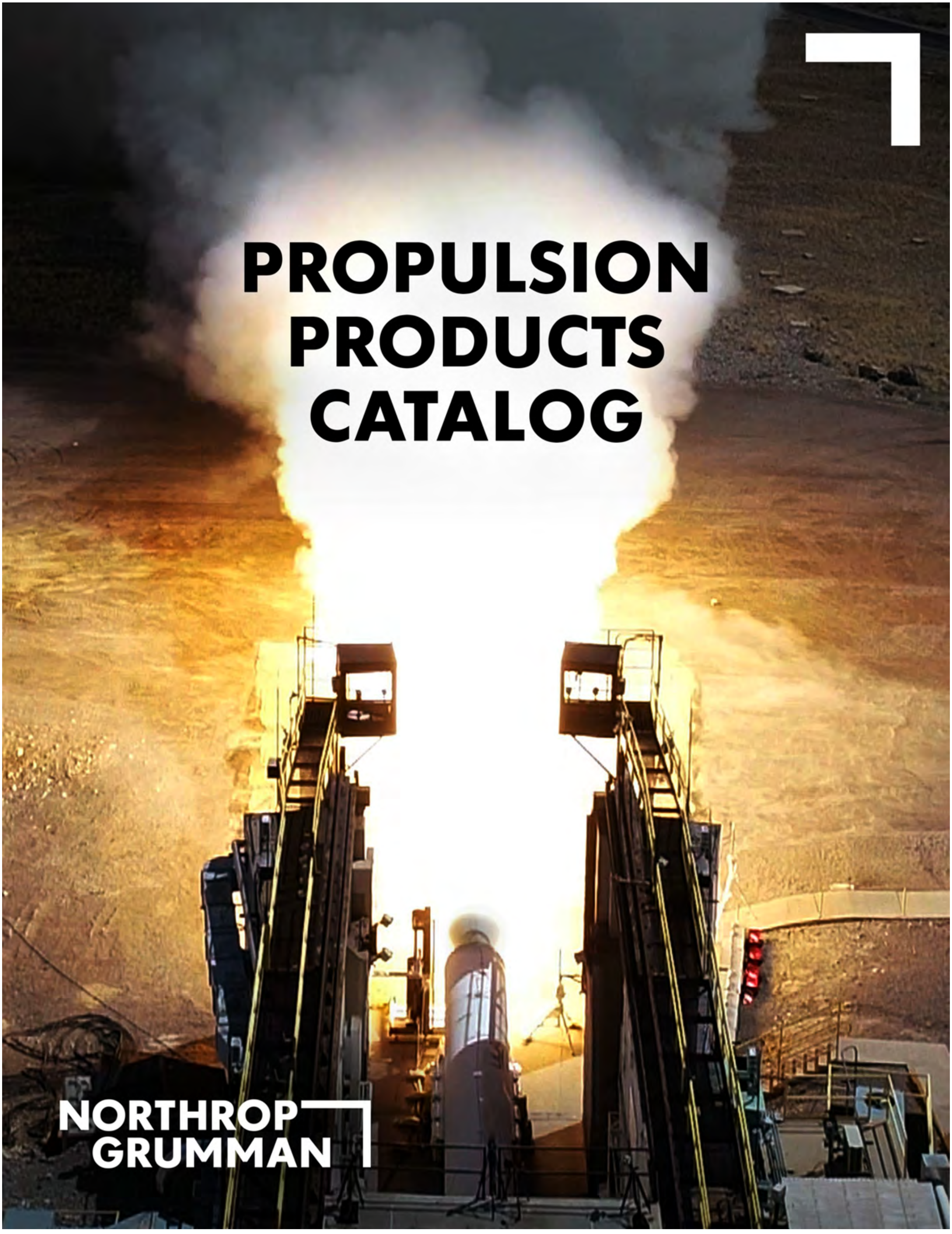

PROPULSION PRODUCTS CATALOG

NORTHROP GRUMMAN

INTRODUCTION

Northrop Grumman's space propulsion, ordnance, and launch structures products described in this catalog reflect more than 60 years of experience providing high-performance and reliable propulsion to the aerospace industry. The product data sheets within are divided into three categories (Large Motors, Small Motors, and Launch Structures) and summarize the principal design and performance characteristics for initial evaluation. Northrop Grumman routinely modifies products to meet evolving customer needs through detailed design, analysis, and testing that maintain the heritage of prior, flight-proven designs. We welcome the opportunity to provide additional evaluation and optimal solutions for your mission needs.

- Inquiries regarding large motor products and launch structures should be directed to our business development representatives at psbdev@ngc.com. Additional information can be found at northropgrumman.com/space/propulsion-systems/
- Inquiries regarding small motor products should be directed to our business development representatives at starmotors@ngc.com

For information about these and other Northrop Grumman products, please visit www.northropgrumman.com.

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LARGE MOTOR SUMMARY INFORMATION

ORION, CASTOR®, GEM, AND HEAVY-LIFT BOOSTER CAPABILITIES

Northrop Grumman's large motor series (Orion, CASTOR, GEM, and Heavy-Lift Boosters) span a significant range of size and boost capability, with motors ranging from approximately 2,000 pounds up to 1.6 million pounds. The figure on the following page provides a graphic comparison of the relative sizes of the principal motors in these series.

Tabular summaries of motor dimensions, weights, and performance data across these motor series are provided in Table 1 and a summary of test and flight experience is provided in Table 2.

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

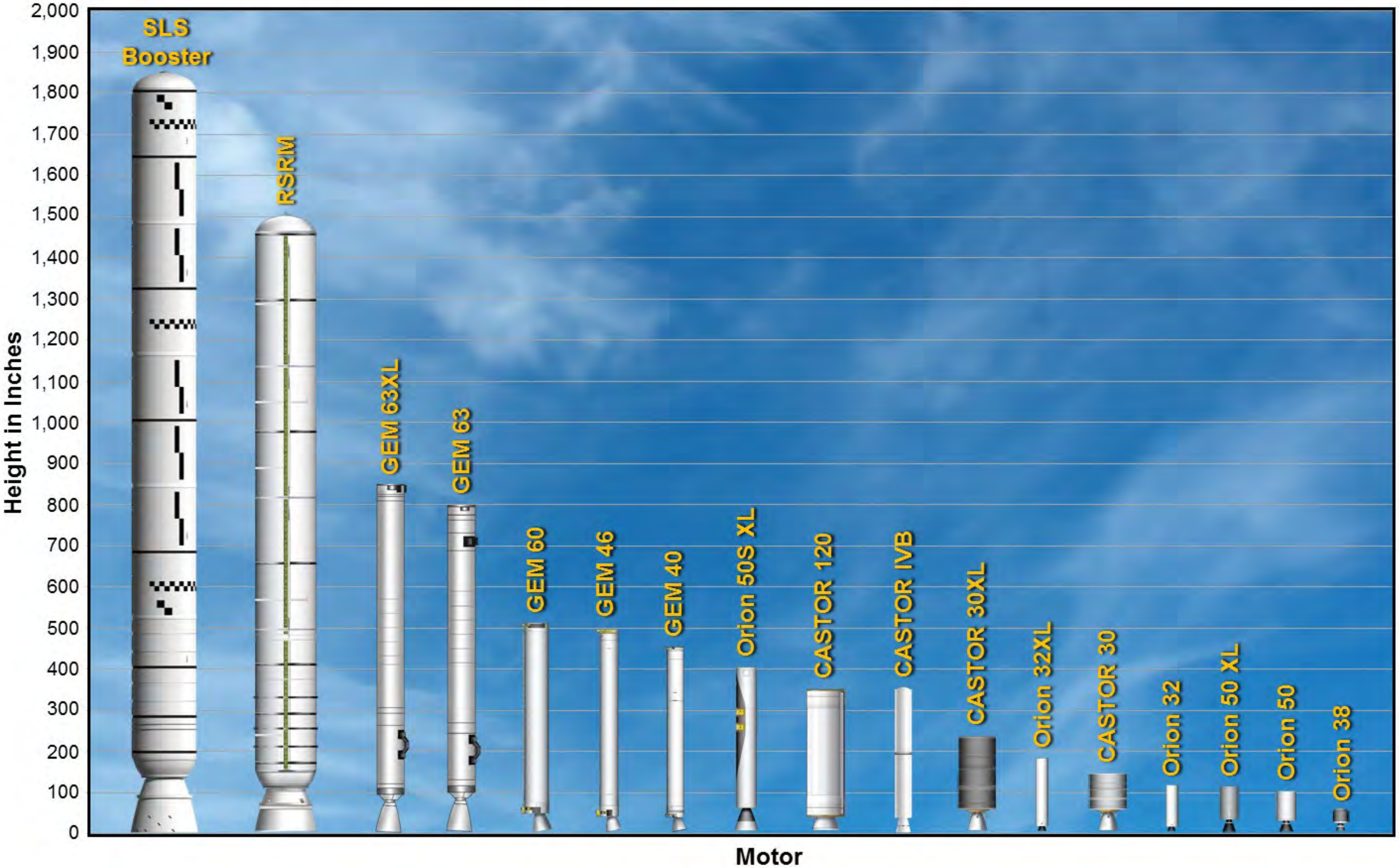

Height in Inches
2,000
1,900
1,800
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
SLS Booster
RSRM
GEM 63XL
GEM 63
GEM 60
GEM 46
GEM 40
Orion 50S XL
CASTOR 120
CASTOR IVB
CASTOR 30XL
Orion 32XL
CASTOR 30
Orion 32
Orion 50 XL
Orion 50
Orion 38
Motor

Table 1. Large Motor Summary

Motor	Nozzle	Diameter (inches)	Overall Length (inches)	Propellant Weight (lbm)	Total Weight (lbm)	Mass Frac-tion	Total Impulse (lbf-sec)	Burn Time (sec)	Status
Orion Motor Family									
Orion 32	Vectorable	32.5	119.6	4,429	4,908	0.90	1,231,750	53.6	Component-qualified
Orion 32 XL	Vectorable	32.5	179.5	6,953	7,756	0.90	1,838,200	52.4	Component-qualified
Orion 38	Vectorable	38	52.6	1,698	1,924	0.88	491,140	66.8	Flight-proven
Orion 50	Vectorable	50.2	103.2	6,669	7,395	0.90	1,949,000	75.1	Flight-proven
Orion 50 XL	Vectorable	50.2	120.9	8,631	9,494	0.91	2,521,900	71.0	Flight-proven
Orion 50S	Fixed	50.2	350.1	26,801	29,529	0.91	7,873,000	74.9	Flight-proven
Orion 50ST	Vectorable	50.2	335.4	26,801	29,103	0.92	7,676,500	74.2	Flight-proven
Orion 50S XL	Fixed	50.2	404.3	33,145	36,153	0.92	9,744,300	69.7	Flight-proven
Orion 50S XLT	Vectorable	50.2	390.8	33,145	35,763	0.93	9,472,400	69.0	Flight-proven
Orion 50S XLG	Vectorable	50.2	344.0	33,145	35,525	0.93	9,061,400	69.0	Flight-proven
CASTOR Motor Family									
CASTOR IVA	Fixed	40.1	363.4	22,286	25,737	0.87	5,967,840	55.2	Flight-proven
CASTOR IVA-XL	Fixed	40.1	457.0	28,906	33,031	0.88	8,140,170	58.0	Flight-proven
CASTOR IVB	Vectorable	40.1	353.7	21,990	25,441	0.86	5,880,600	63.6	Flight-proven
CASTOR 30	Vectorable	92	144.2	28,098	30,590	0.92	8,239,110	149.8	Flight-proven
CASTOR 30B	Vectorable	92	169.9	28,405	30,800	0.92	8,539,320	126.7	Flight-proven
CASTOR 30XL	Vectorable	92	235.8	54,949	58,217	0.94	16,174,800	155.0	Flight-proven
CASTOR 120	Vectorable	92	355	107,914	116,993	0.92	30,000,000	79.4	Flight-proven
CASTOR 120XL	Vectorable	92.1	378.3	114,194	123,383	0.93	31,872,000	83.5	Qualified
Graphite Epoxy Motor (GEM) Family									
GEM 40	Fixed (Air- Ignited)	40.4	449.1	25,940	28,883	0.90	7,351,000	63.3	Flight-proven
GEM 40 VN	Vectorable	40.4	425.1	25,940	28,886	0.90	6,950,000	64.6	Flight-proven
GEM 46	Fixed (Ground-Ignited)	45.1	495.8	37,180	41,590	0.89	10,425,000	75.9	Flight-proven
GEM 46	Vectorable (Ground-Ignited)	45.1	491.5	37,180	42,196	0.88	10,400,000	76.9	Flight-proven
GEM 46	Fixed (Air-Ignited)	45.1	508.6	37,180	42,039	0.88	10,803,000	75.9	Flight-proven

Motor	Nozzle	Diameter (inches)	Overall Length (inches)	Propellant Weight (lbm)	Total Weight (lbm)	Mass Frac-tion	Total Impulse (lbf-sec)	Burn Time (sec)	Status
GEM 60	Fixed	60	518	65,472	73,156	0.89	17,965,776	90.8	Flight-proven
GEM 60	Vectorable	60	518	65,472	74,185	0.88	17,928,000	90.8	Flight-proven
GEM 63	Fixed	63.2	792.2	97,195	108,781	0.89	27,110,000	97.6	Flight-proven
GEM 63XL	Fixed	63.7	865.3	105,497	116,920	0.90	29,570,000	87.3	Production
Reusable Solid Rocket Motor (RSRM)									
RSRM	Vectorable	146.1	1,513.5	1,106,059	1,255,334	0.88	297,001,731	122.2	Flight-proven
Space Launch System (SLS) Motors									
SLS Booster (5-Segment)	Vectorable	146.1	1,864.7	1,427,807	1,616,123	0.87	298,000,000	132.8	Production
Booster Separation Motor (BSM)	Fixed	12.88	31.1	77	167	0.46	18,400	0.68	Flight-proven
Launch Abort Motor	Turn-flow mani-fold/vectorable	36.7 (82.0 if manifold is included)	223.7	4,750	7,629	0.632	1,046,600	4.3	Flight-proven

*** In development, subject to refinement**

Table 2. Large Motor Test and Flight History

Motor	Applications/Uses	Number of Static Fire Tests	Number of Motors Flown	TVC	Production Status
Orion 32	Technology Demonstration	1	0	Yes	Component-qualified
Orion 32XL	Technology Demonstration	1	0	Yes	Component-qualified
Orion 38	Pegasus/Taurus/Pegasus XL/ Taurus XL/Minotaur I/Minotaur IV/Minotaur-C/ GMD OBV	3	89	Optional	Production
Orion 38HP	Technology Demonstration	1	0	Yes	Development
Orion 50	Pegasus Std	1	10	Optional	Out of Production
Orion 50T	Taurus Std	0	6	Optional	Out of Production
Orion 50 XL	Pegasus XL/Minotaur/OBV	2	65	Optional	Production
Orion 50 XLT	Taurus XL/Minotaur-C/IRBM Target	0	13	Optional	Production
Orion 50S	Pegasus Std/Hyper-X	1	13	No	Out of Production
Orion 50ST	Taurus Std	1	6	Optional	Out of Production
Orion 50SG		0	0	Optional	Out of Production
Orion 50S XL	Pegasus XL	1	35	No	Production
Orion 50S XLG	GMD OBV/ALV/IRBM Target	5	28	Optional	Production
Orion 50S XLT	Taurus XL/Minotaur-C	0	4	Optional	Production
CASTOR IVA	Delta II/Atlas 2AS	7	313	No	Out of Production
CASTOR IVB	MAXUS/Targets	3	34	Yes	Production
CASTOR IVA-XL	HII-A	4	34	No	Out of Production
CASTOR 30	Antares/Athena Ic/Athena IIc	1	2	Yes	Production
CASTOR 30B	Antares	0	2	Yes	Production
CASTOR 30XL	Antares	1	13	Yes	Production
CASTOR 120	Athena Ic/Athena IIc/ Taurus/Taurus XL/Minotaur-C	4	17	Yes	Out of production
CASTOR 120XL		0	0	Yes	Out of production
GEM 40	Delta 2	13	1003	No	Out of Production
GEM 40VN	GMD BV+	3	3	Yes	Out of Production
GEM 46	Delta 2 Heavy/Delta 3	6	81	Fixed/TVC	Out of Production
GEM 60	Delta 4	14	68	Fixed/TVC	Out of Production

Motor	Applications/Uses	Number of Static Fire Tests	Number of Motors Flown	TVC	Production Status
GEM 63	Atlas V	3	22	Fixed	Production
GEM 63XL	Vulcan	2	0	Fixed	Production
RSRM	Space Shuttle	28 (+5-seg ETM-3)	220	Yes	Out of Production
SLS Booster (5-Segment)	Space Launch System (SLS) / formerly Ares I First Stage	7	2 (+Ares I-X, 4-seg)	Yes	Production
BSM	Space Shuttle/Ares I-X/SLS	41	240	No	Production
Launch Abort Motor	SLS Orion Crew Module	4	2	No	Production

Reliability/Success Rate: Demonstrated success rate of 99.79% in flight and static tests. One static test failure and four flight failures in 2,446 tests and flights (two TVC related). Two of the flight failures were subsequently attributed to damage resulting from handling and post-delivery flight processing.

ORION MOTOR SERIES

AFFORDABLE, LOW-RISK FLEXIBLE CAPABILITIES

The Orion family of motors began with three stages originally designed for use on the Pegasus® launch vehicle. Modifications to the original three Orion motors, first for extended length (XL) versions and subsequently for skirt, nozzle, and other smaller differences, have accommodated additional applications and enhanced performance capabilities. Vehicle applications successfully flown using Orion motors include Pegasus, Taurus®, Pegasus XL, Minotaur®, Hyper-X, Taurus® Lite, and Taurus XL launch vehicles, and the Ground-based Midcourse Defense ground-based interceptor. New applications continue to evolve, such as target vehicle configurations for the Missile Defense Agency.

The multiple configurations and applications currently existing demonstrate that these flight-proven motors are readily adaptable to a wide range of launch scenarios (e.g., ground-start, air-start, silo-launched, etc.) and missions. Northrop Grumman has also demonstrated support for their deployment and use at a wide range of launch sites and field locations, including multiple non-Continental United States launch sites. Further, it should be noted that much of the adaptation has been accomplished with only relatively minor changes (skirt thicknesses and hole patterns, nozzle length, etc.), with little or no changes to the basic motor.

The current major vehicle applications and variants for Orion motors are shown in the table on the following page. The motor identification key provides a further explanation for nomenclature designations in the Orion motor series.

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

Flight-Proven Orion Motor Configurations

Orion Motor				Vehicle Application
First Stage	**Second Stage**	**Third Stage**	**Fourth Stage**	
50S	50	38		Pegasus
50S XL	50 XL	38		Pegasus XL
50ST	50T	38		Taurus
50S XLT	50 XLT	38		Taurus XL/ Minotaur-C
50S XLG	50 XL	38		Taurus Lite
		50 XL	38	Minotaur I
			38	Minotaur IV
50S				Hyper-X
50S XLG	50 XL	38		GMD GBI
50S XLG*	50 XLT			IRBM target

*** with lengthened nozzle**

Motor Identification Key

Example **Orion** **50** **S** **XL** **G** **T**

SRM class → Orion

SRM diameter (in) → 50

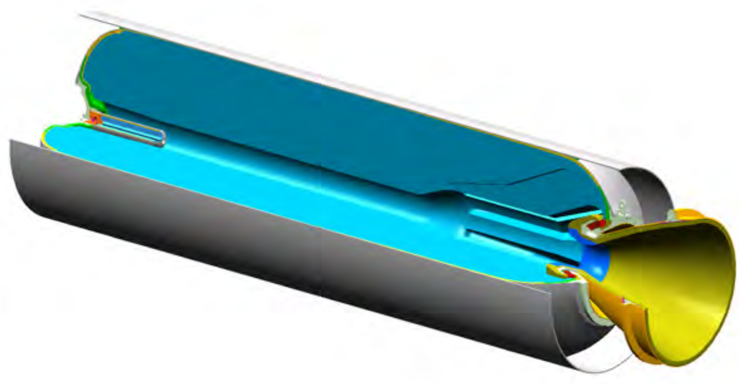
Stretch → S
- *With "S" denotes Stage 1*
- *Without "S" denotes Stage 2*

XL or Std motor length → XL
- *"XL" denotes extra length (otherwise standard length)*

Nozzle configuration → G
- *"G" denotes ground-launched (truncated exit cone)*

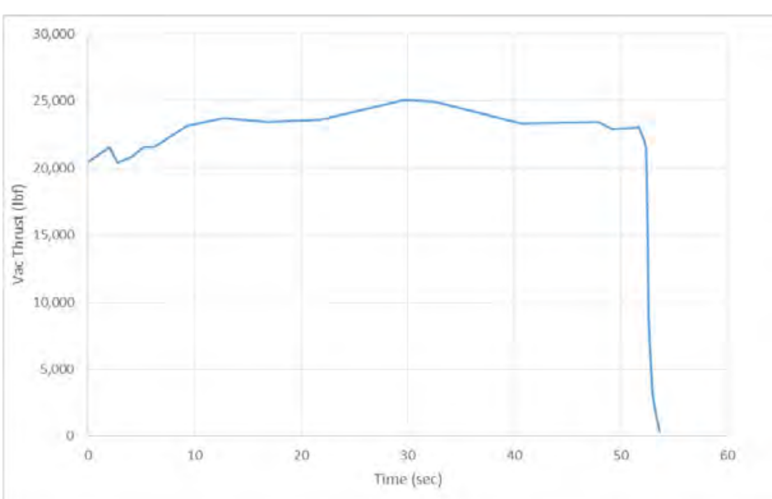
Thicker skirt → T
- *"T" denotes thicker skirt (increased structural capacity)*

ORION 32



VECTORABLE NOZZLE IN-LINE BOOSTER

The Orion 32 is a low-cost, high-performance derivative of an existing upper-stage motor. This development motor is 120 inches long and nominally designed as a second-stage motor. A longer version (Orion 32XL) for potential first stage application is also in design evaluation. This motor configuration has not flown; however, all components, except skirts, are flight-proven.



MOTOR DIMENSIONS
Motor diameter, in. 32.5
Overall motor length (including nozzle), in. 119.6

MOTOR PERFORMANCE (73°F VACUUM, VACUUM)
Burn time, sec. 53.6
Average chamber pressure, psia 756
Total impulse, lbf-sec 1,231,750
Burn time average thrust, lbf 22,970

NOZZLE
Housing material ....Aluminum
Exit diameter, in. 22.04
Expansion ratio, average 21.8

WEIGHTS, lbm
Total loaded 4,908
Propellant 4,429
Burnout 449

PROPELLANT DESIGNATION
.... QDL, HTPB POLYMER, 19% ALUMINUM

RACEWAY .... OPTIONAL

ORDNANCE .... OPTIONAL

TVA .... OPTIONAL

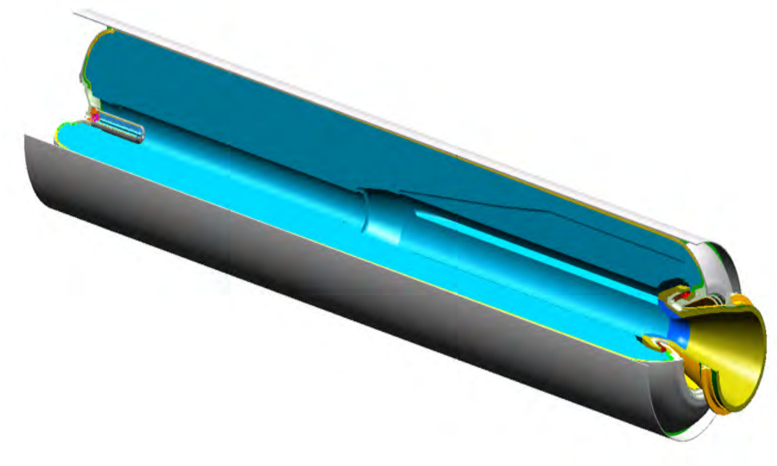
TEMPERATURE LIMITS
Operation ....+20°-100°F
Storage ....+20°-100°F

PRODUCTION STATUS .... DEVELOPMENT

For more information, contact:
psbdev@ngc.com

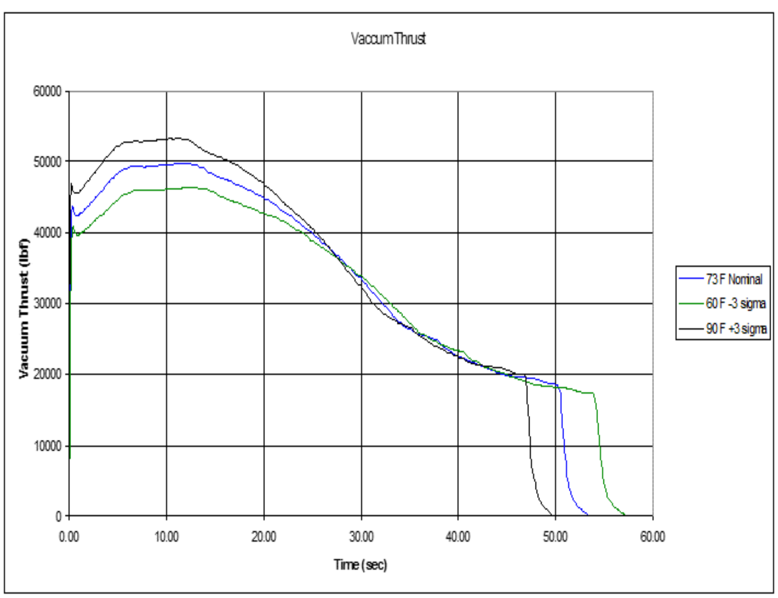
northropgumman.com

ORION 32XL



VECTORABLE NOZZLE IN-LINE BOOSTER

The Orion 32XL is a low-cost, high-performance derivative of an existing upper-stage motor. This development motor is 180 inches long and nominally designed as a first-stage motor. A shorter version (Orion 32) for potential second stage application is also in design evaluation. This motor configuration has not flown; however, all components, except skirts, are flight-proven.



