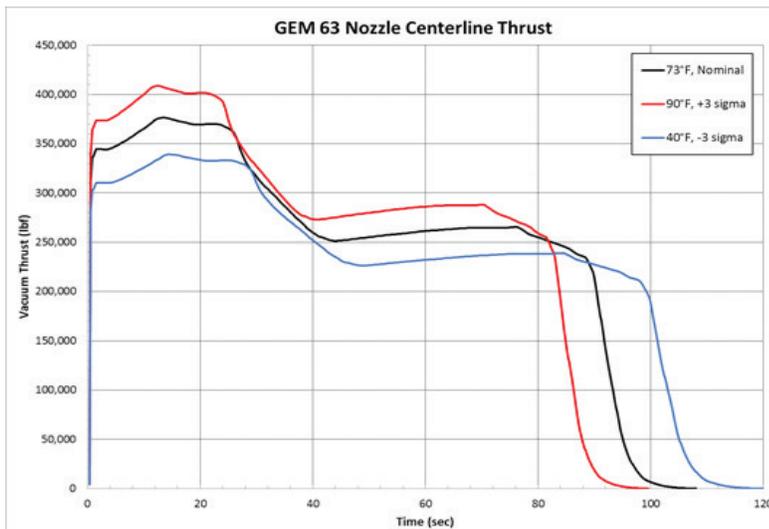
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GEM 63



FIXED-NOZZLE BOOSTER

The GEM 63 is a low-cost, robust, state-of-the-art strap-on booster designed for use on ULA's Atlas V launch vehicle. It capitalizes on existing common designs and materials, plus lessons learned and low-cost manufacturing processes advanced from prior GEM, Orion, and CASTOR motors. The motor is 792.2 inches long and nominally designed as a strap-on booster for medium- to large-sized launch vehicles. It features a fixed nozzle canted at three degrees. The motor is in production and flight-proven with first flight on ULA's Atlas V in November 2020.



MOTOR DIMENSIONS

Motor diameter, in.....63.2
 Overall motor length (incl. nozzle/fairing, etc)in.792.2
 Nozzle exit cone diameter, in.....58.8

MOTOR PERFORMANCE (73°F VACUUM, VACUUM)

Burn time, sec97.6
 Total time to 21 psi, sec98.55
 Maximum thrust, lbf370,835
 Specific impulse, lbf-sec/lbm279.06
 Total impulse, lbf-sec.....27,110,000
 Burn time average thrust, lbf277,589
 Total time average thrust, lbf275.053

WEIGHTS, LBM

Total motor108,781
 Propellant97,195
 Burnout (est).....10,607

PROPELLANT DESIGNATION

.....QDL-4, HTPB POLYMER, 19% ALUMINUM

HAZARDS CLASSIFICATION.... 1.3

RACEWAY YES

ORDNANCE NO
 (CUSTOMER FURNISHED)

TVA..... NO

TEMPERATURE LIMITS

Operation.....+40°-90°F
 Storage.....+40°-90°F

PRODUCTION STATUS

..... FLIGHT-PROVEN, IN PRODUCTION

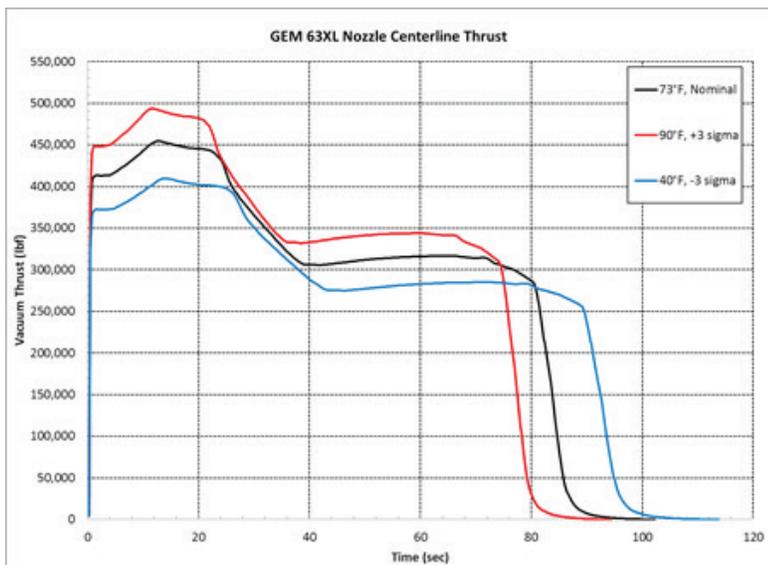
For more information, contact:
psbdev@ngc.com

northropgrumman.com



FIXED-NOZZLE BOOSTER

The GEM 63XL is a new low-cost, robust, state-of-the-art strap-on booster designed for use on ULA's Vulcan launch vehicle. The motor is an evolution of the current GEM motors. It capitalizes on existing common designs and materials, plus lessons learned and low-cost manufacturing processes advanced from prior GEM, Orion, and CASTOR motors. The GEM 63XL was co-developed with the GEM 63 to share several common components and provide more thrust and impulse with a longer composite case. The motor is 865.0 inches long and nominally designed as a strap-on booster for large-sized launch vehicles. It features a fixed nozzle canted at three degrees. The motor is in production with first flight on ULA's Vulcan Centaur scheduled for 2021.



MOTOR DIMENSIONS

Motor diameter, in.....63.7
 Overall motor length (incl. nozzle/fairing, etc) in.865.3
 Nozzle exit cone diameter, in.....60.3

MOTOR PERFORMANCE (73°F VACUUM, VACUUM)

Burn time, sec.....87.3
 Total time to 21 psi, sec.....88.31
 Maximum thrust,lbf.....463,249
 Specific impulse, lbf-sec/lbm280.3
 Total impulse, lbf-sec.....29,570,000
 Burn time average thrust, lbf337,871
 Total time average thrust, lbf334,063

WEIGHTS, LBM

Total motor.....116,920
 Propellant105,497
 Burnout (est).....9,966

PROPELLANT DESIGNATION

.....QDL-4, HTPB POLYMER, 19% ALUMINUM

HAZARDS CLASSIFICATION..... 1.3

RACEWAY..... YES

ORDNANCE NO
 (CUSTOMER FURNISHED)

TVA..... NO

TEMPERATURE LIMITS

Operation.....+40°-90°F
 Storage.....+40°-90°F

PRODUCTION STATUS

..... IN PRODUCTION

For more information, contact:
psbdev@ngc.com

northropgrumman.com