MOTOR DIMENSIONS

Motor diameter, in. 32.5
Overall motor length (incl nozzle/fairing), in. 179.5

MOTOR PERFORMANCE (73°F VACUUM, VACUUM)

Burn time, sec..52.4
Average chamber pressure, psia.........................922
Total impulse, lbf-sec................................1,838,200
Burn time average thrust, lbf 35,056

NOZZLE

Housing material.......................................Aluminum
Exit diameter, in. 15.5
Expansion ratio, average...................................7.99

WEIGHTS, lbm

Total loaded 7,756
Propellant 6,953
Burnout..745

PROPELLANT DESIGNATION

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

RACEWAY .... OPTIONAL

ORDNANCE .... OPTIONAL

TVA .... OPTIONAL

TEMPERATURE LIMITS

Operation...+20°-100°F
Storage...+20°-100°F

PRODUCTION STATUS......... DEVELOPMENT

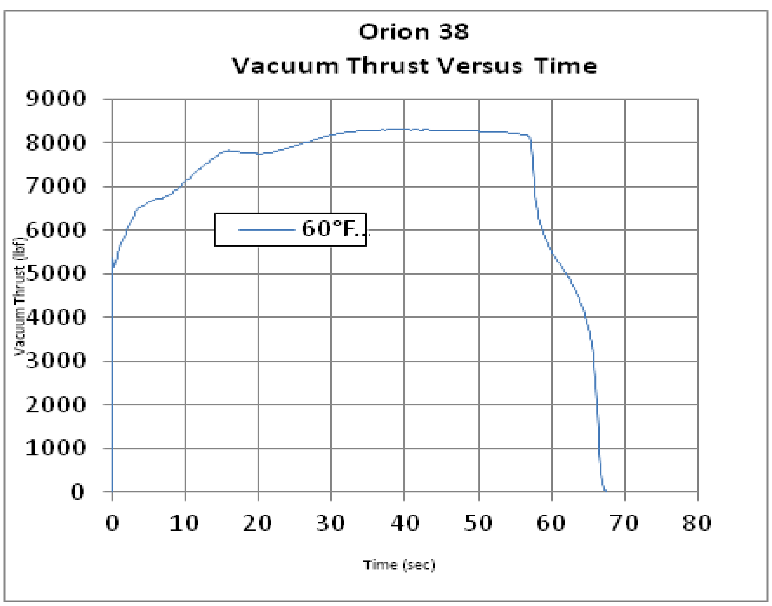
For more information, contact:
psbdev@ngc.com

northropgumman.com

ORION 38

AIR-IGNITED, VECTORABLE NOZZLE
UPPER-STAGE BOOSTER

The Orion 38 was developed as a low-cost, high-performance third stage for the Pegasus launch vehicle and incorporates a ± 5-degree vectorable nozzle. It also functions as the standard third-stage motor for other launch vehicles such as the Pegasus XL, Taurus, Taurus XL, Taurus Lite, and Minotaur-C launch vehicles and as the fourth stage of Minotaur-I and Minotaur IV vehicles. This motor has performed successfully in more than 80 flights over two decades of use.



MOTOR DIMENSIONS

Motor diameter, in. 38.0
Overall motor length (including nozzle), in. 52.6
Nozzle exit cone diameter, in. 20.7

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)

Burn time to 30 psia, sec 66.8
Maximum thrust, lbf. 8,303
Effective specific impulse, lbf-sec/lbm 286.97*
Total impulse, lbf-sec 491,140*
Burn time average thrust, lbf 7,352
* Includes 14.6 lbm of expended inerts

WEIGHTS, lbm

Total motor 1,924
Propellant 1,698
Burnout 206

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

HAZARDS CLASSIFICATION... .... 1.3

RACEWAY .... NO

ORDNANCE .... OPTIONAL

TVA .... OPTIONAL

TEMPERATURE LIMITS

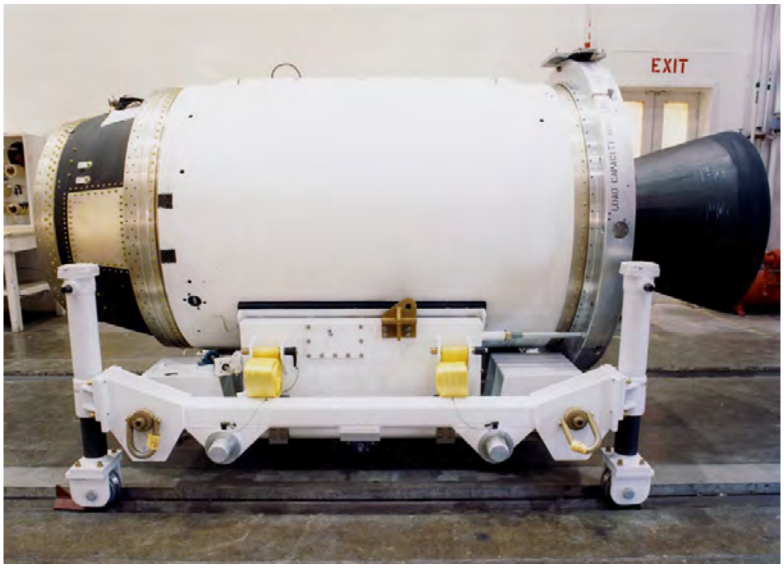
Operation .... +36°-100°F
Storage .... +30°-100°F

PRODUCTION STATUS
.... FLIGHT-PROVEN, PRODUCTION

For more information, contact:
psbdev@ngc.com

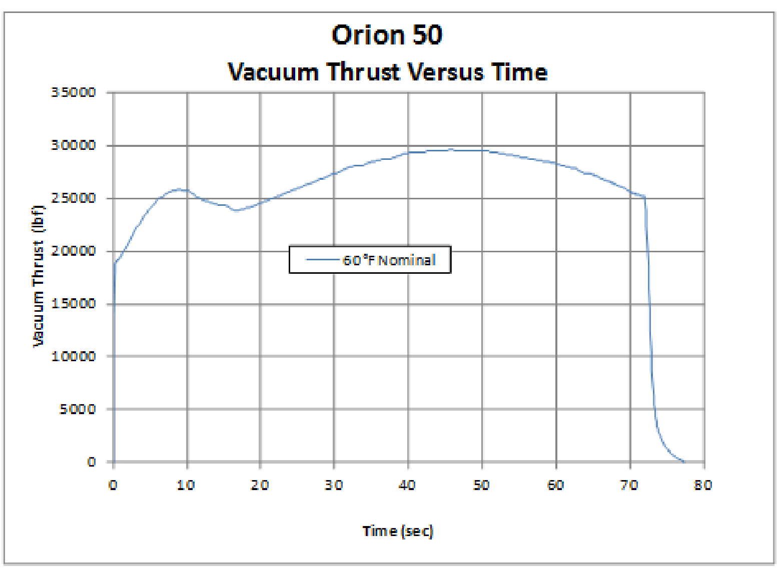
northropgumman.com

ORION 50 (50T)



AIR-IGNITED, VECTORABLE NOZZLE

The Orion 50 was developed as a low-cost, high-performance second stage for the Pegasus launch vehicle. It incorporates a moveable nozzle with ± 5-degree vector capability. The motor was designed for upper stage applications but can readily accommodate lower expansion ratios, such as for ground-launch application, using a truncated nozzle. The Orion 50 has propelled several satellite missions into successful orbit, including: Pegsat, Microsat, SCD-1 (Brazil's first data collection satellite), Alexis, and Space Test Experiment Platform (STEP)-2. A nearly identical version with slightly enhanced skirts, the Orion 50T, has also flown successfully as a second stage on Taurus launch vehicle flights.



MOTOR DIMENSIONS
Motor diameter, in. 50.2
Overall motor length (including nozzle), in. 103.2
Nozzle exit cone diameter, in. 33.9

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)
Burn time to 30 psia, sec 75.1
Maximum thrust, lbf 29,554
Effective specific impulse, lbf-sec/lbm 290.23*
Total impulse, lbf-sec 1,949,000*
Burn time average thrust, lbf 25,939
* Includes 46.4 lbm of expended inerts

WEIGHTS, LBM
Total motor 7,395
Propellant 6,669
Burnout 670

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

HAZARDS CLASSIFICATION 1.3

RACEWAY ..... YES

ORDNANCE ..... OPTIONAL

TVA ..... OPTIONAL

TEMPERATURE LIMITS
Operation ..... +36°-100°F

STORAGE ..... +30°-100°F

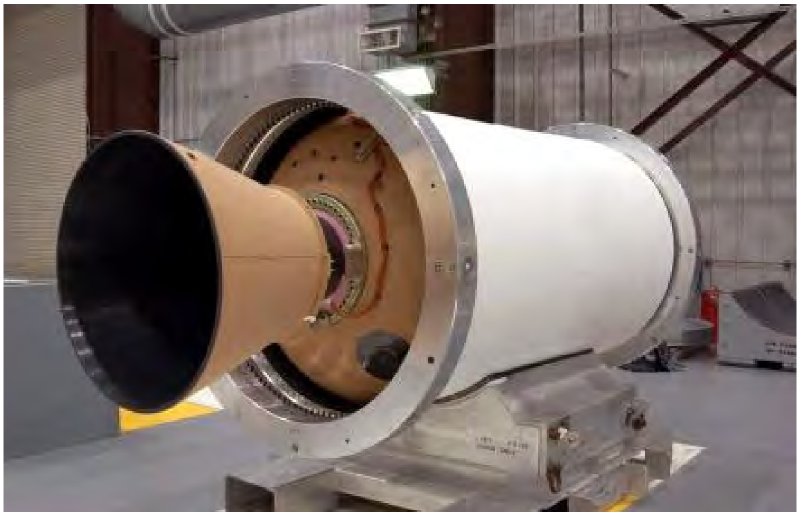
PRODUCTION STATUS
..... FLIGHT-PROVEN, INACTIVE PRODUCTION

For more information, contact:
psbdev@ngc.com

northropgumman.com

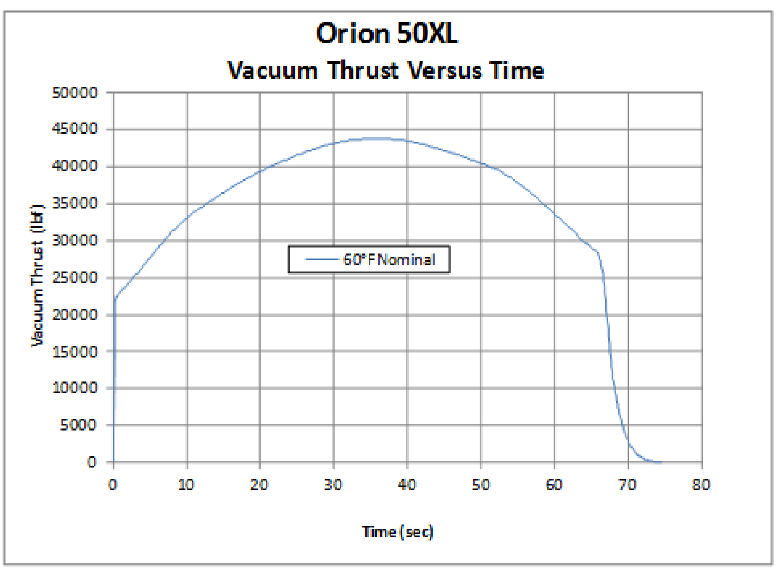
ORION 50 XL (50 XLT)

NORTHROP GRUMMAN



AIR-IGNITED, VECTORABLE NOZZLE

A flight-proven, extended-length version of the initial Orion 50 is also available. The Orion 50 XL is 18 inches longer and contains almost 2,000 lbm more propellant than the Orion 50. It flew on the 1995 Space Test Experiment Platform (STEP)-3 mission as the second stage of the Pegasus XL. It has also flown as the third-stage motor for the Air Force's Minotaur launch vehicle as part of the Orbital/Suborbital Program and as the second stage on the Taurus Lite vehicle. In addition, a nearly identical version with heavier skirts, the Orion 50 XLT, launched in May 2004 as a second-stage motor on the enhanced Taurus XL launch vehicle and in October 2017 on Minotaur-C.



MOTOR DIMENSIONS

Motor diameter, in. 50.2
Overall motor length (including nozzle), in. 120.9
Nozzle exit cone diameter, in. 33.9

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)

Burn time to 30 psia, sec 71.0
Maximum thrust, lbf. 43,713
Effective specific impulse, lbf-sec/lbm 290.65*
Total impulse, lbf-sec 2,521,900*
Burn time average thrust, lbf 35,511
* Includes 46.4 lbm of expended inerts

WEIGHTS, lbm

Total motor 9,494
Propellant 8,631
Burnout 808

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

HAZARDS CLASSIFICATION... .... 1.3

RACEWAY .... YES

ORDNANCE .... OPTIONAL

TVA .... OPTIONAL

TEMPERATURE LIMITS

Operation .... +36°-100°F
Storage .... +30°-100°F

PRODUCTION STATUS
.... FLIGHT-PROVEN, PRODUCTION

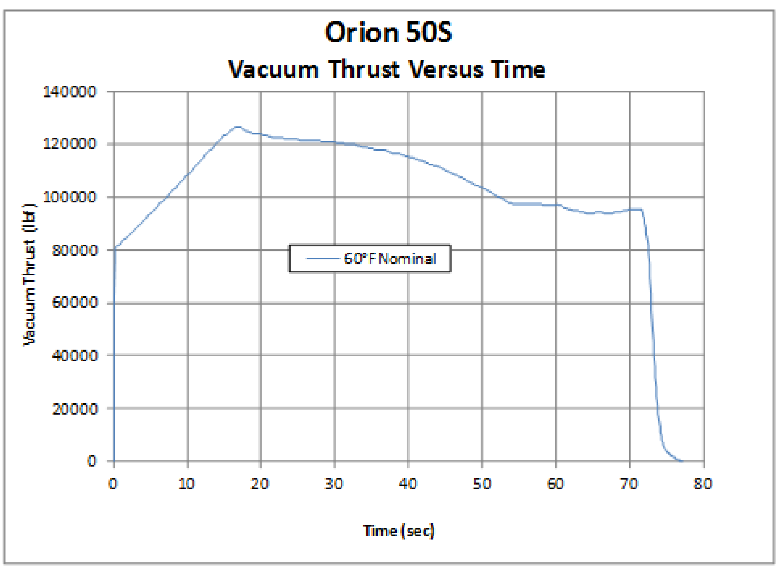
For more information, contact:
psbdev@ngc.com

northropgumman.com

ORION 50S

AIR-IGNITED, FIXED NOZZLE

The Orion 50S was developed as a low-cost, high-performance first stage for the Pegasus launch vehicle. The 50S configuration, shown above incorporating a saddle attachment, has a fixed nozzle and is air ignited after a 5-second freefall drop from approximately 40,000 ft. The Orion 50S has launched Pegasus satellite missions into successful orbit, some of which were Pegsat, Microsat, SCD-1 (Brazil's first data collection satellite), Alexis, and Space Test Experiment Platform (STEP)-2. This motor, with some additional modifications, has also been used as a booster in Hyper-X flights to support scramjet flight-testing.



MOTOR DIMENSIONS

Motor diameter, in...50.2
Overall motor length (including nozzle), in. 350.1
Nozzle exit cone diameter, in..............................56.0

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)

Burn time to 30 psia, sec....................................74.9
Maximum thrust, lbf.....................................126,641
Effective specific impulse, lbf-sec/lbm... .... 292.25*
Total impulse, lbf-sec.............................. 7,873,000*
Burn time average thrust, lbf 105,097
* Includes 137 lbm of expended inerts

WEIGHTS, LBM

Total motor...29,529
Propellant 26,801
Burnout..2,533

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION... .... 1.3

RACEWAY..................................... OPTIONAL

ORDNANCE.................................. OPTIONAL

TVA ....NO

TEMPERATURE LIMITS

Operation..+36°-100°F
Storage.... ....+30°-100°F

PRODUCTION STATUS

..........FLIGHT PROVEN, INACTIVE PRODUCTION

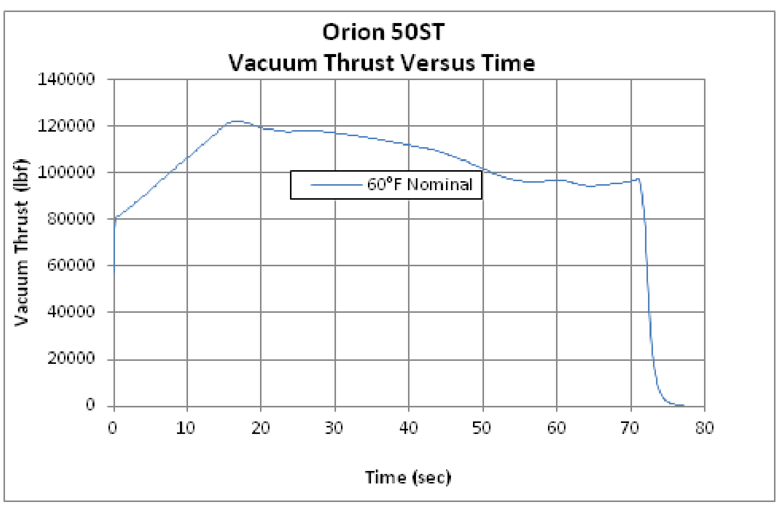
For more information, contact:
psbdev@ngc.com

northropgumman.com

ORION 50ST

AIR-IGNITED, VECTORABLE NOZZLE

Another version, Orion 50ST, incorporates a ± 5-degree moveable nozzle for the air-ignited Taurus Stage 1. This version has flown on all Taurus missions (both Air Force and commercial versions), such as the Multi-Spectral Thermal Imager (MTI), Orbview-4, Korea Multi-Purpose Satellite (KOMPSAT), etc.



MOTOR DIMENSIONS

Motor diameter, in. 50.2
Overall motor length (including nozzle), in. 335.4
Nozzle exit cone diameter, in. 47.6

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)

Burn time, sec. 74.2
Maximum thrust, lbf 122,099
Effective specific impulse, lbf-sec/lbm… 284.97*
Total impulse, lbf-sec 7,676,500*
Burn time average thrust, lbf 103,356
* Includes 137 lbm of expended inerts

WEIGHTS, LBM

Total motor 29,103
Propellant 26,801
Burnout 2,165

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION… 1.3

RACEWAY .... OPTIONAL

ORDNANCE .... OPTIONAL

TVA .... OPTIONAL

TEMPERATURE LIMITS

Operation .... +36°-100°F
Storage .... +30°-100°F

PRODUCTION STATUS

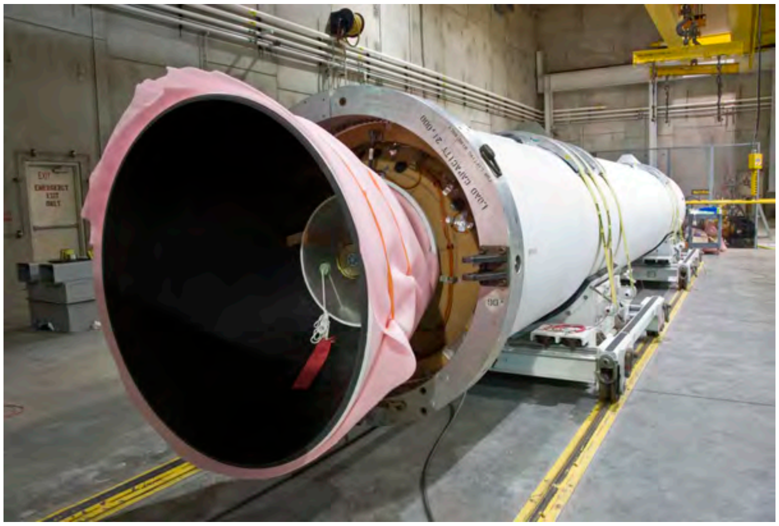
.... FLIGHT-PROVEN, INACTIVE PRODUCTION

For more information, contact:

psbdev@ngc.com

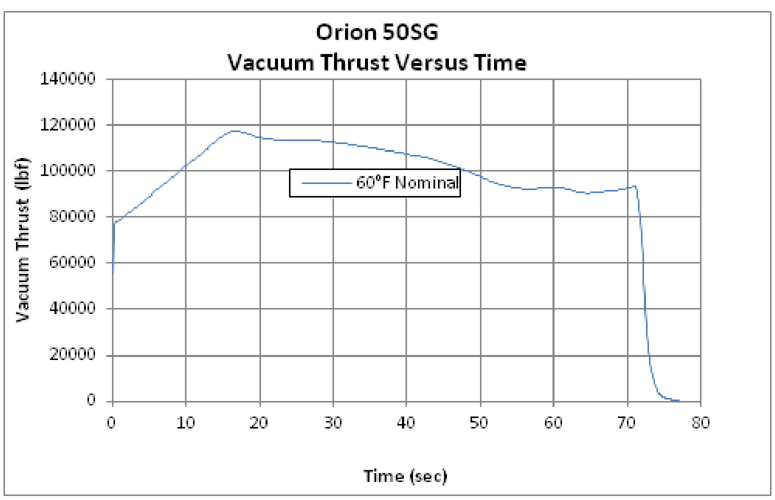
northropgumman.com

ORION 50SG



GROUND-IGNITED, VECTORABLE NOZZLE

Another version, Orion 50SG, incorporates a ± 3-degree moveable nozzle for a ground-ignited Stage 1 configuration. This version is similar to what has flown on the standard Taurus missions, but with a shorter nozzle.



MOTOR DIMENSIONS

Motor diameter, in. 50.2
Overall motor length (including nozzle), in. 318.3
Nozzle exit cone diameter, in..............................36.0

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)

Burn time, sec..74.2
Maximum thrust, lbf 117,358
Effective specific impulse, lbf-sec/lbm… 273.7*
Total impulse, lbf-sec 7,372,900*
Burn time average thrust, lbf 99,268
* Includes 137 lbm of expended inerts

WEIGHTS, LBM

Total motor..28,865
Propellant 26,801
Burnout...1,930

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION… 1.3

RACEWAY..................................... OPTIONAL

ORDNANCE .... OPTIONAL

TVA .... OPTIONAL

TEMPERATURE LIMITS

Operation...+36°-100°F
Storage..+30°-100°F

PRODUCTION STATUS

.... QUALIFIED, INACTIVE PRODUCTION

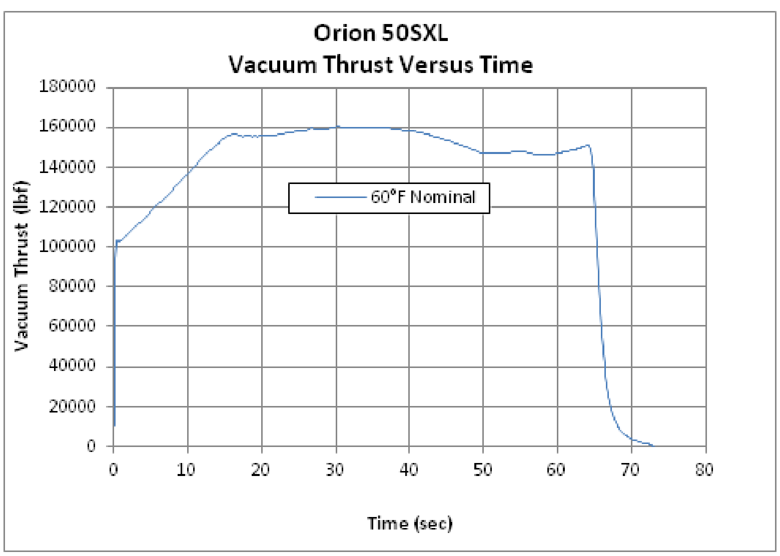
For more information, contact:
psbdev@ngc.com

northropgumman.com

ORION 50S XL

AIR-IGNITED, FIXED NOZZLE

A performance upgrade of the Orion 50S, the Orion 50S XL is 55.4 inches longer and contains 6,500 lbm more propellant. This fixed-nozzle XL version has performed successfully on all Pegasus XL launch vehicle missions, such as the Solar Radiation and Climate Experiment (SORCE), Fast Auroral Snapshot (FAST), High Energy Solar Spectroscopic Imager (HESSI), Orbview-3, and Transition Region and Coronal Explorer (TRACE).



MOTOR DIMENSIONS
Motor diameter, in. 50.2
Overall motor length (including nozzle), in. 404.3
Nozzle exit cone diameter, in. 56.0

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)
Burn time to 30 psia, sec 69.7
Maximum thrust, lbf 160,404
Effective specific impulse, lbf-sec/lbm 292.78*
Total impulse, lbf-sec 9,744,300*
Burn time average thrust, lbf 139,726
* Includes 137 lbm of expended inerts

WEIGHTS, LBM
Total motor 36,153
Propellant 33,145
Burnout 2,837

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

HAZARDS CLASSIFICATION 1.3

RACEWAY ..... OPTIONAL

ORDNANCE ..... OPTIONAL

TVA ..... NO

TEMPERATURE LIMITS
Operation ..... +36°-100°F
Storage ..... +30°-100°F

PRODUCTION STATUS
..... FLIGHT-PROVEN, PRODUCTION

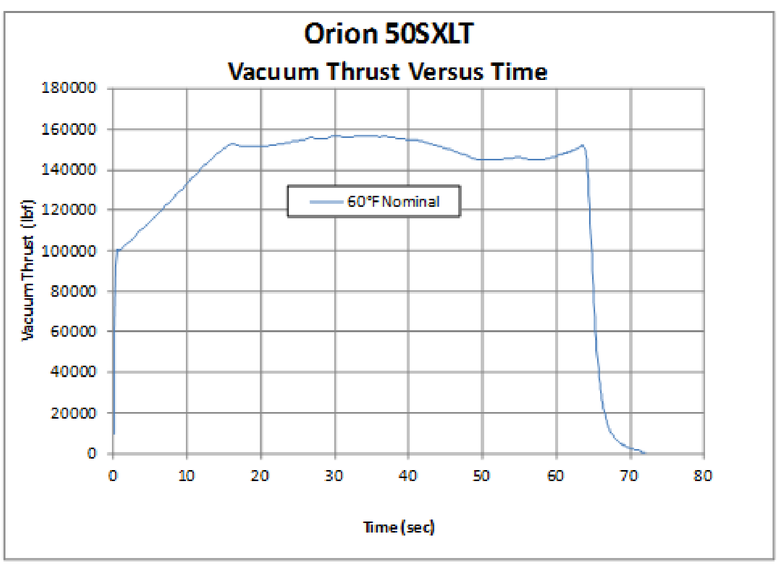
For more information, contact:
psbdev@ngc.com

northropgumman.com

ORION 50S XLT

AIR-IGNITED, VECTORABLE NOZZLE

Vectorable nozzle configurations of the Orion 50S XL have also been added to support versatility and new applications. One such configuration, Orion 50S XLT, has been used as a second-stage motor on the enhanced Taurus XL vehicle, which first launched in May 2004. This version incorporates a ± 5-degree vectorable nozzle and thicker skirts.



MOTOR DIMENSIONS

Motor diameter, in. 50.2
Overall motor length (including nozzle), in. 390.8
Nozzle exit cone diameter, in..............................47.6

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)

Burn time to 30 psia, sec 69.0
Maximum thrust, lbf.. 156,823
Effective specific impulse, lbf-sec/lbm 284.61*
Total impulse, lbf-sec 9,472,400*
Burn time average thrust, lbf 137,192
* Includes 137 lbm of expended inerts

WEIGHTS, LBM

Total motor..35,763
Propellant 33,145
Burnout 2,472

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION... .... 1.3

RACEWAY .... OPTIONAL

ORDNANCE .... OPTIONAL

TVA .... OPTIONAL

TEMPERATURE LIMITS

Operation...+36°-100°F
Storage ....+30°-100°F

PRODUCTION STATUS

............................FLIGHT-PROVEN, PRODUCTION

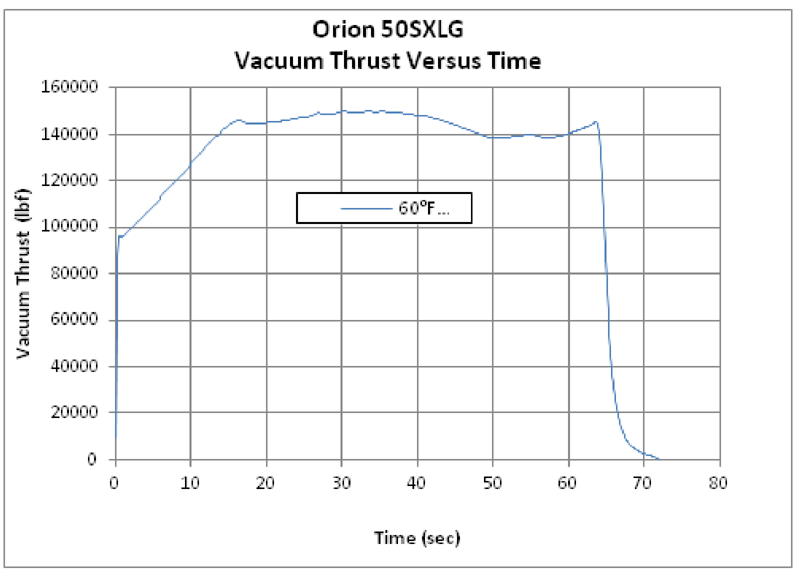
For more information, contact:
psbdev@ngc.com

northropgrumman.com

ORION 50S XLG

GROUND-IGNITED, VECTORABLE NOZZLE

A ground-ignited, vectorable nozzle configuration with ± 5-degree vector capability has also been developed, designated Orion 50S XLG. This motor was first flown on the Taurus Lite vehicle, February 2003, as the ground-ignited first stage. It is also used on the Orbital Boost Vehicle (OBV) for the Missile Defense Agency (MDA) Ground-based Midcourse Defense (GMD) and as an Intermediate Range Ballistic Missile (IRBM) target for MDA.



MOTOR DIMENSIONS

Motor diameter, in. 50.2
Overall motor length (including nozzle), in. 344.0
Nozzle exit cone diameter, in. 36.0

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)

Burn time to 30 psia, sec 69.0
Maximum thrust, lbf. 150,010
Effective specific impulse, lbf-sec/lbm 272.26*
Total impulse, lbf-sec 9,061,400*
Burn time average thrust, lbf 131,200
* Includes 137 lbm of expended inerts

WEIGHTS, LBM

Total motor 35,525
Propellant 33,145
Burnout 2,237

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION... .... 1.3

RACEWAY .... OPTIONAL

ORDNANCE .... OPTIONAL

TVA .... OPTIONAL

TEMPERATURE LIMITS

Operation...+36°-100°F
Storage..+30°-100°F

PRODUCTION STATUS

............................FLIGHT-PROVEN, PRODUCTION

For more information, contact:
psbdev@ngc.com

northropgumman.com

CASTOR® MOTOR SERIES

LOW-COST, HIGH-RELIABILITY BOOSTERS

The CASTOR motor family was originally developed in the mid-to-late 1950s to support the NASA Scout and Little Joe vehicles. In 1969, the CASTOR IV was developed to provide first stage propulsion for the Athena H and was later adapted as a strap-on booster for Delta II. The CASTOR I-IV family has a combined total of over 1,900 flights and a demonstrated reliability of 99.95%. Since then, newer derivatives including the CASTOR IVA, IVA-XL, and IVB have replaced the CASTOR IV motor.

- CASTOR IVA, high-performance strap-on propulsion launch vehicles
- CASTOR IVA-XL, 8-foot extended length version with 30% greater launch capability
- CASTOR IVB, thrust vector control version with first stage, second stage, or strap-on booster application

Northrop Grumman currently manufactures a complete line of first- and second-stage and strap-on solid rocket motors. Over 50% of the U.S. space launches carry commercial satellites and CASTOR motors are designed to provide low-cost, high-reliability propulsion to support that access to space. Northrop Grumman has used the base technology from four generations of ballistic missile boosters and the technology and experience from expendable launch vehicle programs to continue to add to the CASTOR series.

Development of the CASTOR 120 motor began in 1989. The CASTOR 120 was designed, using proven technology, to meet the need for a medium-sized, reliable, solid rocket booster. The primary goals of the program were to achieve a >0.999 reliability rating and a 50% cost reduction. CASTOR 120 motors have served as stage one of the Lockheed Martin Athena I and stages one and two on Athena II, and Northrop Grumman Taurus and Minotaur-C vehicles used it as an initial stage (Stage 0) booster.

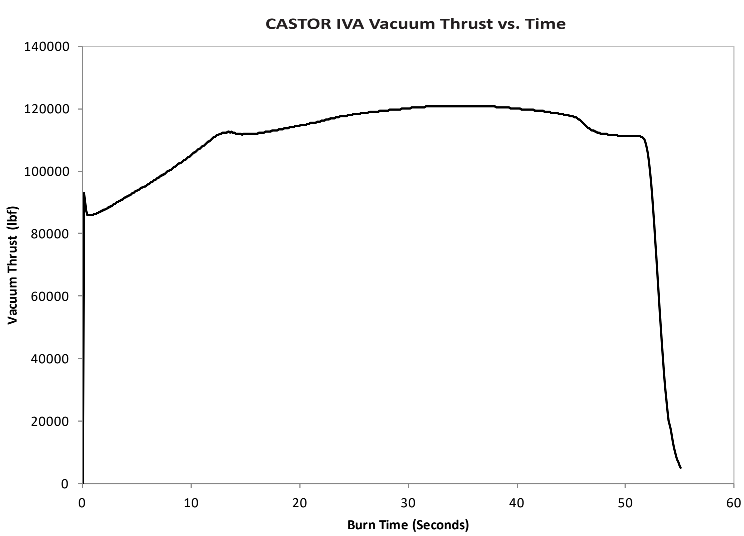
The CASTOR 30/30B/30XL upper stages have each flown successfully on Northrop Grumman's Antares launch vehicle for International Space Station resupply missions.

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

CASTOR IVA

FIXED NOZZLE

The CASTOR IVA motor was developed in the early 1980s for NASA. By switching to HTPB propellant (from the earlier CASTOR IV), NASA was able to improve Delta II performance by 11%. Development and qualification motors were fired in 1983. Three additional qualification tests were conducted. Each Delta vehicle carried nine CASTOR IVA strap-on motors until 1993. In addition, a straight nozzle version powered Orbital Sciences' Prospector suborbital vehicle and two motors flew on the Conestoga in October 1995. CASTOR IVA motors have also flown on the Lockheed Martin Atlas IIAS, which was first flown in 1993. The four strap-on boosters on the Atlas IIAS increased payload capacity by 1,500 lb. Two boosters are ground-lit at ignition and two are air-ignition. Two configurations are available; -03, with an 11-degree canted nozzle, and -04, with a 7-degree canted nozzle.



MOTOR DIMENSIONS

Motor diameter, in. 40.1
Overall motor length (including nozzle), in. 363.4
Nozzle exit cone diameter, in.……….................33.6

MOTOR PERFORMANCE (73°F NOMINAL, VACUUM)

Burn time, sec...55.2
Maximum thrust, lbf 120,880
Specific impulse, lbf-sec/lbm….........................265.3
Total impulse, lbf-sec 5,967,840
Burn time average thrust, lbf 108,190

WEIGHTS, LBM

Total motor..25,737
Propellant 22,286
Burnout 3,239

PROPELLANT DESIGNATION

.... TP-H8299, HTPB POLYMER, 20% 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

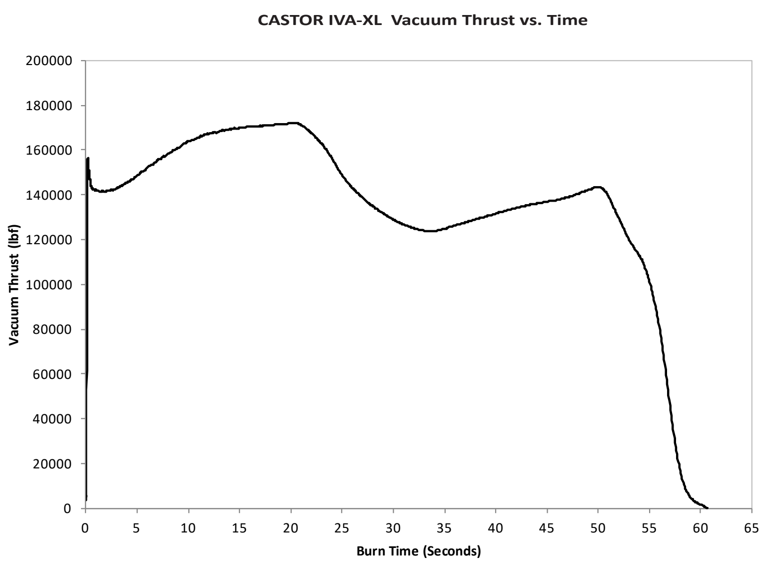
For more information, contact:
psbdev@ngc.com

northropgumman.com

CASTOR IVA-XL

FIXED NOZZLE

The CASTOR IVA-XL motor, an 8-foot extension of the CASTOR IVA motor, was first tested in 1992. Successful qualification tests followed in 1992 and 1993. A more recent demonstration motor test was conducted in 1999. The Japanese H-IIA launch vehicle used modified CASTOR IVA-XL motors with 6-degree canted nozzles as solid strap-on boosters. The H-IIA can use two or four solid strap-on boosters depending on mission requirements and vehicle configuration. The first CASTOR IVA-XL solid strap-on booster motors flew on the H-IIA vehicles in 2002.



MOTOR DIMENSIONS
Motor diameter, in. 40.1
Overall motor length (including nozzle), in. 457.0
Nozzle exit cone diameter, in. 50.5

MOTOR PERFORMANCE (73°F NOMINAL, VACUUM)
Burn time, sec 58.0
Maximum thrust, lbf 172,060
Specific impulse, lbf-sec/lbm 282.4
Total impulse, lbf-sec 8,140,170
Burn time average thrust, lbf 140,480

WEIGHTS, LBM
Total motor 33,031
Propellant 28,906
Burnout 3,653

PROPELLANT DESIGNATION
.... TP-H8299, HTPB POLYMER, 20% 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

VECTORABLE NOZZLE IN-LINE BOOSTER

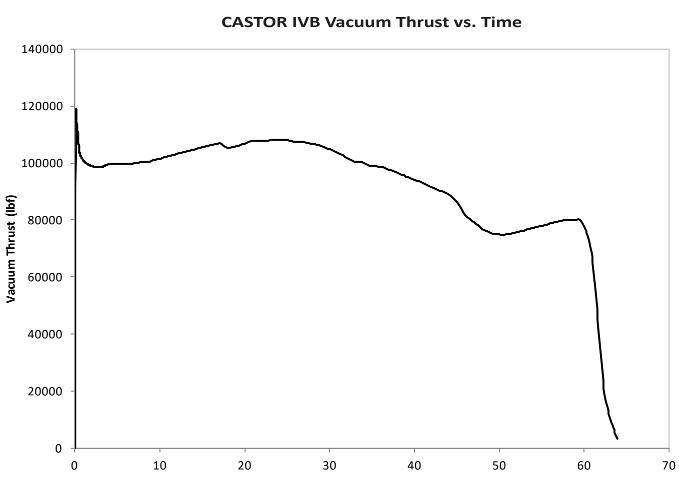
For more information, contact:
psbdev@ngc.com

northropgumman.com

CASTOR IVB

VECTORABLE NOZZLE IN-LINE BOOSTER

The CASTOR IVB motor was the first in the series of CASTOR IV motors to incorporate thrust vector control and a regressive thrust-time trace for aerodynamic pressure considerations. It was developed for the European Space Agency's MAXUS sounding rockets and first flew in 1991. CASTOR IVB motors have provided first stage boost on all MAXUS flights. CASTOR IVB motors have also served as first stage motors for three of the U.S. Army's Theater Critical Measurement Program launches in 1996 and 1997, for the U.S. Air Force's ait-2 (launched from Kodiak, Alaska in 1999), for Spain's Capricornio in 1997, as first and second stages for the Conestoga launch vehicle in 1995, and as numerous target vehicles for the Missile Defense Agency.



MOTOR DIMENSIONS

Motor diameter, in. 40.1

Overall motor length (including nozzle), in. 353.7

Nozzle exit cone diameter, in.............................37.0

MOTOR PERFORMANCE (73°F NOMINAL, VACUUM)

Burn time, sec..63.6

Maximum thrust, lbf….................................119,150

Specific impulse, lbf-sec/lbm 267.3

Total impulse, lbf-sec 5,880,600

Burn time average thrust, lbf 92,490

WEIGHTS, LBM

Total motor...25,441

Propellant 21,990

Burnout 3,254

PROPELLANT DESIGNATION

.... TP-H8299, HTPB POLYMER, 20% 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, PRODUCTION

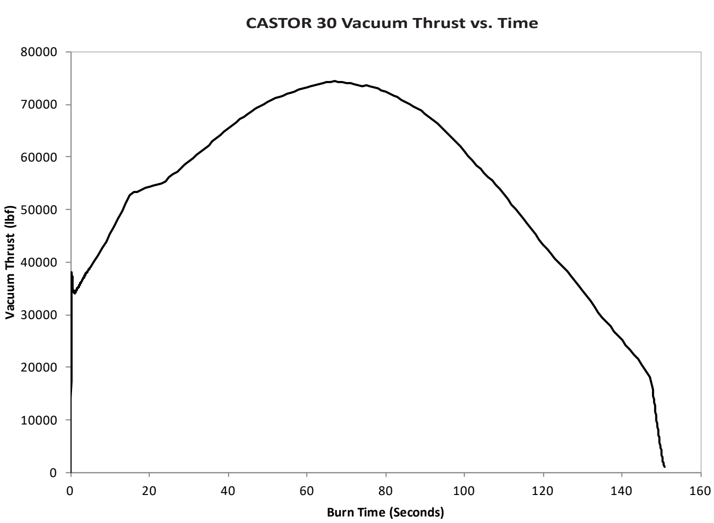
For more information, contact:
psbdev@ngc.com

northropgumman.com

CASTOR 30

VECTORABLE NOZZLE IN-LINE UPPER STAGE BOOSTER

The CASTOR 30 is a low-cost, robust, state-of-the-art upper stage motor. This commercially developed motor is 144 inches long and nominally designed as an upper stage that can function as a second or third stage depending on the vehicle configuration. The design of the CASTOR 30 uses all flight-proven technology and materials.



MOTOR DIMENSIONS

Motor diameter, in...92
Overall motor length (including nozzle), in. 144.2
Nozzle exit cone diameter, in..............................49.7

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec..149.8
Maximum thrust, lbf 74,359
Specific impulse, lbf-sec/lbm............................293.1
Total impulse, lbf-sec 8,239,110
Burn time average thrust, lbf 53,700

WEIGHTS, LBM

Total motor..30,590
Propellant 28,098
Burnout 2,268

PROPELLANT DESIGNATION

...... TP-H1265, HTPB POLYMER, 20% ALUMINUM

HAZARDS CLASSIFICATION... .... 1.3

RACEWAY..................................... OPTIONAL

ORDNANCE.................................. OPTIONAL

TVA .... YES

TEMPERATURE LIMITS

Operation..+30°-100°F
Storage.... ....+30°-105°F

PRODUCTION STATUS.......... FLIGHT-PROVEN

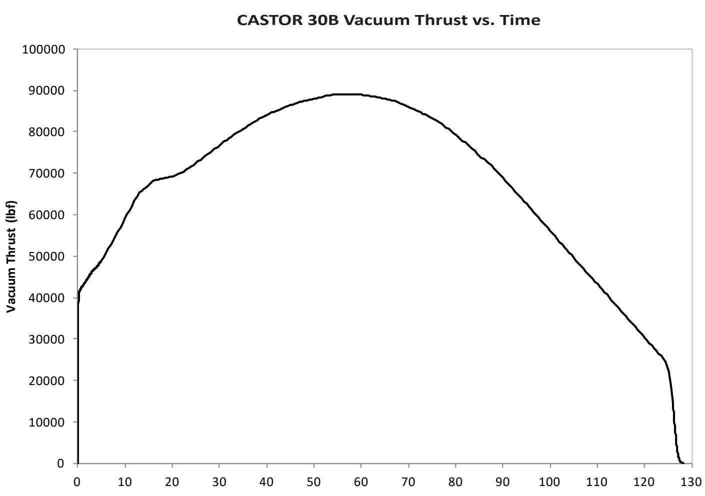
For more information, contact:
psbdev@ngc.com

northropgumman.com

CASTOR 30B

VECTORABLE NOZZLE IN-LINE UPPER STAGE BOOSTER

The CASTOR 30B is a low-cost, robust, state-of-the-art upper stage motor. This production motor incorporates a few modifications from the CASTOR 30, primarily a change in propellant and a longer nozzle. It is 169.9 inches long and nominally designed as an upper stage that can function as a second or third stage depending on the vehicle configuration.



MOTOR DIMENSIONS

Motor diameter, in.....92
Overall motor length (including nozzle), in. 169.9
Nozzle exit cone diameter, in.....62.4

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec.....126.7
Maximum thrust, lbf.....89,090
Specific impulse, lbf-sec/lbm.....300.6
Total impulse, lbf-sec.....8,539,320
Burn time average thrust, lbf.....67,370

WEIGHTS, LBM

Total motor.....30,800
Propellant.....28,405
Burnout.....2,203

PROPELLANT DESIGNATION
.... TP-H8299, HTPB POLYMER, 20% ALUMINUM

HAZARDS CLASSIFICATION.... .... 1.3

RACEWAY..... OPTIONAL

ORDNANCE ..... OPTIONAL

TVA ..... YES

TEMPERATURE LIMITS

Operation.....+30°-100°F
Storage... .....+30°-105°F

PRODUCTION STATUS.......... FLIGHT-PROVEN

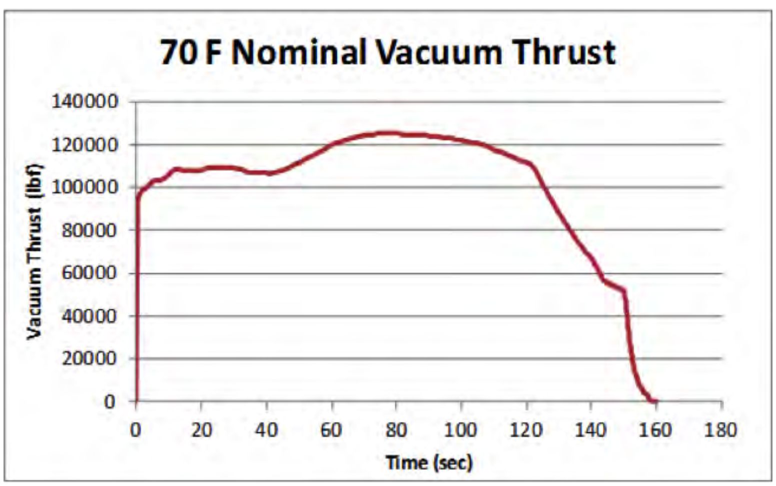
For more information, contact:
psbdev@ngc.com

northropgumman.com

CASTOR 30XL

VECTORABLE NOZZLE IN-LINE UPPER STAGE BOOSTER

The CASTOR 30XL is a low-cost, robust, state-of-the-art upper stage motor. CASTOR 30XL is more than a stretched version of the CASTOR 30. The motor also capitalizes on existing common designs and materials, plus lessons learned while developing the Large Class Stage I and III. The motor is 235.8 inches long and nominally designed as an upper stage that can function as a second or third stage depending on the vehicle configuration. The nozzle is 8 feet long with a submerged design with a high-performance expansion ratio (55.9:1) and a dual density exit cone well suited for high altitude operation. It features an electro-mechanical thrust vector actuation system with actuators, thermal battery, and electronic controller. First flight on Antares was October 2016.



MOTOR DIMENSIONS

Motor diameter, in. 92
Overall motor length (including nozzle), in. 235.8
Nozzle exit cone diameter, in. 78.7

MOTOR PERFORMANCE (70°F VACUUM, VACUUM)

Burn time, sec 155.0
Maximum thrust, lbf 119,900
Effective specific impulse, lbf-sec/lbm 294.4
Total impulse, lbf-sec 16,174,800
Burn time average thrust, lbf 104,350

WEIGHTS, LBM

Total motor 58,217
Propellant 54,949
Burnout (est.) 3,069

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

HAZARDS CLASSIFICATION.... 1.3

RACEWAY ....NO

ORDNANCE ....NO

TVA ....YES

TEMPERATURE LIMITS

Operation ....+55°-85°F
Storage ....+30°-100°F

PRODUCTION STATUS ....FLIGHT-PROVEN,
....IN PRODUCTION

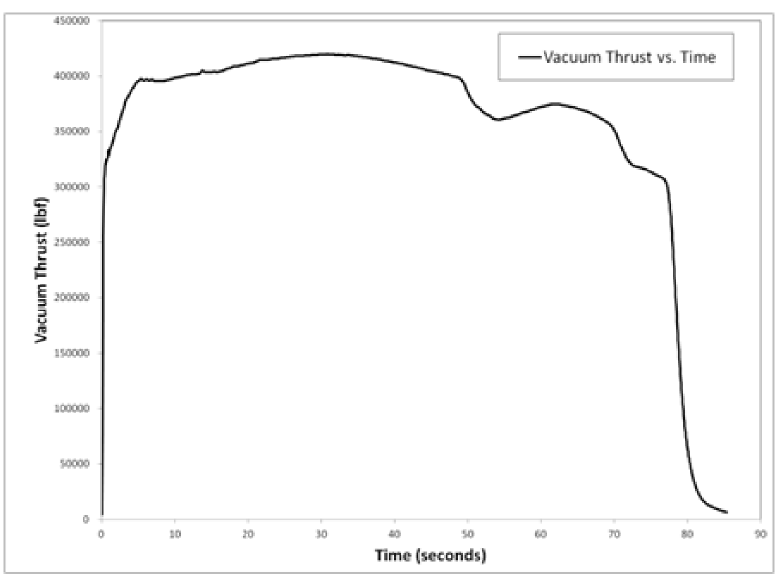
For more information, contact:
psbdev@ngc.com

northropgumman.com

CASTOR 120

VECTORABLE NOZZLE

The CASTOR 120 was designed, using proven technology, to meet the need for a medium-sized, reliable solid rocket booster. While primarily anticipated for in-line use, the CASTOR 120 motor can also be configured as a strap-on booster with a moveable nozzle and a cold-gas blowdown system thrust vector control. The thrust vector control system can be removed and the nozzle fixed. The propellant grain can also be tailored to reduce thrust during max-Q pressure for high initial thrust or for a regressive thrust to reduce acceleration. To date, the CASTOR 120 has been used in both first stage and second stage applications.



MOTOR DIMENSIONS

Motor diameter, in. 92.0
Overall motor length (including nozzle), in. 355
Nozzle exit cone diameter, in. 59.7

MOTOR PERFORMANCE (70°F VACUUM, VACUUM)

Burn time, sec. 79.4
Maximum thrust, lbf 440,000
Specific impulse, lbf-sec/lbm. 280
Total impulse, lbf-sec 30,000,000
Burn time average thrust, lbf 379,000

WEIGHTS, lbm

Total motor 116,993
Propellant 107,914
Burnout 9,097

PROPELLANT DESIGNATION

.... TP-H1246, 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

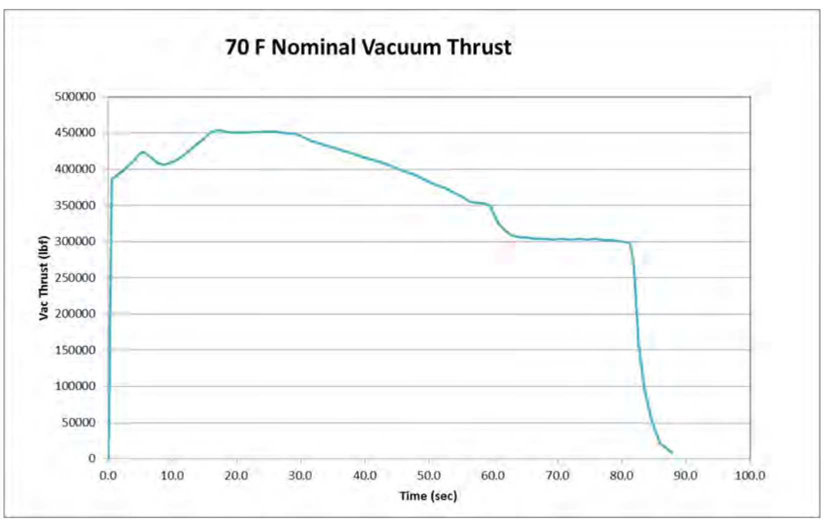
For more information, contact:
psbdev@ngc.com

northropgumman.com

CASTOR 120XL

VECTORABLE NOZZLE BOOSTER

The CASTOR 120XL is a new low-cost, robust, state-of-the-art booster stage. CASTOR 120XL is more than just a stretched version of the CASTOR 120. The motor also capitalizes on existing common designs and materials, as well as lessons learned while developing the Large Class Stage I and III for the U.S. Air Force. The motor is 378.3 inches long and nominally designed as a medium-sized in-line booster. It features an electro-mechanical thrust vector actuation system with actuators, thermal battery and electronic controller.



MOTOR DIMENSIONS

Motor diameter, in. 92.1
Overall motor length (including nozzle), in. 378.3
Nozzle exit cone diameter, in..............................59.8

MOTOR PERFORMANCE (70°F VACUUM, VACUUM)

Burn time, sec..83.5
Maximum thrust, lbf 458,500
Effective specific impulse, lbf-sec/lbm…. 279.1
Total impulse, lbf-sec 31,892,000
Burn time average thrust, lbf 381,701

WEIGHTS, LBM

Total motor..123,383
Propellant 114,194
Burnout (est)...8,850

PROPELLANT DESIGNATION

.... TP-H1246, 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

....................QUALIFIED, INACTIVE PRODUCTION

For more information, contact:
psbdev@ngc.com

northropgumman.com

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 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:

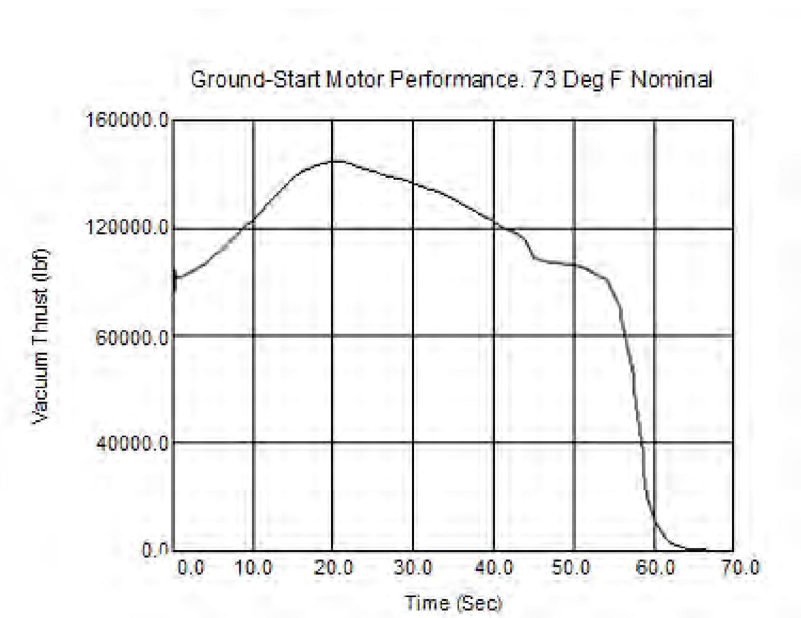
- GEM 40, multiple configurations
- GEM 46, multiple configurations
- GEM 60, multiple configurations
- GEM 63, multiple configurations

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, lbf 144,740
Specific impulse, lbf-sec/lbm 274.0
Total impulse, lbf-sec 7,107,800
Burn time average thrust, lbf 112,200

WEIGHTS, LBM

Total motor 28,577
Propellant 25,940
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

northropgumman.com

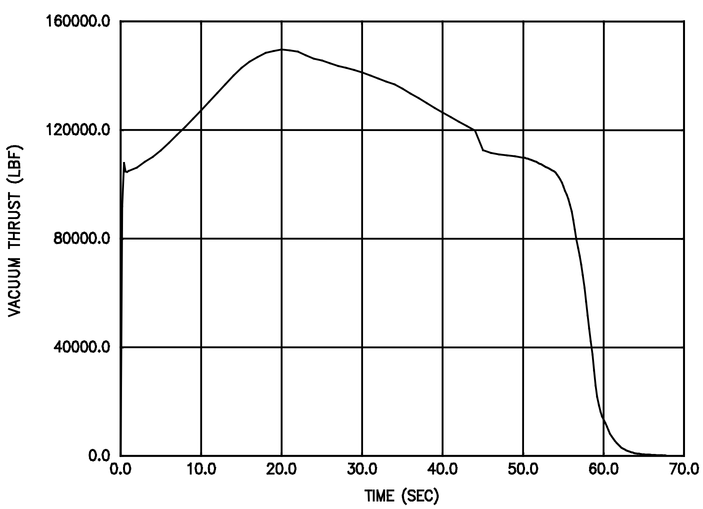
GEM 40 (AIR IGNITED)

NORTHROP GRUMMAN

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/lbm 283.4

Total impulse, lbf-sec 7,351,000

Burn time average thrust, lbf 116,050

WEIGHTS, LBM

Total motor 28,883

Propellant 25,940

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

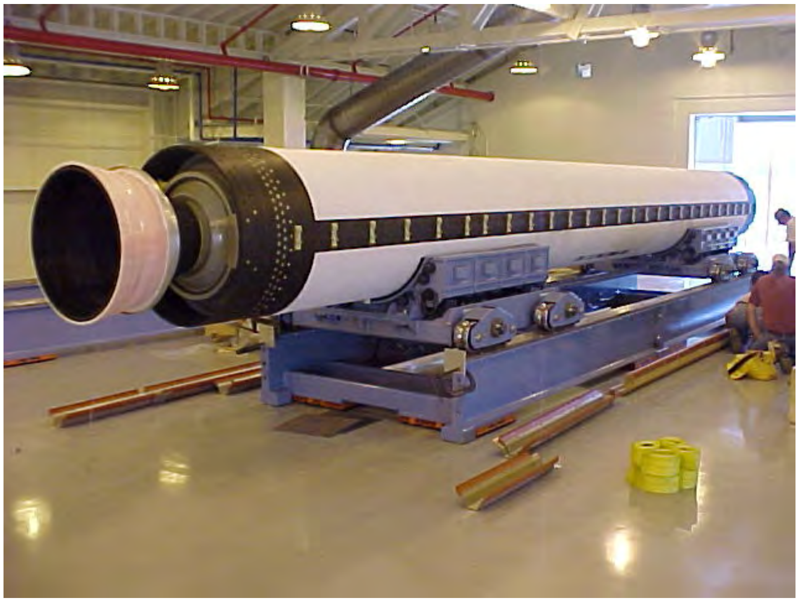
PRODUCTION STATUS

..........FLIGHT PROVEN, INACTIVE PRODUCTION

For more information, contact:
psbdev@ngc.com

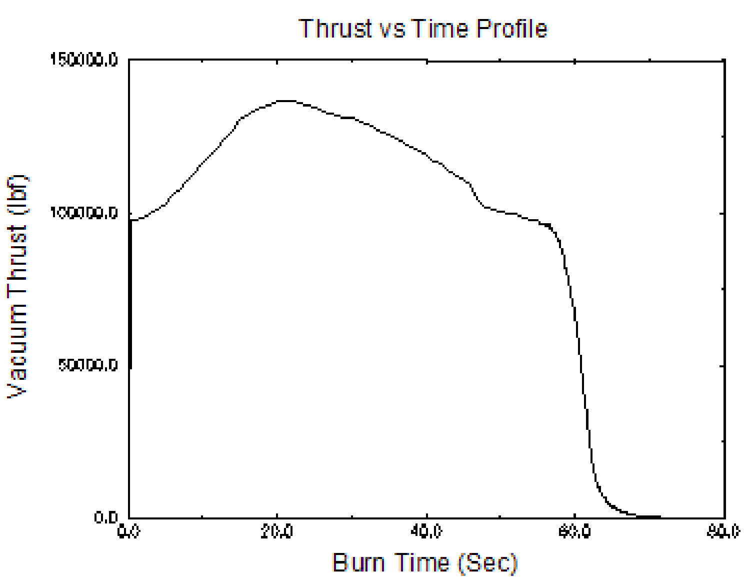
northropgumman.com

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:
psbdev@ngc.com

northropgumman.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/lbm 277.8
Total impulse, lbf-sec 10,425,000
Burn time average thrust, lbf 137,300

WEIGHTS, LBM

Total motor 41,590
Propellant 37,180
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

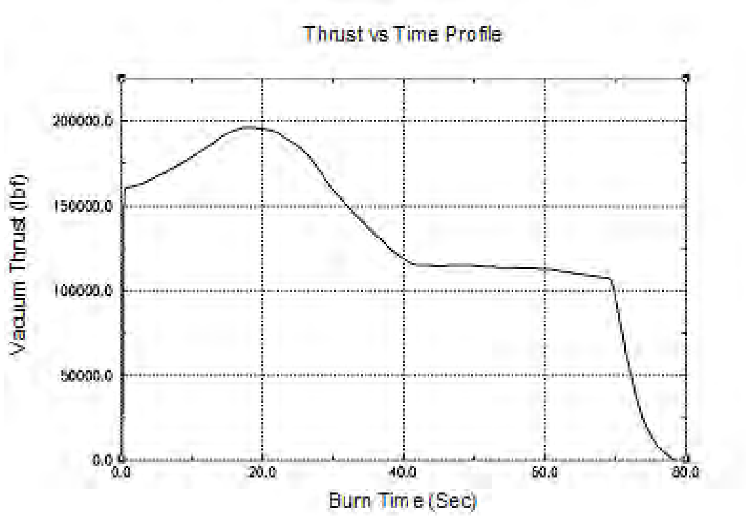
northropgumman.com

GEM 46 (VECTORABLE, GROUND-IGNITED)

NORTHROP GRUMMAN

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

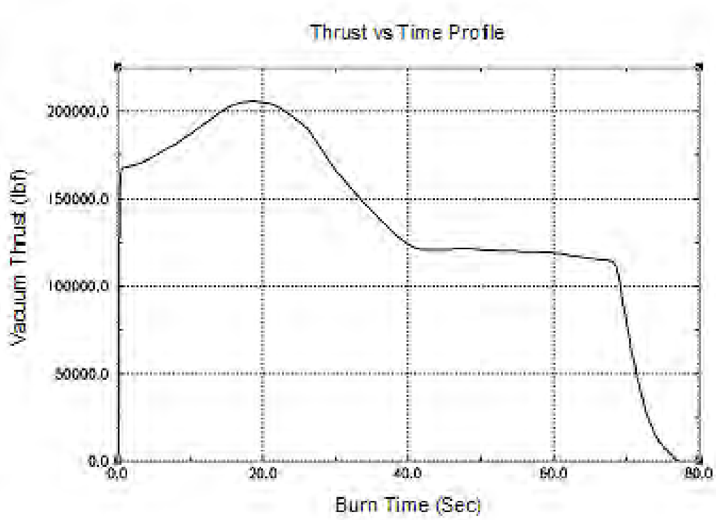
For more information, contact:
psbdev@ngc.com

northropgumman.com

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:
psbdev@ngc.com

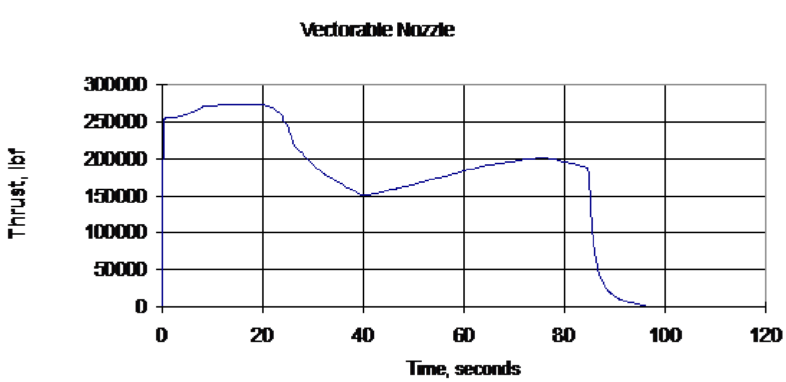
northropgumman.com

GEM 60 (VECTORABLE)

NORTHROP GRUMMAN

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.



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:
psbdev@ngc.com

northropgumman.com

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.

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

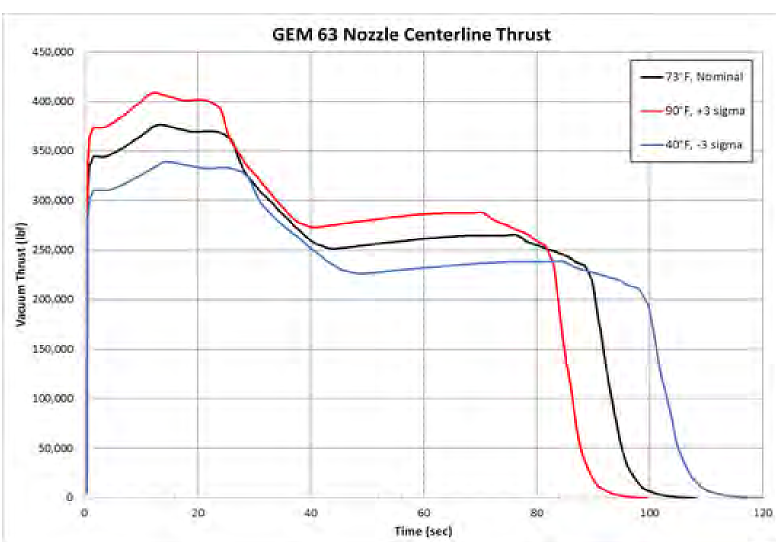
For more information, contact:
psbdev@ngc.com

northropgumman.com

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, sec 97.6

Total time to 21 psi, sec 98.55

Maximum thrust, lbf 370,835

Specific impulse, lbf-sec/lbm 279.06

Total impulse, lbf-sec 27,110,000

Burn time average thrust, lbf 277,589

Total time average thrust, lbf 275.053

WEIGHTS, LBM

Total motor 108,781

Propellant 97,195

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

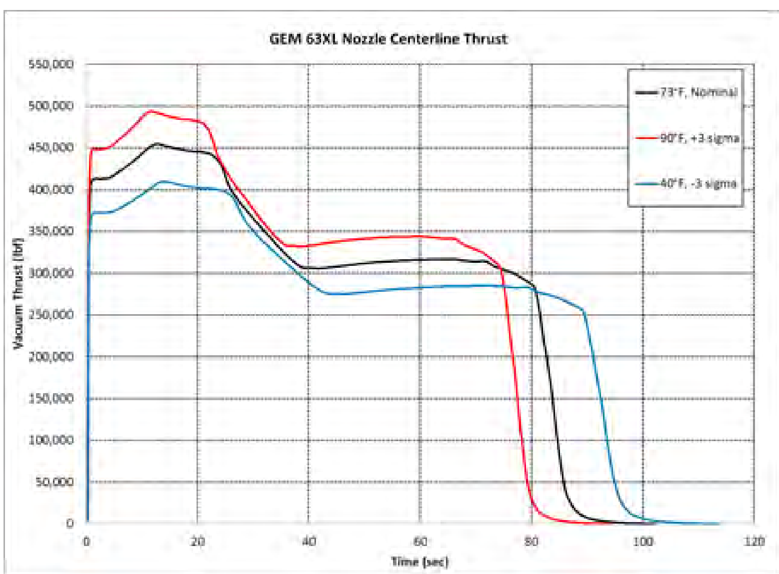
northropgumman.com

GEM 63XL

NORTHROP GRUMMAN

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 2023.



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/lbm 280.3
Total impulse, lbf-sec 29,570,000
Burn time average thrust, lbf 337,871
Total time average thrust, lbf 334,063

WEIGHTS, LBM

Total motor 116,920
Propellant 105,497
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

northropgumman.com

REUSABLE SOLID ROCKET MOTOR (RSRM)

In 1974, NASA chose Thiokol (now part of Northrop Grumman) to design and build the solid rocket motors that would boost the fleet of orbiters from the launch pad to the edge of space. With the maiden flight of Columbia (STS-1) in 1981, a new era in space exploration had begun.

The RSRM was the largest solid rocket motor ever to fly and the only solid rocket motor rated for human flight. It was the first booster designed for reuse; reusability of the RSRM case was an important cost-saving factor in the nation's space program. The boosters provided 80 percent of the thrust needed to launch NASA's Space Shuttle. Each RSRM consists of four solid propulsion segments, thrust vector control, and an aft exit cone assembly. After burnout at approximately two minutes, the boosters were separated pyrotechnically and fell into the Atlantic for recovery. The motors were cleaned, disassembled, and returned to Utah for refurbishment and reloading. Motor segments are designed for reuse on up to 20 flights. The RSRMs were also designed with the capability to be used as strap-on boosters for other heavy-lift launch vehicle applications.

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

RSRM

NASA SPACE SHUTTLE MOTOR

Each motor is just over 126 ft long and 12 ft in diameter. The entire booster (including nose cap, frustum, and forward and aft skirts) is approximately 149 ft long. Of the motor's total weight of 1,252,000 lb, propellant accounts for 1,107,000 lb. Each Shuttle launch required the boost of two RSRMs. From ignition to end of burn, each RSRM generated an average thrust of 2,600,000 lb and burned for approximately 123.6 seconds. By the time the twin RSRMs completed their task, the Space Shuttle orbiter reached an altitude of 24 nautical miles and traveled at a speed in excess of 3,000 miles per hour. Engineers directed approximately 110,000 quality control inspections on each RSRM flight set. RSRMs were also static tested as part of the quality assurance and development process.

MOTOR DIMENSIONS

Motor diameter, in. 146.1
Motor length, in. 1,513.49

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec. 122.2
Average chamber pressure, psia......................620.1
Total impulse, lbf-sec 297,001,731
Web time average thrust, lbf......................2,430,456

NOZZLE

Housing material.....................................D6AC steel
Exit diameter, in. 149.64
Expansion ratio, average....................................7.72

WEIGHTS, LBM

Total loaded 1,255,334
Propellant 1,106,059
Case 98,748
Nozzle 23,942
Other...26,585
Burnout 144,206

PROPELLANT DESIGNATION

.... TP-H1148, PBAN POLYMER, 86% SOLIDS

HAZARDS CLASSIFICATION.... .... 1.3

TEMPERATURE LIMITS

Operation..+40º-90ºF

PRODUCTION STATUS

.... FLIGHT PROVEN, OUT OF PRODUCTION

For more information, contact:
psbdev@ngc.com

northropgumman.com

SPACE LAUNCH SYSTEM (SLS) MOTORS

For NASA's Space Launch System (SLS), Northrop Grumman manufactures the five-segment SLS heavy-lift boosters, the booster separation motors (BSM), and the Launch Abort System's (LAS) launch abort motor and attitude control motor.

The SLS five-segment booster is the largest solid rocket motor ever built for flight. The SLS booster shares some design heritage with flight-proven four-segment space shuttle reusable solid rocket motors (RSRM), but generates 20 percent greater average thrust and 24 percent greater total impulse. While space shuttle RSRM production has ended, sustained booster production for SLS helps provide cost savings and access to reliable material sources.

Designed to push the spent RSRMs safely away from the space shuttle, Northrop Grumman BSMs were rigorously qualified for human space flight and successfully used on the last fifteen space shuttle missions. These same motors are a critical part of NASA's SLS. Four BSMs are installed in the forward frustum of each five-segment booster and four are installed in the aft skirt, for a total of 16 BSMs per launch.

The launch abort motor is an integral part of NASA's LAS. The LAS is designed to safely pull the Orion crew module away from the SLS launch vehicle in the event of an emergency on the launch pad or during ascent. Northrop Grumman is on contract to Lockheed Martin to build the abort motor and attitude control motor—Lockheed is the prime contractor for building the Orion Multi-Purpose Crew Vehicle designed for use on NASA's SLS.

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

SLS BOOSTER

VECTORABLE NOZZLE GROUND LAUNCH

The five-segment Space Launch System (SLS) boosters are in production. Each booster generates thrust of approximately 3.6 million pounds. Each SLS launch uses two boosters. The SLS booster incorporates new technologies and materials that provide cost and weight savings. SLS is a super-heavy launch vehicle used for NASA Artemis missions and for November 16, 2022, in support of NASA's successful Artemis I mission.

MOTOR DIMENSIONS

Motor diameter, in. 146.1
Motor length, in. 1,864.7

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec. 132.8
Average chamber pressure, psia 572
Total impulse, lbf-sec 298,000,000
Burn time average thrust, lbf 2,247,233

NOZZLE

Housing material .... D6AC steel
Exit diameter, in. 149.6
Expansion ratio, average 7.72

WEIGHTS, lbm

Total loaded 1,616,123
Propellant 1,427,807
Case 99,326
Nozzle 24,140
Other 40,456
Burnout 158,604

PROPELLANT DESIGNATION

........TP-H1148 VIII, PBAN POLYMER, 86% SOLIDS

HAZARDS CLASSIFICATION.... .... 1.3

TEMPERATURE LIMITS

Operation .... +40º-90ºF

PRODUCTION STATUS

.... IN PRODUCTION

For more information, contact:
psbdev@ngc.com

northropgumman.com

Pressure, psia

BSM

VERSATILE BOOSTER SEPARATION, DECELERATION, OR TUMBLE MOTOR

Designed to push the spent reusable solid rocket motors safely away from the capsule, Northrop Grumman BSMs were rigorously qualified for human space flight and successfully used on the last fifteen space shuttle missions. These same motors are a critical part of NASA's SLS. Four BSMs are installed in the forward frustum of each booster and four are installed in the aft skirt, for a total of 16 BSMs per launch. All 16 BSMs fire simultaneously at booster separation a little over two minutes into the mission, approximately 25 nautical miles above the earth's surface. Traveling 3,000 miles per hour at ignition, each BSM provides about 20,000 pounds average thrust over its one-second burn, ensuring successful launch to orbit.

Variants of the BSM have also been developed and successfully used as first stage deceleration and tumble motors on NASA's Ares I-X vehicle in 2009.

MOTOR DIMENSIONS

Motor diameter, in. 12.88
Motor length, in. 31.1
Nozzle exit cone diameter, in. 7.564

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)

Burn time, sec. 0.68
Maximum thrust, lbf 22,500
Effective specific impulse, lbf-sec/lbm 239
Total impulse, lbf-sec 18,400
Burn time average thrust, lbf 22,100

WEIGHTS, LBM

Total loaded 167
Propellant 77

PROPELLANT DESIGNATION TP-H1262

HAZARDS CLASSIFICATION.... .... 1.3

RACEWAY .... NO

ORDNANCE .... NO

THRUST VECTOR CONTROL .... NO

TEMPERATURE LIMITS

Operation .... 30-120 °F
Storage .... 30-120 °F

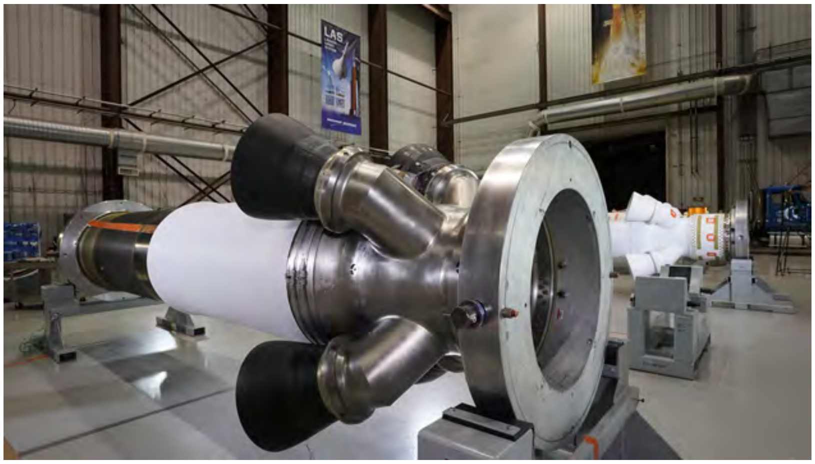
PRODUCTION STATUS

.... FLIGHT-PROVEN, IN PRODUCTION

For more information, contact:
psbdev@ngc.com

northropgumman.com

LAUNCH ABORT MOTOR



INNOVATIVE TURN-FLOW MANIFOLD TECHNOLOGY

The Launch Abort Motor is an integral part of the Launch Abort System (LAS). Attached atop of Orion spacecraft on the SLS, the LAS is designed to safely pull the Orion crew module away from the launch vehicle in the event of an emergency on the launch pad or during ascent. The abort motor is more than 17 feet tall and measures three feet in diameter, and includes a revolutionary turn-flow rocket manifold technology. The initial abort motor was successfully static tested in 2008, and the initial flight test was successfully completed in 2019.".

MOTOR DIMENSIONS

Motor diameter, in...36.7
Overall motor length (incl. nozzle/fairing, in.......223.7
Nozzle exit cone diameter, in..............................20.2

MOTOR PERFORMANCE (70°F VACUUM, VACUUM))

Burn time, sec...4.3
Maximum thrust, lbf 412,240
Effective specific impulse, lbf-sec/lbm 226.4
Total impulse, Mlbf-sec 1,046,600
Burn time average thrust, lbf 261,000

WEIGHTS, LBM

Total motor...7,629
Propellant 4,750
Burnout (est)...N/A

PROPELLANT DESIGNATION ....
.... TP-H1264, HTPB POLYMER, 6% ALUMINUM

HAZARDS CLASSIFICATION.... .... 1.3

RACEWAY... YES

ORDNANCE... NO

THRUST VECTOR CONTROL............................ NO

TEMPERATURE LIMITS

Operation...27-100 °F
Storage...27-100 °F

PRODUCTION STATUS...
....In Production

For more information, contact:
psbdev@ngc.com

northropgumman.com

LAUNCH STRUCTURES SUMMARY INFORMATION

Inquiries regarding launch structures should be directed to our business development representatives at psbdev@ngc.com.

ATLAS V STRUCTURES

NORTHROP GRUMMAN

CORE VEHICLE

5M DIAMETER STRUCTURES FABRICATED WITH AUTOMATED TECHNOLOGY

Featuring state-of-the art designs, materials, and processes, the Atlas V family of rockets offers higher performance and greater reliability than its predecessors.

The robustness of the Atlas V system is enhanced by the use of common system elements assembled into a family of vehicles that satisfy a wide range of mission requirements while providing substantial performance margins.

Northrop Grumman's Role

- Three part configurations
  1. Heat shield
  2. Centaur interstage adapter
  3. Boattail
- Up to 5.4m in diameter (17.5 ft)
- Fabricated using automated fiber placement and advanced hand layup techniques
- Manufactured at the Large Structures Center of Excellence facility

Customer: United Launch Alliance

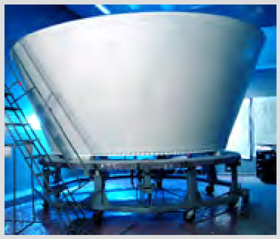
Prime Contractor: United Launch Alliance

Northrop Grumman has pioneered the use of automated fiber placement for launch vehicle structures.

PRODUCTS

Heat Shield

Interstage



Boattail

For more information, contact:
psbdev@ngc.com

northropgrumman.com

DELTA IV STRUCTURES

COMMON BOOSTER CORE AND PAYLOAD ACCOMMODATIONS

5M DIAMETER CORE VEHICLE STRUCTURES

Delta IV is one of two rockets currently in use by the United States Air Force's Evolved Expendable Launch Vehicle program. The Delta IV is designed to reduce launch costs and provide assured access to space for U.S. government, commercial, and civilian launch customers.

The Delta IV family consists of five launch vehicles based on a common booster core first stage. The second stage is derived from the Delta III, with expanded fuel and oxidizer tanks. GEM 60 strap-ons can be added to provide additional launch capability.

Northrop Grumman's Role

- Family of 10 configurations
    1. Centerbodies
    2. Interstages
    3. Thermal shields
    4. Nose cones
    5. Payload fairings
    6. Payload adapters
    7. X-Panels
- Up to 5m in diameter (16 ft)
- Up to 19m in length (63 ft)
- Manufactured using advanced hand layup techniques, machining, and inspection techniques at the Large Structures Center of Excellence facility

Customer: United Launch Alliance

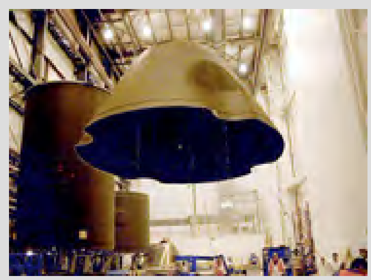
Prime Contractor: United Launch Alliance

Northrop Grumman provides over 17 different part configurations for the Delta IV family of launch vehicles.

PRODUCTS

Nose Cone

Centerbody



Thermal Shield

For more information, contact:
psbdev@ngc.com

northropgumman.com

GEM MOTOR CASES

FAMILY OF COMPOSITE CASES

LIGHTWEIGHT CASES SUPPORT MISSION AND COST OBJECTIVES

The Delta family of launch vehicles is configured with affordable, high-performance graphite epoxy motor (GEM) cases to provide additional lift capability during first stage ignition.

Designed to take advantage of proven, off-the-shelf technologies, the GEM system provides increased performance and heavier lift capability than the boosters of its predecessors. GEMs have demonstrated - through qualification and flight – that they are the most reliable, lowest cost boosters available.

State-of-the-art automation, robotics, and process controls are used to produce GEMs. Cases are filament wound at Northrop Grumman's facility in Clearfield, Utah by computer-controlled winding machines using high-strength graphite fiber and durable epoxy resin.

Northrop Grumman's Role

- Composite filament-wound cases
    1. 40, 46 and 60 inches in diameter
    2. Up to 42.5 ft. in length
    3. Over 1150 cases delivered
    4. Production is in the 26th year
- Composite filament-wound igniter casings
- Composite aeroskirts and nose cones

Customer: Northrop Grumman

Prime Contractor: United Launch Alliance

PRODUCTS

Northrop Grumman uses proven hand layup techniques to produce GEM 60 nose cones

GEM cases are produced using advanced filament winding techniques developed and refined by Northrop Grumman for over 40 years

For more information, contact:
psbdev@ngc.com

northropgumman.com

ORION MOTOR CASES

FAMILY OF COMPOSITE ROCKET MOTOR CASES

OFF-THE-SHELF COMPOSITE CASES FOR COMMERCIAL LAUNCH, MISSILE DEFENSE, AND SCRAM JET APPLICATIONS

The Orion family of composite structures is a versatile line of structures supporting a range of mission platforms. Proven manufacturing techniques, an outstanding performance record, and affordability make Orion the rocket motor of choice.

Northrop Grumman's Role

- Pegasus - First, second, and third stage rocket motor cases, interstage, and payload fairing
- Taurus - First, second, and third stage rocket motor cases
- Minotaur - Third and fourth stage rocket motor cases
- Ground-based Midcourse Defense Orbital Boost Vehicle - First, second, and third stage rocket motor cases
- Proven filament winding and hand layup techniques
- Demonstrated reliability and repeatability

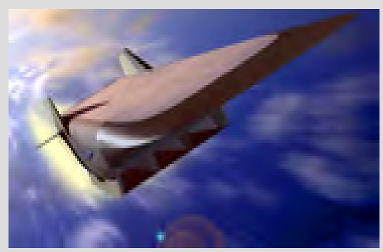
Customer: Northrop Grumman

Prime Contractors: Northrop Grumman

PRODUCTS

Pegasus

Taurus



X-43C

GMD

For more information, contact:
psbdev@ngc.com

northropgumman.com

PEGASUS FAIRING

NORTHROP GRUMMAN

PAYLOAD FAIRING

LIGHTWEIGHT, AFFORDABLE COMPOSITES

Initiated as a joint Air Force and industry venture in 1987, the Pegasus launches small, mainly experimental Air Force payloads into low earth orbit. With over 37 successful missions and delivering more than 70 satellites to date, the Pegasus rocket has earned a reputation as the world's standard for affordable and reliable small launch vehicles.

The composite payload fairing produced by Northrop Grumman separates approximately 110 seconds into flight, following second stage ignition.

Northrop Grumman's Role

- Graphite/epoxy skins
- Aluminum honeycomb core
- 4.2-ft diameter; 14.2-ft length
- Hand layup construction
- Production is in 16th year

Customer: Northrop Grumman

Prime Contractor: Northrop Grumman

The Pegasus rocket is the first all-composite rocket to enter service.

A proven hand layup process developed by Northrop Grumman. Composites are used to fabricate the fairing components.

For more information, contact:
psbdev@ngc.com

northropgumman.com

SMALL MOTOR SUMMARY INFORMATION

TALOS™ II, CASTOR® IB, STAR, STAR STAGES, ASAS, AND ORDNANCE PRODUCTS

Northrop Grumman's small motor series (Talos, CASTOR IB, STAR, ASAS and ordnance products) span a significant range of size and boost capability, with motors ranging from a few pounds up to approximately 37,000 pounds.

Tabular summaries of STAR motor dimensions, weights, and performance data across the series are provided in the STAR Motor Performance and Experience Summary table within.

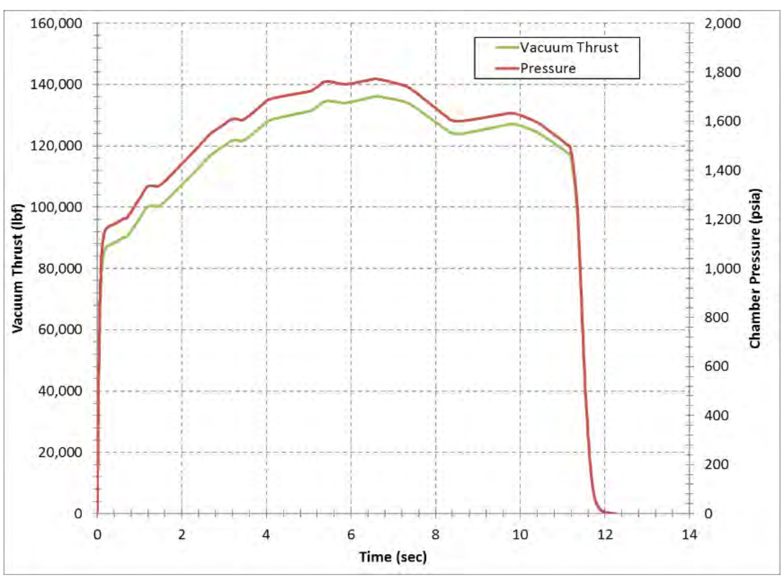
Inquiries regarding small motor products should be directed to our business development representatives at starmotors@ngc.com.

TALOS II AND CASTOR® IB MOTORS

Inquiries regarding Talos and CASTOR IB motor products should be directed to our business development representatives at starmotors@ngc.com.

TALOS II™

The Talos II motor is an upgrade to the Talos rocket motor. The Talos II is a high-performance, low-cost booster motor suitable for launch vehices, sounding rockets, and target vehicles. The motor is upgraded with a composite motor case, a higher performance propellant, and a simplified propellant grain geometry. The motor is designed to have common components with the CASTOR IB motor, such as nozzle, igniter, and motor materials. The motor is also designed to be capable of incorporating a thrust vector control nozzle.



MOTOR DIMENSIONS
Motor diameter, in. 32.0
Motor length in. 161.0

MOTOR PERFORMANCE (70°F VACUUM)
Burn time, sec. 12.7
Burn time average chamber pressure, psia 1,427
Maximum chamber pressure,psia 1,772
Total impulse, lbf-sec 1,387,370
Propellant specific impulse, lbf-sec/lbm 273.3
Effective specific impulse, lbf-sec/lbm 271.7
Burn time average thrust, lbf 116,300
Maximum thrust, lbf 136,000

NOZZLE
Initial throat diameter, in. 6.47
Exit diameter, in. 26.7
Expansion ratio, average 16:3:1

WEIGHTS, LBM
Total loaded* 5,753
Propellant 5,083
Insulated case assembly 457
Nozzle 193
Igniter 20
Burnout* 646
*Excludes ETA lines and S&A

TEMPERATURE LIMITS
Operation .....0°-120°F
Storage .....-10°-125°F

PROPELLANT DESIGNATION TP-H-3505

CASE MATERIAL.... ....Graphite epoxy composite

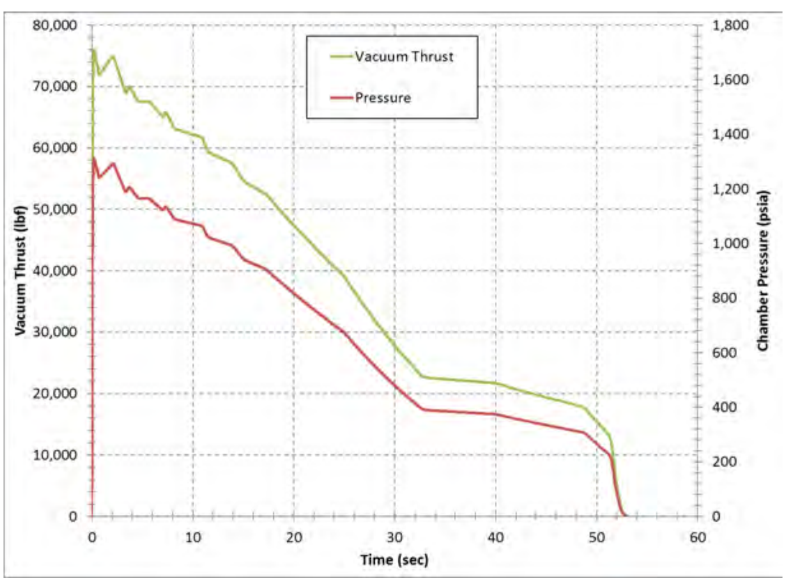
PRODUCTION STATUS.... .... Development

For more information, contact:
starmotors@ngc.com.

northropgumman.com

CASTOR® IB

The CASTOR IB is an upgrade to the Northrop Grumman CASTOR IA rocket motor. The CASTOR IB is a high performance, low-cost booster motor suitable for launch vehicles, sounding rockets, and target vehicles. The motor is upgraded with a composite motor case and a higher performance propellant. The forward and aft interfaces are identical to that of the CASTOR IA to enable vehicles that have used the CASTOR IA to easily interface with the CASTOR IB. The motor is also designed to be capable of incorporating a thrust vector control nozzle.



MOTOR DIMENSIONS

Motor diameter, in. 32.0
Motor length in. 224.0

MOTOR PERFORMANCE (70°F VACUUM)

Burn time, sec. 51.4
Burn time average chamber pressure, psia..........692
Maximum chamber pressure, psia 1,310
Total impulse, lbf-sec... 2,061,680
Propellant specific impulse, lbf-sec/lbm............278.3
Effective specific impulse, lbf-sec/lbm 276.2
Burn time average thrust, lbf 40,100
Maximum thrust, lbf 75,890

NOZZLE

Initial throat diameter, in. 6.47
Exit diameter, in. 26.7
Expansion ratio, average 16.1:1

WEIGHTS, LBM

Total loaded 8,403
Propellant 7,356
Insulated case assembly 834
Nozzle..193
Igniter...20
Burnout*..982
*Excludes S&A

TEMPERATURE LIMITS

Operation..0°-120°F
Storage ....-10°-125°F

PROPELLANT DESIGNATION

.... TP-H-8299

CASE MATERIAL..... ...Graphite-epoxy composite

PRODUCTION STATUS ....Development

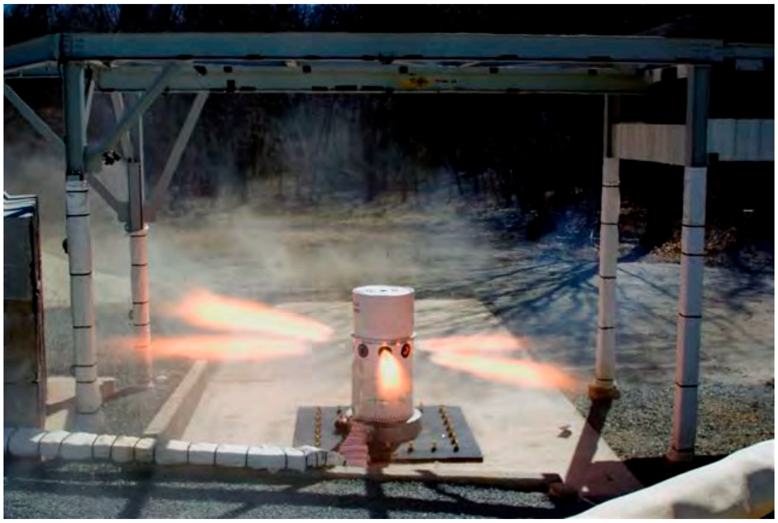
For more information, contact:
starmotors@ngc.com.

northropgumman.com

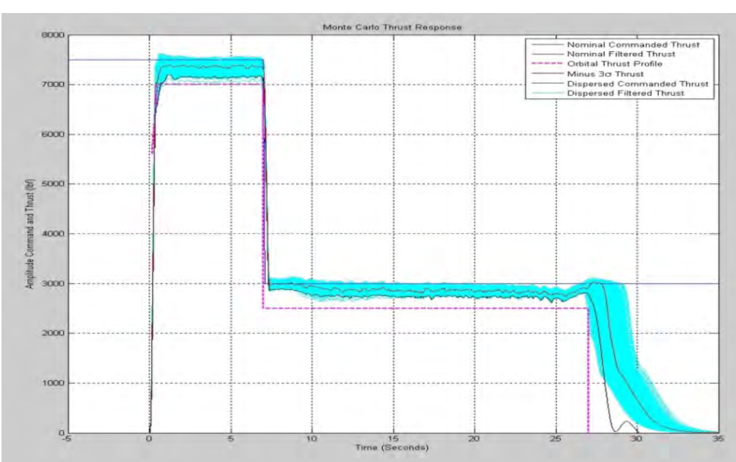
ORION SPACECRAFT LAUNCH ABORT SYSTEM (LAS) ATTITUDE CONTROL MOTOR (ACM)

ORION LAS ACM
TE-M-1174-1

NORTHROP GRUMMAN



The attitude control motor was designed and tested between 2007 and 2010 to control pitch and yaw of the launch abort tower for the Orion spacecraft during an abort maneuver. It is the first human-rated, single fault tolerant solid control system to be flight qualified and flew May 6, 2010 on the PA-1 flight. The design uses a medium-energy propellant and high-strength D6AC steel case. The eight proportional valves utilize 4-D carbon-carbon, silicon carbide for the erosion-sensitive parts. The Launch Abort System attitude control motor was successfully tested during the Orion Crew Vehicle's Pad Abort 1 Test in 2010 and Ascent Abort 2 test in 2019.



MOTOR DIMENSIONS

Motor diameter, in. 32.0
Motor length, in. 62.8

MOTOR PERFORMANCE (60°F VACUUM)**

Burn time/action time, sec 29.4/32.3
Ignition rise time, sec 0.120
Pressure, psia............. 2,180 boost/600 sustain
Maximum chamber pressure, psia 2,400
Total impulse, lbf-sec ....99,000 min
Thrust, lbf.....7,000 min boost/2,500 min sustain

NOZZLES

Eight, fully proportional valves with single fault tolerant electromechanical actuation and 100 msec response full stroke

WEIGHTS, LBM

Total loaded* 1,629.1
Propellant (including igniter propellant) 608.2
Case assembly 538.0
Valve assembly (each including actuator) .. 23.3
Total inert 1,020.9
Burnout* 1,019.0
Propellant mass fraction* 0.37
*Excluding remote S&A/ETA

TEMPERATURE LIMITS

Operation .... 33°-99°F
Storage .... 30°-100°F

PROPELLANT DESIGNATION TP-H-3174

CASE MATERIAL .... D6AC steel

For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR™ MOTOR SERIES

PERFORMANCE, CAPABILITY, INTERFACE TAILORING, AND TECHNICAL SUPPORT SERVICES FOR STAR MOTORS

Northrop Grumman's STAR, ASAS, Orion, CASTOR, GEM, and RSRM motors span a significant range of impulse capability. Specific applications often require design tailoring and technical support to best achieve mission goals.

The sections that follow describe how Northrop Grumman tailors ballistic performance, provides mission specific capabilities, and/or delivers technical support for STAR series space motors. Similar performance tailoring and support can be provided for our other products.

Tailor Ballistic Performance. Specific examples include efforts to achieve the following goals:

- Increase propellant loading and thus total impulse by stretching motor length
- Cut back or off-load the propellant grain to reduce propellant weight and total impulse
- Limit peak thrust/acceleration levels on the payload/spacecraft by altering propellant formulations and/or grain geometry and/or operating pressure
- Modify the nozzle to adjust throat erosion and thrust profiles
- Incorporate an exit cone extension (e.g., a gas-deployed skirt) to enhance expansion ratio and overall performance
- Minimize performance variation by machining propellant grains to precise weight tolerances and by providing thermal systems to maintain propellant grain temperature
- Incorporate mission-specific propellants that provide desired energy levels, environmental compatibility, and/or exhaust characteristics

Provide Desired Mission-Specific Capabilities. Northrop Grumman is pleased to support our customers with designs that will meet mission-specific conditions. This includes incorporation of additional capabilities and/or providing design compliance with customer-specified flight envelopes, interfaces, and environments. Examples include the following:

- Use of alternative case materials (steel, aluminum, titanium, composite)
- Qualification to new environments
- Use of proven materials to ensure space storability

- Exit cone length truncation or shortening to fit within a restricted envelope
- Provision of active thrust vector control for vehicle steering
- Incorporation of a reaction control system for motor and stage pointing
- Furnishing of thermal protection of spacecraft structures from the heat of motor operation through postfiring heat soak
- Provision of thermal management, using heaters and/or blankets prior to operation
- Integration of motors/stages with spin and de-spin motors and collision avoidance systems
- Design of stages with associated command timers and/or avionics and power systems and related software to enable autonomous stage operation
- Integration of advanced ordnance components for motor initiation, stage separation, and flight termination
- Accommodation of specific spacecraft structural interfaces including incorporation of tabs, skirts, and/or complete interstage structures fabricated from metal or composite material
- Movement or modification of attachment features as required to mate with space-craft/payload

Technical Support. Northrop Grumman can provide technical alternatives and support for design and flight efforts, including the following:

- Inert mass simulators for system ground tests
- Technical trades on critical design parameters needed for overall system design
- System engineering data and analysis support including performance modeling
- Test and analysis to demonstrate operational capability under new environmental conditions (temperatures, spin conditions, space aging, etc.)
- Logistic, personnel, and technical support for motor shipping, packaging, and integration with the spacecraft or launch vehicle at the launch site including, but not limited to, preparing field handling manuals and providing ground support equipment for the motor (e.g., turnover stands, handling stands, and leak test equipment)

Northrop Grumman has the experience to modify our basic motor designs and can design completely new motors at minimum risk to support specific flight applications (see following figure). We are also prepared to provide required technical support for all of our motor, ordnance, and stage products.

STAR 30BP

STAR 30E

STAR 30BP Motor Was Stretched 7 in. to Yield the STAR 30E

Documentation and Field Support. Northrop Grumman has prepared and provided to various customers documentation and field support for launches from Cape Canaveral Air Force Station, Kennedy Space Center, Vandenberg Air Force Base, Kodiak Launch Complex, Tanegashima Space Center, Xi Chang, Wallops Flight Facility, Fort Churchill, San Marcos Test Center, Kwajelin Test Center, China Lake Test Center, and Kourou. For most programs, Northrop Grumman prepares the documents; conducts a training session with the responsible ground crew; participates in auditing and modifying the documents to comply with on-site equipment, facilities, and safety practices; and prepares the final documents prior to delivery of the first flight motor in the field, thereby facilitating safe and efficient handling of the first flight system. Northrop Grumman can also be enlisted to review and assess customer-prepared procedures for the safe handling of our rocket motors.

Field Support. Northrop Grumman has the trained personnel to lead, instruct, and assist ground crews for receipt, maintenance, inspection, checkout, and assembly of motors and ordnance items. Training or instructional sessions are often of value to customers and launch range personnel and can be conducted at Northrop Grumman or on-site.

Instructional Field Handling Documentation. The table below lists the procedural documents that can be prepared at customer request for each motor. Many motor programs have adopted these materials for use in the field as supplemental information in the preparation of vehicle stage or spacecraft propulsion units for inspection, buildup, and assembly at the various launch sites.

Typical Instructional Documentation

Document Type	Description
Engineering Instruction	Describes proper unpacking, handling, storage, and maintenance of the rocket motor in the field (safety precautions)
X-ray Inspection Procedure	Establishes radiographic inspection procedure to be used for preflight evaluation using launch site facilities
Inspection Procedure	Delineates proper use of equipment and procedures for verification of motor component integrity
Safe-and-Arm (S&A) Checkout Procedure	Describes electrical checkout of live S&A devices
Ordnance Assembly Procedure	Delineates proper procedure for checkout and installation of squibs, through-bulkhead initiators, explosive transfer assemblies, and S&A devices
Motor Final Inspection and Assembly Procedure	Delineates inspection and preflight buildup of the rocket motor. This procedure can contain many or all other instructional documents for field support and surveillance
Safety Plan	Provides information on the proper safety procedures for handling of explosive devices
Handling Equipment Maintenance Procedure	Describes conduct of periodic proof or load tests to verify equipment adequacy. Delineates proper procedures for maintenance of equipment
Motor Flight Instrumentation Installation and Checkout	Describes proper procedures for installation and checkout of items such as pressure transducers, strain gauges, etc. Delineates precautions and need for testing following installation
Other Instruction	Many systems have unique requirements for ancillary equipment or ordnance items. Procedures can be prepared to meet almost any system need (e.g., spin balancing)

Motor Ground Support Equipment. In addition to shipping containers, we can provide a variety of ground support equipment for use in handling, inspection, and assembly of the rocket motor and ordnance devices. Northrop Grumman also designs mission-specific equipment for installation of the motor into the spacecraft or stage. Typical ground support equipment available includes the following:

- Shipping containers
- Turnover stands
- Inert mass simulators
- Leak test equipment

In-Transit Instrumentation. Space motors are sensitive to temperature, humidity, and shock loads. Monitoring of the environmental conditions during transportation of space motors is critical. Several standard and proven devices are available. We can also accommodate special problems, such as long periods of transit. Some of the items readily available are:

- Temperature recorders
- Shock indicators
- Humidity indicators

Generally, Northrop Grumman personnel have monitored all activities during development, qualification, and lot acceptance testing of Northrop Grumman motors at various test sites in the United States, Japan, French Guiana, and China. We strongly recommend this support for every flight program. We can provide trained personnel to monitor activities at the launch site or in customer test facilities and to assist in resolution of problems.

Postflight Analysis. Analysis of flight data can help identify trends in motor performance and thus eliminate potential problems. Further, evaluation during a program helps enhance the predictability of flight performance. For example, comparison of ground data with other flight data may enable the customer to reduce the weight of fuel for velocity trimming and reaction control system, allowing for potential of enhanced spacecraft usable weight on subsequent launches.

Typical postflight analysis that Northrop Grumman can support includes the following:

- Ballistic performance
- Acceleration profile
- Derived nonaxial (lateral) thrust data
- Motor temperatures
- Residual thrust
- Other (dependent on flight instrumentation)

Motor Data. A summary of STAR motor performance is presented in the following table. The pages that follow contain data sheets for the various STAR motor configurations.

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

STAR Motor Performance and Experience Summary

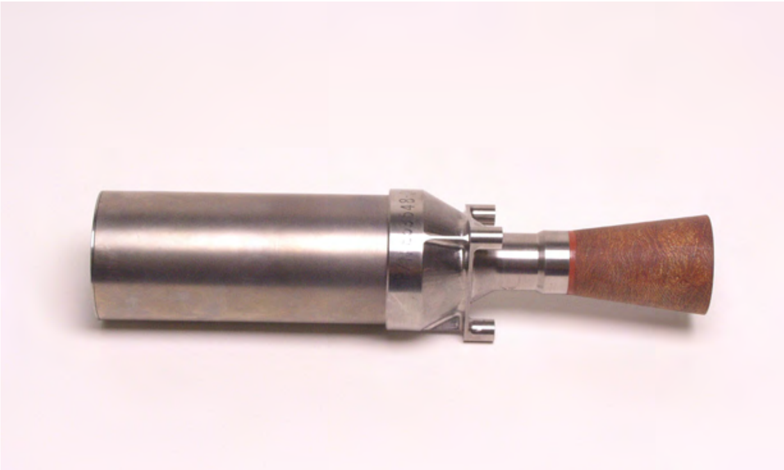
STAR Designation	Model Number	Nominal Diameter		Total Impulse, lb_f-sec	Effective **Specific** Impulse, lb_f-sec/lb_m	Propellant Weight		Propellant Mass Fraction	Tests	Flights
		in.	cm			lb_m	kg			
3	TE-M-1082-1	3.18	8.08	281.4	266.0	1.06	0.48	0.42	26	3
3A	TE-M-1089	3.18	8.08	64.4	241.2	0.27	0.12	0.14	2	3
4G	TE-M-1061	4.45	11.30	595	269.4	2.16	0.98	0.65	2	0
5*	TE-M-500	5.05	12.83	895	189.0	3.8	1.72	0.87	4	11
5A	TE-M-863-1	5.13	13.02	1,289	250.8	5.05	2.27	0.49	6	3
5C/5CB	TE-M-344-15 TE-M-344-16	4.77 4.77	12.11 12.11	1,252 1,249	268 262.0	4.55 4.62	2.06 2.10	0.47 0.47	245 20	686 160
5D	TE-M-989-2	4.88	12.39	3,950	256.0	15.22	6.90	0.68	13	3
5F	TE-M-1198	4.85	12.32	2,216	262.9	8.42	3.82	0.37	9	194
6	TE-M-541-3	6.2	15.75	3,077	287.0	10.7	4.85	0.80	47	238
6A*	TE-M-542-3	6.2	15.75	2,063	285.3	7.2	3.27	0.72		
6B	TE-M-790-1	7.32	18.59	3,686	269.0	13.45	6.10	0.60	8	18
8	TE-M-1076-1	8.06	20.47	7,430	272.9	27.12	12.30	0.71	26	6
9	TE-M-956-2	9.0	22.86	9,212	289.1	31.8	14.42	0.78	1	0
10*	TE-M-195	10.0	25.40	6,600	251.0	26.3	11.93	0.68	46	Classified
12*	TE-M-236	12.0	30.48	10,350	252.0	40.3	18.28	0.66	160	349
12A*	TE-M-236-3	12.1	30.73	13,745	270.0	50.2	22.77	0.67	6	Classified
12GV	TE-M-951	12.24	31.58	20,669	282.4	72.6	32.9	0.79	5	2
13*	TE-M-458	13.5	34.29	18,800	273.0	68.3	30.98	0.87	7	2
13A*	TE-M-516	13.5	34.29	21,050	286.5	73.0	33.11	0.87	5	9
13B	TE-M-763	13.57	34.47	26,050	285.0	90.9	41.23	0.88	1	2
13C*	TE-M-345-11/12	13.5	34.29	18,200	218.0	66.5	30.16	0.80	125	131
13D*	TE-M-375	13.5	34.29	17,200	223.0	63.0	28.58	0.81	10	2
13E*	TE-M-385	12.7	32.26	14,200	211.0	55.4	25.13	0.82	65	48
13F*	TE-M-444	13.5	34.29	21,190	240.0	73.5	33.34	0.83	5	9
15G	TE-M-1030-1	15.04	38.2	50,210	281.8	175.5	79.61	0.85	11	10
17	TE-M-479	17.4	44.20	44,500	286.2	153.5	69.63	0.88	6	4
17A	TE-M-521-5	17.4	44.20	71,800	286.7	247.5	112.26	0.89	10	7
20 Spherical*	TE-M-251	20.0	50.80	66,600	234.0	253	114.76	0.93	1	1
20	TE-M-640-1	19.7	50.04	173,560	286.5	601.6	273.20	0.91	10	32
20A*	TE-M-640-3	19.7	50.04	184,900	291.9	630.0	285.76	0.91	2	0
20B*	TE-M-640-4	19.8	50.29	174,570	289.1	601.6	272.88	0.89	6	5
24	TE-M-604	24.5	62.23	126,000	282.9	440.6	199.85	0.92	9	6
24A*	TE-M-604-2	24.5	62.23	112,400	282.4	393.8	178.62	0.92		
24B*	TE-M-604-3	24.5	62.23	126,230	282.9	441.4	200.22	0.92		
24C	TE-M-604-4	24.5	62.23	138,000	282.3	484.0	219.54	0.92		
26	TE-M-442	26.0	66.04	138,500	271.0	508.5	230.65	0.86	4	14
26C	TE-M-442-2	26.1	66.29	139,800	272.1	511.4	231.97	0.88		
26B	TE-M-442-1	26.1	66.29	142,760	271.7	524.0	237.68	0.91	1	8

STAR Designation	Model Number	Nominal Diameter		Total Impulse, lb_f-sec	Effective **Specific** Impulse, lb_f-sec/lb_m	Propellant Weight		Propellant Mass Fraction	Tests	Flights
		in.	cm			lb_m	kg			
27	TE-M-616	27.3	69.34	213,790	287.9	735.6	333.66	0.92	18	31
27H	TE-M-1157	27.3	69.34	219,195	291.4	744.8	337.84	0.92	1	1
30*	TE-M-700-2	30.0	76.20	300,940	293.0	1,021.7	463.44	0.94	4	0
30A*	TE-M-700-4	30.0	76.20	302,350	294.7	1,021.0	463.12	0.94	1	0
30B*	TE-M-700-5	30.0	76.20	328,200	293.0	1,113.0	504.85	0.94	14	29
30BP	TE-M-700-20	30.0	76.20	328,455	292.3	1,113.6	505.12	0.93	5	23
30C	TE-M-700-18	30.0	76.20	376,095	286.4	1,302.5	590.80	0.94	4	22
30C/BP	TE-M-700-25	30.0	76.20	383,270	291.8	1,302.5	590.80	0.93	0	4
30E	TE-M-700-19	30.0	76.20	407,550	290.4	1,392.0	631.40	0.93	3	11
31	TE-M-762	30.1	76.45	840,000	293.5	2,835.0	1285.94	0.93	6	17
37*	TE-M-364-1	36.8	93.47	356,200	260.0	1,123.0	509.38	0.90	50	6
37B*	TE-M-364-2	36.8	93.47	417,900	291.0	1,440.0	653.17	0.91	1	21
37C*	TE-M-364-18	36.8	93.47	608,600	285.5	2,125.0	963.88	0.92	1	8
37D*	TE-M-364-3	36.8	93.47	417,900	266.0	1,440.0	653.17	0.91	14	18
37E*	TE-M-364-4	36.8	93.47	654,200	283.6	2,290.0	1038.73	0.93	13	75
37F*	TE-M-364-19	36.8	93.47	549,536	286.0	1,909.3	866.04	0.93	8	10
37FM	TE-M-1139	36.8	93.47	695,620	294.1	2,344.1	1063.27	0.93	5	30
37FMV	TE-M-1139	36.8	93.47	685,970	289.8	2350.1	1065.99	0.93	0	0
37G*	TE-M-364-11	36.8	93.47	671,809	289.9	2,348.0	1065.04	0.92	4	0
37GV	TE-M-1007-1	35.2	89.41	634,760	293.5	2,148	974.3	0.92	1	0
37N*	TE-M-364-14	36.8	93.47	357,500	290.0	1,232.0	558.83	0.90	1	8
37S*	TE-M-364-15	36.8	93.47	420,329	287.3	1,449.5	657.48	0.92	2	24
37X*	TE-M-714-1	36.8	93.47	685,148	295.6	2,350.7	1066.26	0.93	1	0
37XF*	TE-M-714-6	36.7	93.22	571,470	290.0	1,950.4	884.69	0.93	9	9
37XFP	TE-M-714-16/17	36.7	93.22	570,040	290.0	1,948.2	883.69	0.92	3	41
37XFPV	TE-M-988-1	36.7	93.22	570,040	290.0	1,948.2	883.69	0.91	1	0
37Y*	TE-M-714-2	36.8	93.47	701,000	297.0	2,360.0	1070.48	0.93	2	0
40*	TE-M-186-2	40.1	101.85	443,026	207.0	1,995.0	904.92	0.92	10	0
48*(short)	TE-M-711-3	49.0	124.46	1,269,610	286.6	4,405.0	1998.08	0.95	18	29
48*(long)	TE-M-711-8	49.0	124.46	1,296,300	292.9	4,405.0	1998.08	0.94		
48A (short)	TE-M-799-1	49.0	124.46	1,528,400	283.4	5,357.2	2429.99	0.94	1	0
48A (long)	TE-M-799	49.0	124.46	1,563,760	289.9	5,357.2	2429.99	0.94		
48B (short)	TE-M-711-17	49.0	124.46	1,275,740	286.0	4,431.2	2009.96	0.94	3	104
48B (long)	TE-M-711-18	49.0	124.46	1,303,700	292.1	4,431.2	2009.96	0.94		
48BV	TE-M-940-1	49.0	124.46	1,303,700	292.1	4,431.2	2009.96	0.94	3	2
48V	TE-M-940-1	49.0	124.46	1,303,700	292.1	4,431.2	2009.96	0.93	3	1
48GXV	--	49.0	120.0	1,911,070	306.0	6,205	2814.54	0.92	1	0
63D	TE-M-936	63.0	160.02	2,042,450	283.0	7,166.5	3250.67	0.93	5	3
63F	TE-M-963-2	63.1	160.27	2,816,700	297.1	9,401.6	4264.50	0.93	4	2
75	TE-M-775-1	75.0	190.50	4,797,090	288.0	16,542	7503.32	0.93	1	0
92	–	93.0	236.22	10,120,100	287.7	34,879	15,820.85	0.94	0	0

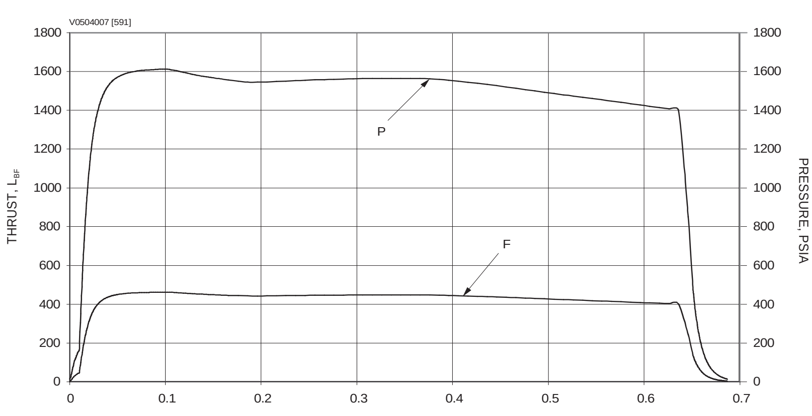
***STAR motors that have been replaced by other motor configurations**

STAR 3
TE-M-1082-1

NORTHROP GRUMMAN



The STAR 3 motor was developed and qualified in 2003 as the transverse impulse rocket system (TIRS) for the Mars Exploration Rover (MER) program for the Jet Propulsion Laboratory (JPL) in Pasadena, CA. Three TIRS motors were carried on each of the MER landers. One of the TIRS motors was fired in January 2004 to provide the impulse necessary to reduce lateral velocity of the MER Spirit lander prior to landing on the Martian surface. The motor also has applicability for spin/despin and separation systems.



MOTOR DIMENSIONS

Motor diameter, in. 3.18
Motor length, in. 11.36

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 0.62/0.66
Ignition delay time, sec 0.12
Burn time average chamber pressure, psia....... 1,502
Maximum chamber pressure, psia 1,596
Total impulse, lbf-sec 281.4
Propellant specific impulse, lbf-sec/lbm............ 266.0
Effective specific impulse, lbf-sec/lbm 266.0
Burn time average thrust, lbf 435
Maximum thrust, lbf 461

NOZZLE

Initial throat diameter, in. 0.461
Exit diameter, in. 2.072
Expansion ratio, initial..................................... 20.2:1

WEIGHTS, LBM ....

Total loaded 2.55
Propellant 1.06
Case assembly 0.40
Nozzle assembly 0.58
Total inert 1.49
Burnout 1.49
Propellant mass fraction 0.42

TEMPERATURE LIMITS

Operation .... -40º-104°F
Storage .... -65º-140°F

PROPELLANT DESIGNATION TP-H-3498

CASE MATERIAL .... TITANIUM

PRODUCTION STATUS

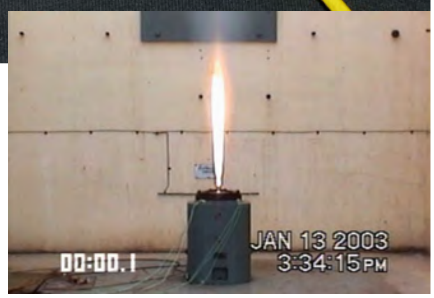
.... FLIGHT-PROVEN

NOTE: Offload configuration delivering 171 lb_f-sec of total impulse also qualified

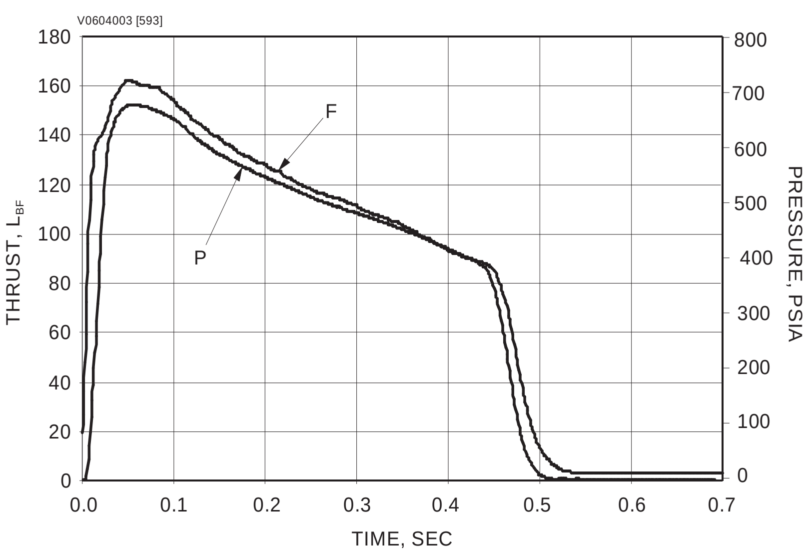
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 3A
TE-M-1089



The STAR 3A was developed and qualified in 2003 as an offloaded and shortened version of the STAR 3 used for JPL's Mars Exploration Rover (MER) transverse impulse rocket system (TIRS). It has a shorter case and truncated exit cone to accommodate a lower propellant weight and smaller available volume. The STAR 3A is ideally suited for separation, spin/despin, deorbit, and small satellite applications.



MOTOR DIMENSIONS

Motor diameter, in.	3.18
Motor length, in.	7.5

MOTOR PERFORMANCE (95°F VACUUM)

Burn time/action time, sec	0.44/0.49
Ignition delay time, sec	0.007
Burn time average chamber pressure, psia	520
Maximum chamber pressure, psia	676
Total impulse, lbf-sec	64.4
Propellant specific impulse, lbf-sec/lbm	241.2
Effective specific impulse, lbf-sec/lbm	241.2
Burn time average thrust, lbf	138
Maximum thrust, lbf	180

NOZZLE

Initial throat diameter, in.	0.46
Exit diameter, in.	1.1
Expansion ratio, initial	5.7:1

WEIGHTS, LBM

Total loaded	1.96
Propellant (including igniter)	0.27
Total inert	1.70
Burnout	1.70
Propellant mass fraction	0.14

TEMPERATURE LIMITS

Operation	-40º-104°F
Storage	-65º-140°F

PROPELLANT DESIGNATION TP-H-3498

CASE MATERIAL .... TITANIUM

PRODUCTION STATUS

.... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

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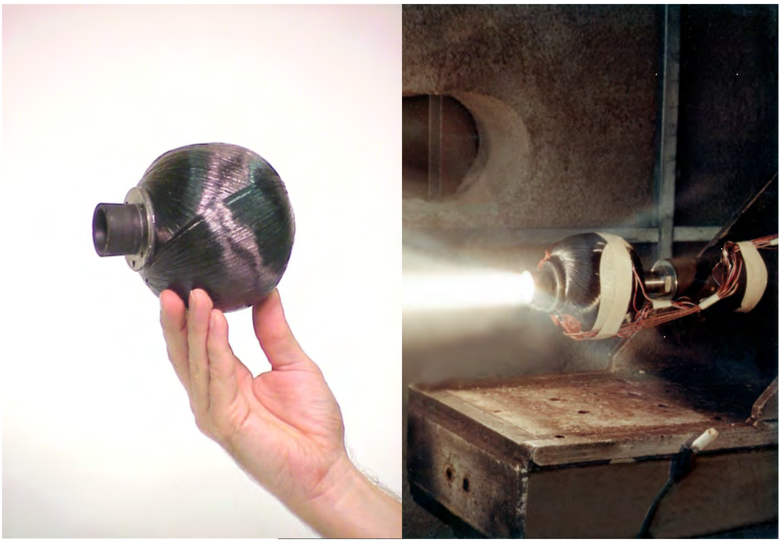
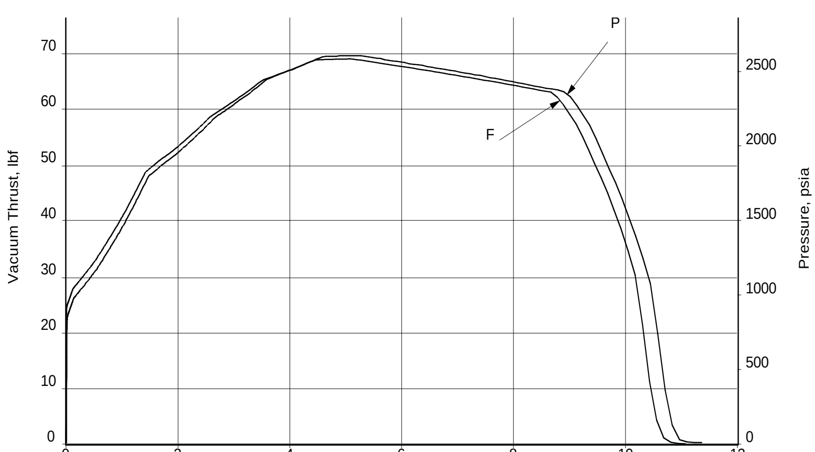
STAR 4G
TE-M-1061



This STAR motor was developed and tested in January 2000 under a NASA Goddard Space Flight Center program for a low-cost, high mass fraction orbit adjust motor for use in deploying constellations of very small satellites (nanosatellites). The first static test of the STAR 4G prototype motor was conducted 8 months after program start. The motor is designed to operate at high chamber pressure and incorporates a noneroding throat insert to maximize specific impulse.



MOTOR DIMENSIONS

Motor diameter, in.	4.45
Motor length, in.	5.43

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec	10.3/10.8
Ignition delay time, sec	0.035
Burn time average chamber pressure, psia	2,185
Maximum chamber pressure, psia	2,600
Total impulse, lbf-sec	595
Propellant specific impulse, lbf-sec/lbm	275.6
Effective specific impulse, lbf-sec/lbm	269.4
Burn time average thrust, lbf	58
Maximum thrust, lbf	69

NOZZLE

Initial throat diameter, in.	0.15
Exit diameter, in.	1.13
Expansion ratio, initial	56.8:1

WEIGHTS, LBM

Total loaded	3.30
Propellant	2.16
Heavyweight nano ESA	0.17
Case assembly	0.49
Nozzle assembly	0.46
Total inert	1.12
Burnout	1.07
Propellant mass fraction	0.65

TEMPERATURE LIMITS

Operation	40º-90°F
Storage	40º-100°F

PROPELLANT DESIGNATION TP-H-3399

CASE MATERIAL

.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS...........DEVELOPMENT

For more information, contact:
starmotors@ngc.com.

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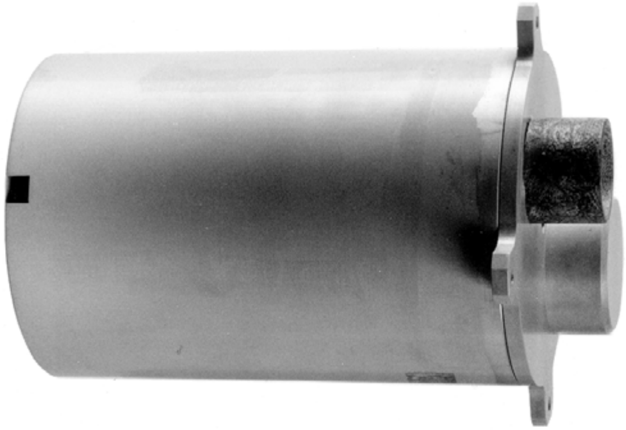
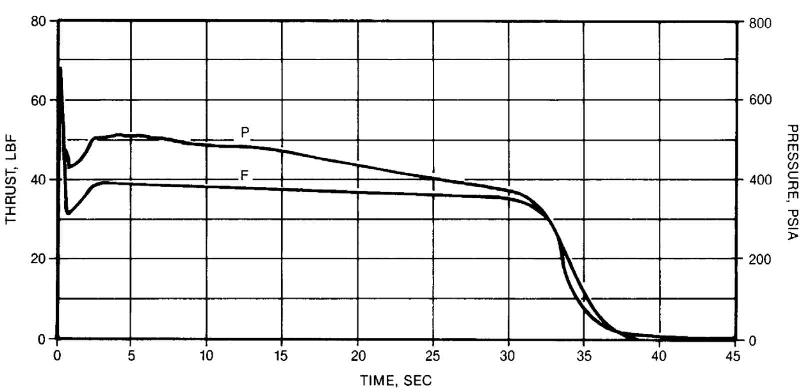
STAR 5A
TE-M-863-1



The STAR 5A rocket motor was qualified in 1988 to provide a minimum acceleration and extended burn delta-V impulse. With a low-average thrust and a unique off-center nozzle design, the motor can be utilized in many nonstandard geometric configurations for small payload placement or spin-up applications. The STAR 5A first flew in 1989 from the Space Shuttle.



MOTOR DIMENSIONS

Motor diameter, in. 5.13
Motor length, in. 8.84

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 32.0/35.6
Ignition delay time, sec 0.04
Burn time average chamber pressure, psia 453
Maximum chamber pressure, psia 516
Total impulse, lbf-sec 1,289
Propellant specific impulse, lbf-sec/lbm 255.3
Effective specific impulse, lbf-sec/lbm 250.8
Burn time average thrust, lbf 38
Maximum thrust, lbf 38

NOZZLE

Initial throat diameter, in. 0.24
Exit diameter, in. 1.284
Expansion ratio, initial 28.6:1

WEIGHTS, LBM

Total loaded 10.24
Propellant 5.05
Case assembly 2.02
Nozzle assembly 0.57
Total inert 5.17
Burnout 5.08
Propellant mass fraction 0.49

TEMPERATURE LIMITS

Operation .... -4º-104°F
Storage .... -76º-140°F

SPIN EXPERIENCE, RPM .... UP TO 60

PROPELLANT DESIGNATION TP-H-3399

CASE MATERIAL .... ALUMINUM

PRODUCTION STATUS

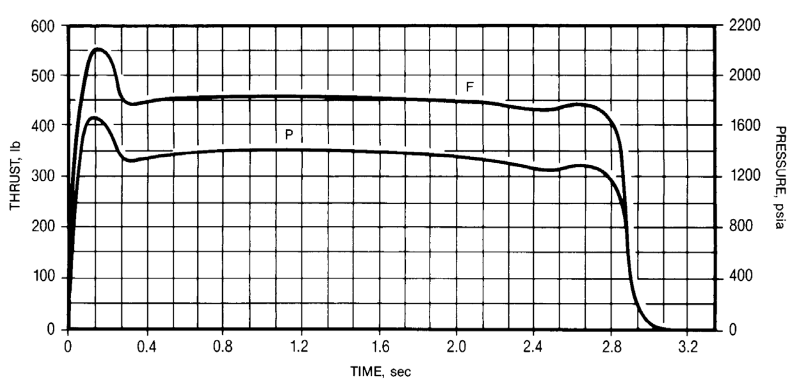
.... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 5C
TE-M-344-15

The STAR 5C rocket motor was initially designed, developed, qualified, and placed in production (1960 through 1963) under a contract with Martin Marietta. The STAR 5C was used to separate the second stage from the trans-stage on the Titan II missile and Titan launch vehicle. The current version was qualified for use in 1976, replacing the earlier main propellant grain with TP-H-3062.



MOTOR DIMENSIONS

Motor diameter, in. 4.77
Motor length, in. 13.43

MOTOR PERFORMANCE (60°F VACUUM)

Burn time/action time, sec 2.80/2.94
Ignition delay time, sec 0.015
Burn time average chamber pressure, psia....1,348
Maximum chamber pressure, psia 1,390
Total impulse, lbf-sec 1,252
Propellant specific impulse, lbf-sec/lbm....275.2
Effective specific impulse, lbf-sec/lbm 268.1
Burn time average thrust, lbf 439
Maximum thrust, lbf 455

NOZZLE

Initial throat diameter, in. 0.483
Exit diameter, in. 2.34
Expansion ratio, initial....23.5:1

WEIGHTS, LBM

Total loaded 9.86
Propellant (including igniter propellant) 4.55
Case assembly 4.24
Nozzle assembly 0.40
Total inert 5.28
Burnout 5.16
Propellant mass fraction 0.46

TEMPERATURE LIMITS

Operation.... 20º-130°F
Storage.... -25º-130°F

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL .... 4130 STEEL

PRODUCTION STATUS....... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

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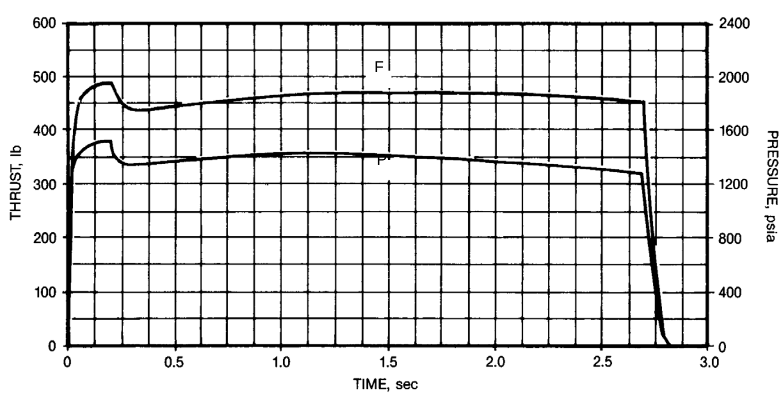
STAR 5CB
TE-M-344-16

NORTHROP GRUMMAN

The STAR 5CB rocket motor was redesigned and requalified to separate the second stage from the upper stage on the Titan IV launch vehicle. The motor incorporates a reduced aluminum content (2% Al) propellant to minimize spacecraft contamination during firing. The case, nozzle, and igniter components are unchanged from the STAR 5C design, but the motor has been qualified (in 1989) for the more severe Titan IV environments. This motor was first flown in 1990.

The STAR 5CB has been adapted for other applications. Mounting lugs and studs can be added to the head-end closure while removing the skirts on either end to accommodate mission-specific attachment features.



MOTOR DIMENSIONS
Motor diameter, in. 4.77
Motor length, in. 13.43

MOTOR PERFORMANCE (60°F VACUUM)
Burn time/action time, sec 2.67/2.77
Ignition delay time, sec 0.013
Burn time average chamber pressure, psia 1,388
Maximum chamber pressure, psia 1,434
Total impulse, lbf-sec 1,249
Propellant specific impulse, lbf-sec/lbm 270
Effective specific impulse, lbf-sec/lbm 262
Burn time average thrust, lbf 459
Maximum thrust, lbf 492

NOZZLE
Initial throat diameter, in. 0.483
Exit diameter, in. 2.34
Expansion ratio, initial 23.5:1

WEIGHTS, LBM
Total loaded 9.93
Propellant (excluding 0.03 lbm igniter propellant) 4.62
Case assembly 4.24
Nozzle assembly 0.40
Total inert 5.28
Burnout 5.16
Propellant mass fraction 0.47

TEMPERATURE LIMITS
Operation .... 0º-130°F
Storage .... -35º-172°F

PROPELLANT DESIGNATION TP-H-3237A

CASE MATERIAL .... 4130 STEEL

PRODUCTION STATUS .... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

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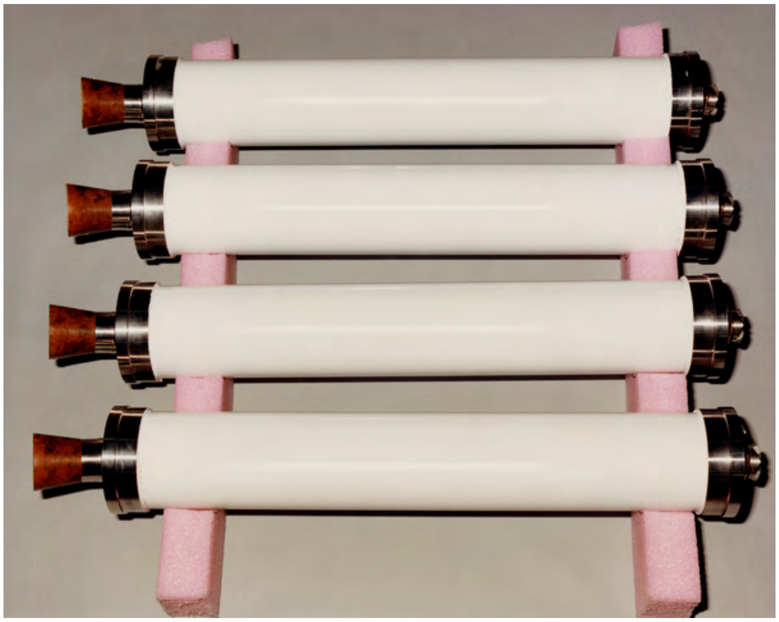
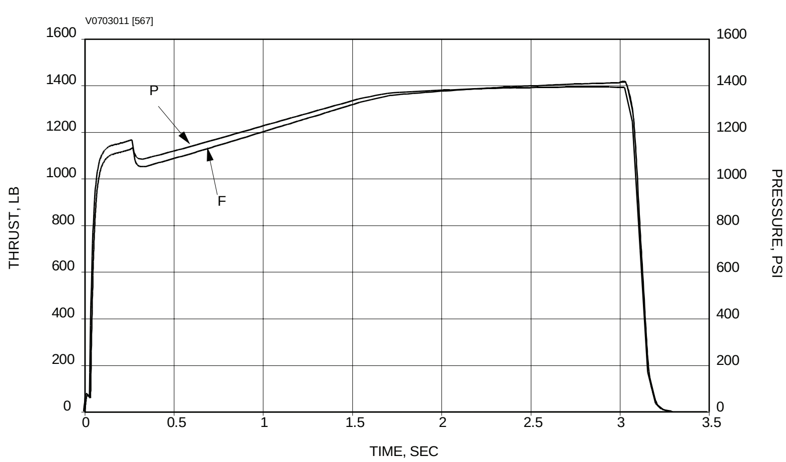
STAR 5D
TE-M-989-2

NORTHROP GRUMMAN



The STAR 5D rocket motor was designed and qualified (1996) to serve as the rocket-assisted deceleration motor on the Mars Pathfinder mission for the Jet Propulsion Laboratory (JPL) in Pasadena, CA. The STAR 5D features a titanium case, head-end ignition system, and canted nozzle design and is based on earlier STAR 5 designs. Three of these motors were fired on July 4, 1997, to slow the Pathfinder spacecraft to near-zero velocity before bouncing on the surface of Mars.



MOTOR DIMENSIONS

Motor diameter, in.	4.88
Motor length, in.	32.7

MOTOR PERFORMANCE (-22°F VACUUM)

Burn time/action time, sec	3.03/3.28
Ignition delay time, sec	0.029
Burn time average chamber pressure, psia	1,299
Maximum chamber pressure, psia	1,406
Total impulse, lbf-sec	3,950
Propellant specific impulse, lbf-sec/lbm	259.5
Effective specific impulse, lbf-sec/lbm	256.0
Burn time average thrust, lbf	1251
Maximum thrust, lbf	1,410

NOZZLE

Initial throat diameter, in.	0.869
Exit diameter, in.	2.345
Expansion ratio, initial	7.3:1
Cant angle, deg	17

WEIGHTS, LBM

Total loaded	22.55
Propellant (including igniter propellant)	15.22
Case assembly	5.93
Nozzle assembly	1.40
Total inert	7.33
Burnout	7.12
Propellant mass fraction	0.68

TEMPERATURE LIMITS

Operation	-67º-158°F
Storage	-80º-172°F

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL ....TITANIUM

PRODUCTION STATUS

.... FLIGHT-PROVEN

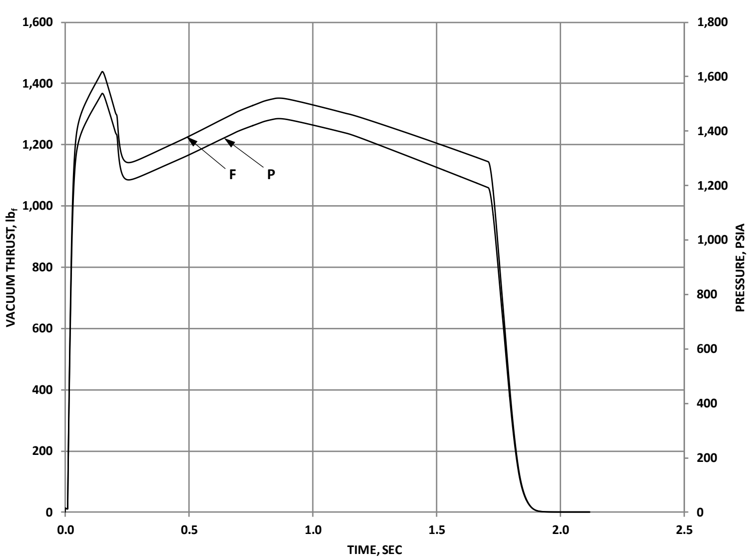
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 5F
TE-M-1198

NORTHROP GRUMMAN

The STAR 5F rocket motor was designed as the Atlas V launch vehicle first stage retro motor for use during first and second stage separation. It incorporates numerous design features from the STAR 5CB, STAR 5D, and STAR 5E designs to maximize heritage and drive high reliability. The STAR 5F features a stainless steel case, closures, and exit cone; a head-end ignition system; a severely canted nozzle design; and reduced aluminum content propellant to minimize spacecraft contamination during firing. The motor has been qualified for the severe Atlas V environments, including nine static tests in 2011 and 2012.



MOTOR DIMENSIONS

Motor diameter, in. 4.85
Motor length, in. 37.26

MOTOR PERFORMANCE (60°F VACUUM)

Burn time/action time, sec 1.75/1.93
Ignition delay time, sec 0.012
Burn time average chamber pressure, psia.......1,315
Maximum chamber pressure, psia 1,757
Total impulse, lbf-sec 2,140
Propellant specific impulse, lbf-sec/lbm............254.2
Burn time average thrust, lbf* 1,188
Maximum thrust, lbf* 1,363
*Along nozzle centerline

NOZZLE

Initial throat diameter, in. 0.85
Exit diameter, in. 2.55
Expansion ratio, initial.......................................9.1:1
Cant angle, deg 20.0

WEIGHTS, LBM

Total loaded 30.95
Propellant 8.42
Total inert 22.53
Propellant mass fraction 0.27

TEMPERATURE LIMITS

Operation... 14º-124°F
Storage.. -35º-160°F

PROPELLANT DESIGNATION TP-H-3237B

CASE MATERIAL ....STAINLESS STEEL

PRODUCTION STATUS
.... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

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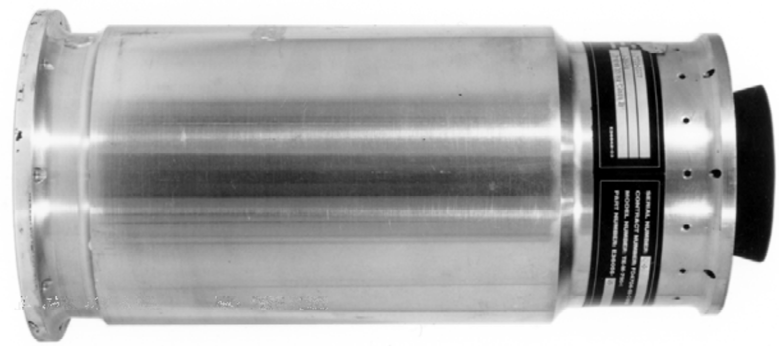
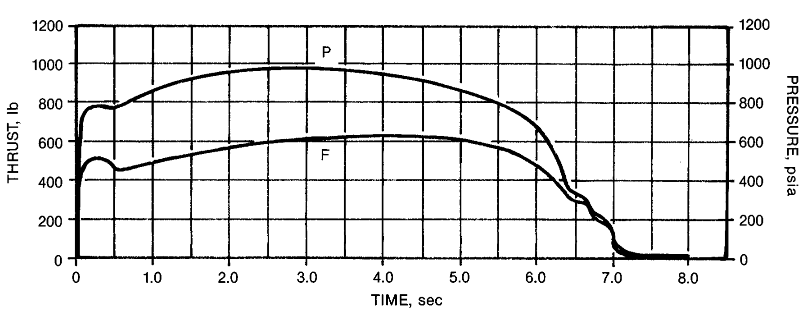
STAR 6B
TE-M-790-1



The STAR 6B rocket motor was developed for spin-up and axial propulsion applications for re-entry vehicles. The design incorporates an aluminum case and a carbon-phenolic nozzle assembly. The STAR 6B was qualified in 1984 and first flew in 1985. The motor is capable of spinning at 16 revolutions per second during firing and is qualified for propellant loadings from 5.7 to 15.7 lbm.



MOTOR DIMENSIONS

Motor diameter, in. 7.32
Motor length, in. 15.89

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 5.9/7.2
Ignition delay time, sec 0.010
Burn time average chamber pressure, psia.......846
Maximum chamber pressure, psia 907
Total impulse, lbf-sec 3,686
Propellant specific impulse, lbf-sec/lbm.......274
Effective specific impulse, lbf-sec/lbm 269
Burn time average thrust, lbf 565
Maximum thrust, lbf 634

NOZZLE

Initial throat diameter, in. 0.662
Exit diameter, in. 3.76
Expansion ratio, initial/average.......32:1/28:1

WEIGHTS, LBM

Total loaded 22.62
Propellant (including igniter propellant) 13.45
Case and closure assembly 6.02
Nozzle assembly 0.80
Total inert 9.17
Burnout 8.92
Propellant mass fraction 0.59

TEMPERATURE LIMITS

Operation.......30º-110°F
Storage ....-20º-160°F

SPIN EXPERIENCE, RPM 960

PROPELLANT DESIGNATION TP-H-3237A

CASE MATERIAL .... ALUMINUM

PRODUCTION STATUS
.... FLIGHT-PROVEN

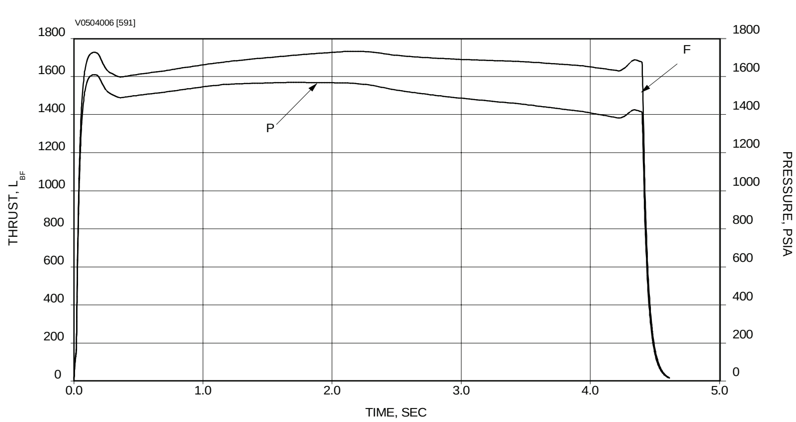
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 8
TE-M-1076-1

NORTHROP GRUMMAN

The STAR 8 was developed and qualified (2002) as the rocket assisted deceleration motor for the Mars Exploration Rover (MER) program for the Jet Propulsion Laboratory (JPL) in Pasadena, CA. The motor is based on the STAR 5D motor technology developed for JPL's Mars Pathfinder program. The STAR 8 first flew in January 2004 when three motors were used to decelerate each of the Spirit and Opportunity rovers for landing at Gusev Crater and Meridiani Planum on Mars.



MOTOR DIMENSIONS

Motor diameter, in. 8.06
Motor length, in. 27.07

MOTOR PERFORMANCE (-22°F vacuum)

Burn time/action time, sec 4.33/4.51
Ignition delay time, sec 0.025
Burn time average chamber pressure, psia 1,500
Maximum chamber pressure, psia 1,572
Total impulse, lbf-sec 7,430
Propellant specific impulse, lbf-sec/lbm 274.0
Effective specific impulse, lbf-sec/lbm 272.9
Burn time average thrust, lbf 1,681
Maximum thrust, lbf 1,742

NOZZLE

Initial throat diameter, in. 0.879
Exit diameter, in. 4.095
Expansion ratio, initial 21.7:1
Cant angle, deg 17

WEIGHTS, LBM

Total loaded 38.43
Propellant 27.12
Case assembly 6.12
Nozzle assembly 3.69
Total inert 11.31
Burnout 11.20
Propellant mass fraction 0.71

TEMPERATURE LIMITS

Operation .... -40º-104°F
Storage .... -65º-140°F

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL .... TITANIUM

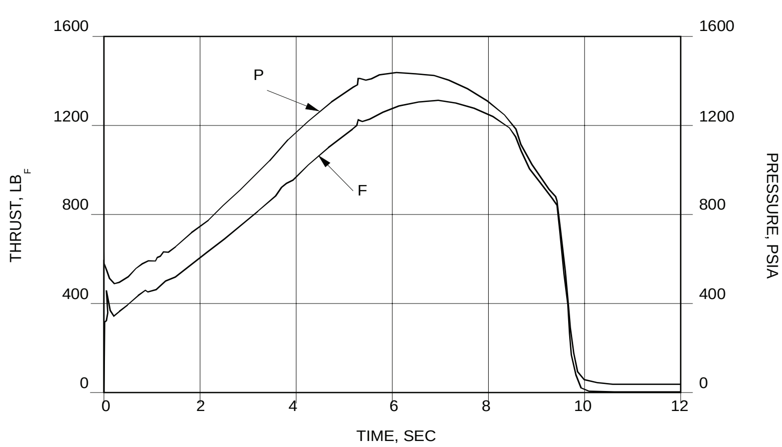
PRODUCTION STATUS
.... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 9
TE-M-956-2

The STAR 9 rocket motor was developed in 1993 on independent research and development funds to demonstrate a number of low-cost motor technologies. These included an integral aft polar boss/exit cone, two-dimensional carbon-carbon throat, and case-on-propellant manufacturing technique.



MOTOR DIMENSIONS

Motor diameter, in.	9.0
Motor length, in.	19.96

MOTOR PERFORMANCE (70°F vacuum)

Burn time/action time, sec	9.4/9.8
Ignition delay time, sec	0.01
Burn time average chamber pressure, psia	1,072
Maximum chamber pressure, psia	1,436
Total impulse, lbf-sec	9,212
Propellant specific impulse, lbf-sec/lbm	289.7
Effective specific impulse, lbf-sec/lbm	289.1
Burn time average thrust, lbf	951
Maximum thrust, lbf	1,311

NOZZLE

Initial throat diameter, in.	0.763
Exit diameter, in.	6.52
Expansion ratio, initial	73:1

WEIGHTS, LBM

Total loaded	41.0
Propellant (including igniter propellant)	31.8
Case assembly (including igniter inerts)	6.5
Nozzle assembly	2.7
Total inert	9.2
Burnout	9.1
Propellant mass fraction	0.78

TEMPERATURE LIMITS

Operation	40º-90°F
Storage	30º-95°F

PROPELLANT DESIGNATION TP-H-1202

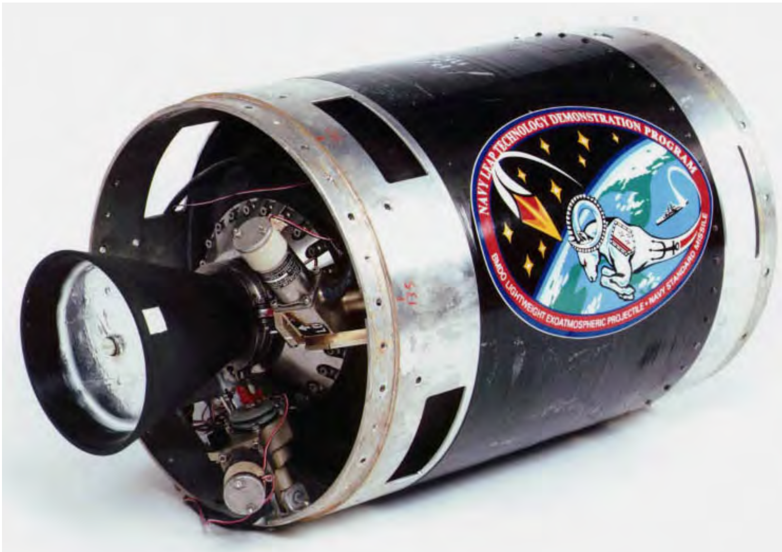
CASE MATERIAL
....................GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS.....DEMONSTRATION

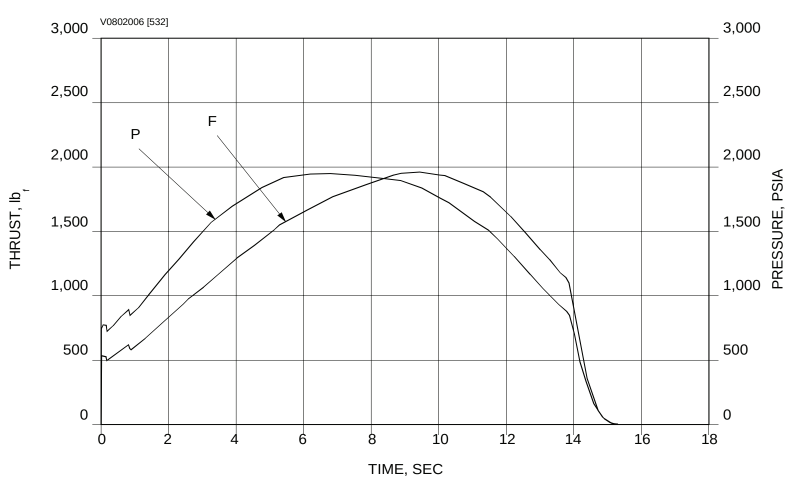
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 12GV
TE-M-951



The STAR 12GV rocket motor served as the third stage of the U.S. Navy/Missile Defense Agency Terrier Lightweight Exoatmospheric Projectile (LEAP) experiments. The motor first flew in March 1995. The stage has thrust vector control capability, head-end flight destruct ordnance, and utilizes a graphite-epoxy composite case. It is compatible with an aft-end attitude control system module. Northrop Grumman developed the motor design and component technology between 1992 and 1995 under the Advanced Solid Axial Stage (ASAS) program.



MOTOR DIMENSIONS
Motor diameter, in. 12.24
Motor length, in. 22.5

MOTOR PERFORMANCE (70°F VACUUM)
Burn time/action time, sec 13.9/14.8
Ignition delay time, sec 0.02
Burn time average chamber pressure, psia 1,550
Maximum chamber pressure, psia 1,950
Total impulse, lbf-sec 20,669
Propellant specific impulse, lbf-sec/lbm 284.7
Effective specific impulse, lbf-sec/lbm 282.4
Burn time average thrust, lbf 1,455
Maximum thrust, lbf 1,980

NOZZLE
Initial throat diameter, in. 0.691
Exit diameter, in. 5.26
Expansion ratio, initial 58:1
TVC angle, deg .... ± 5 deg

WEIGHTS*, LBM
Total loaded 92.5
Propellant 72.6
Case assembly 14.3
Nozzle assembly 4.5
Total inert 19.8
Burnout 19.2
Propellant mass fraction 0.79

TEMPERATURE LIMITS
Operation .... 40º-95°F
Storage .... 0º-130°F

PROPELLANT DESIGNATION
.... TP-H-3340A

CASE MATERIAL
.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS
.... FLIGHT-PROVEN

*Includes actuators and cables only. Battery and controller weights and ACS are not included

For more information, contact:
starmotors@ngc.com.

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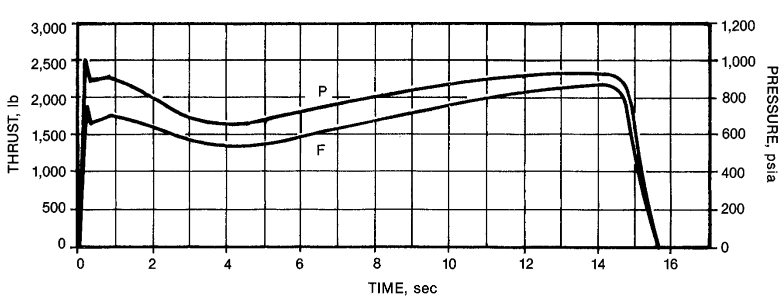
STAR 13B
TE-M-763

The STAR 13B incorporates a titanium case developed for the STAR 13 with the propellant and nozzle design of an earlier STAR 13 apogee motor. The motor design was qualified in 1983 and was used in 1984 to adjust orbit inclinations of the Active Magnetosphere Particle Tracer Experiment (AMPTE) satellite launched from Delta 180 and in 1988 as a kick motor for a missile defense experiment.



MOTOR DIMENSIONS

Motor diameter, in.	13.57
Motor length, in.	25.11

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec	14.8/16.1
Ignition delay time, sec	0.02
Burn time average chamber pressure, psia	823
Maximum chamber pressure, psia	935
Total impulse, lbf-sec	26,050
Propellant specific impulse, lbf-sec/lbm	286.6
Effective specific impulse, lbf-sec/lbm	285.0
Burn time average thrust, lbf	1,708
Maximum thrust, lbf	2,160

NOZZLE

Initial throat diameter, in.	1.20
Exit diameter, in.	8.02
Expansion ratio, initial/average	49.8:1/41.0:1

WEIGHTS, LBM

Total loaded	103.7
Propellant	90.9
Case assembly	5.6
Nozzle assembly	3.7
Total inert	12.8
Burnout	12.3
Propellant mass fraction	0.88

TEMPERATURE LIMITS

Operation	40º-110°F
Storage	40º-110°F

SPIN EXPERIENCE, RPM 120

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL ....TITANIUM

PRODUCTION STATUS

.... FLIGHT-PROVEN

For more information, contact:
[starmotors@ngc.com.](mailto:starmotors@ngc.com)

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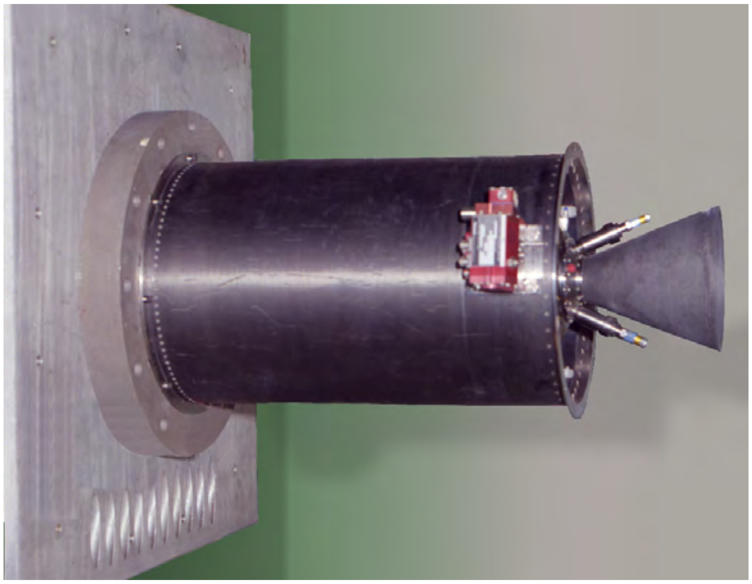
STAR 15G
TE-M-1030-1

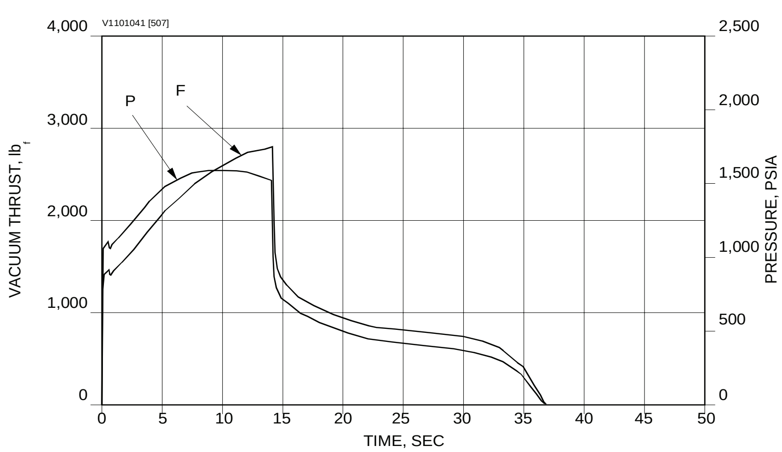
NORTHROP GRUMMAN



AN UPPER-STAGE MOTOR

The STAR 15G rocket motor was designed and qualified during 1997 in two different grain design configurations. The motor design was based on the ASAS 15-in. diameter development motor that was used to evaluate design features and component and material technology in seven tests between December 1988 and June 1991. Northrop Grumman employed its Thiokol Composite Resin technology on this motor, one of several STAR designs to use a wound graphite-epoxy composite case.

The motor's unique regressive thrust-time profile is an example of propellant grain tailoring to restrict thrust to maintain a low level of acceleration to the payload. An alternative propellant loading of 131 lbm was also tested during qualification.



MOTOR DIMENSIONS
Motor diameter, in. 15.04
Motor length, in. 31.57

MOTOR PERFORMANCE (70°F VACUUM)
Burn time/action time, sec 33.3/36.4
Ignition delay time, sec 0.334
Burn time average chamber pressure, psia 885
Maximum chamber pressure, psia 1,585
Total impulse, lbf-sec 50,210
Propellant specific impulse, lbf-sec/lbm 285.9
Effective specific impulse, lbf-sec/lbm 281.8
Burn time average thrust, lbf 1,470
Maximum thrust, lbf 2,800

NOZZLE
Initial throat diameter, in. 0.97
Exit diameter, in. 8.12
Expansion ratio, initial 70:1

WEIGHTS, LBM
Total loaded (excluding ETA and S&A) 206.6
Propellant (excluding 0.12 lbm of igniter propellant) 175.5
Case assembly 22.6
Nozzle assembly 4.6
Total inert 30.9
Burnout 28.3
Propellant mass fraction 0.85

TEMPERATURE LIMITS
Operation .... 40º-110°F
Storage .... 40º-110°F

SPIN EXPERIENCE, RPM 125

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL
.... GRAPHITE-EPOXY COMPOSITE

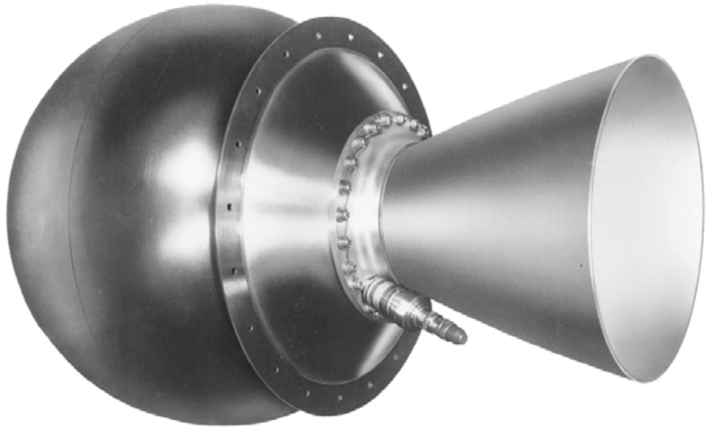
PRODUCTION STATUS
.... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

northropgumman.com

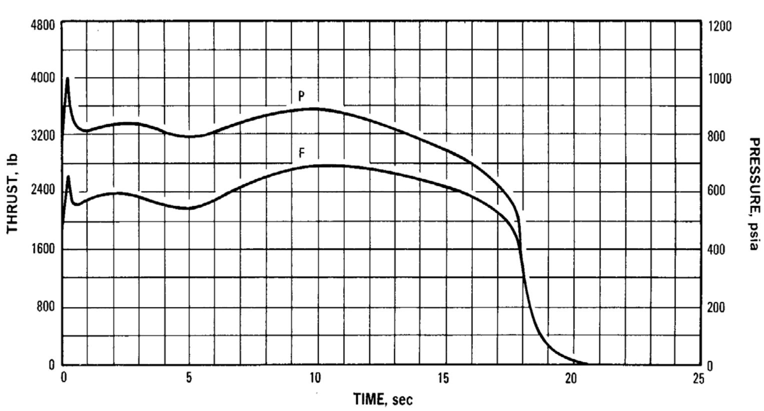
STAR 17
TE-M-479

NORTHROP GRUMMAN



The STAR 17 motor has served as the apogee kick motor for several programs. The STAR 17 features a silica-phenolic exit cone and a titanium case with a mounting ring on the aft end that can be relocated as required by the customer.

The STAR 17 motor was developed and qualified in six tests conducted at Northrop Grumman and Arnold Engineering Development Center through March 1967. The initial STAR 17 flight was on Delta 57 in July 1968 from the Western Test Range. Subsequent launches have been conducted from Eastern Test Range on Delta and the Atlas vehicle from Western Test Range.



MOTOR DIMENSIONS
Motor diameter, in. 17.4
Motor length, in. 27.06

MOTOR PERFORMANCE (70°F VACUUM)
Burn time/action time, sec 17.6/18.6
Ignition delay time, sec 0.060
Burn time average chamber pressure, psia 803
Maximum chamber pressure, psia 1,000
Total impulse, lbf-sec 44,500
Propellant specific impulse, lbf-sec/lbm 290.0
Effective specific impulse, lbf-sec/lbm 286.2
Burn time average thrust, lbf 2,460
Maximum thrust, lbf 2,775

NOZZLE
Initial throat diameter, in. 1.372
Exit diameter, in. 10.69
Expansion ratio, initial 60.7:1

WEIGHTS, LBM
Total loaded 174.3
Propellant 153.5
Case assembly 8.8
Nozzle assembly 7.0
Total inert 20.8
Burnout 18.8
Propellant mass fraction 0.88

TEMPERATURE LIMITS
Operation .... 0º-120°F
Storage .... 0º-120°F

SPIN EXPERIENCE, RPM 100

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL ....TITANIUM

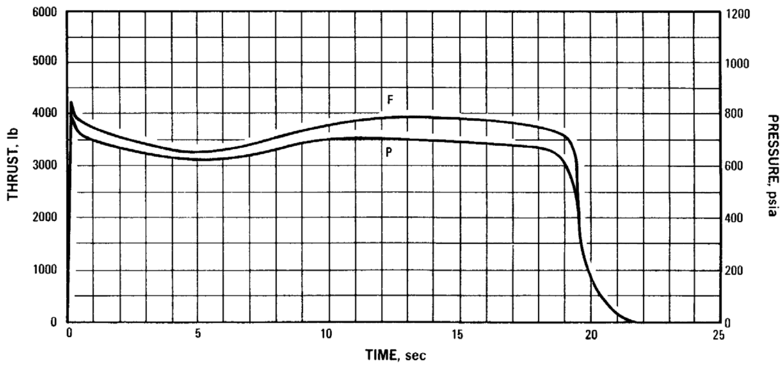
PRODUCTION STATUS
.... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 17A
TE-M-521-5

The STAR 17A motor is an apogee kick motor used for the interplanetary monitoring platform and other small satellites. The motor utilizes an extended titanium case to increase total impulse from the STAR 17 and has been used for various missions in launches from Delta and Atlas vehicles between 1969 and 1977. The STAR 17A motor was qualified in the -5 configuration for interplanetary monitoring platform H and J.



MOTOR DIMENSIONS

Motor diameter, in. 17.4*
Motor length, in. 38.64

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 19.4/20.6
Ignition delay time, sec 0.070
Burn time average chamber pressure, psia 670
Maximum chamber pressure, psia 700
Total impulse, lbf-sec 71,800
Propellant specific impulse, lbf-sec/lbm 290.1
Effective specific impulse, lbf-sec/lbm 286.7
Burn time average thrust, lbf 3,600
Maximum thrust, lbf 3,900

NOZZLE

Initial throat diameter, in. 1.884
Exit diameter, in. 13.75
Expansion ratio, initial 53.2:1

WEIGHTS, LBM

Total loaded 277
Propellant 247.5
Case assembly 13.1
Nozzle assembly 10.3
Total inert 29.5
Burnout 26.5
Propellant mass fraction 0.89

TEMPERATURE LIMITS

Operation .... 0º-110°F
Storage .... 0º-110°F

SPIN EXPERIENCE, RPM 100

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL .... TITANIUM

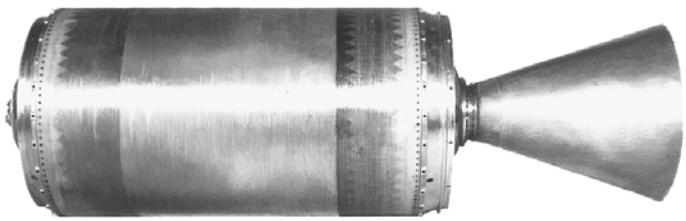
PRODUCTION STATUS
.... FLIGHT-PROVEN

*The diameter extends to 18.38 in. at the location of the attachment flange

For more information, contact:
starmotors@ngc.com.

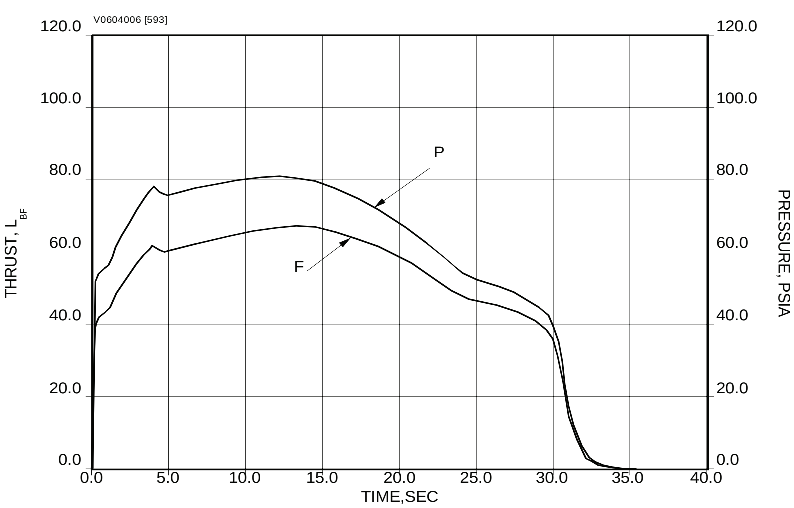
northropgumman.com

STAR 20
TE-M-640-1



The STAR 20 Altair III rocket motor was developed as the propulsion unit for the fourth stage of the Scout launch vehicle. The filament-wound, fiberglass-epoxy case contains a 16% aluminum carboxyl-terminated polybutadiene (CTPB) propellant grain. The lightweight, external nozzle is a composite of graphite and plastic that is backed by steel. The STAR 20 Altair III was developed in testing between 1972 and 1978 with flights from the Western Test Range, San Marcos, and Wallops Flight Facility beginning with Scout 189 in August 1974.

Northrop Grumman also developed a modified version of the STAR 20. The STAR 20B design increased case structural capability over the standard STAR 20 to support launch from an F-15 aircraft for the Antisatellite Weapons (ASAT) program. The STAR 20B ASAT motor was qualified during testing in 1982 to 1983 to support flights between January 1984 and September 1986.



MOTOR DIMENSIONS

Motor diameter, in. 19.7
Motor length, in. 58.5

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 27.4/31.5
Ignition delay time, sec 0.04
Burn time average chamber pressure, psia..........654
Maximum chamber pressure, psia 807
Total impulse, lbf-sec 173,560
Propellant specific impulse, lbf-sec/lbm............288.5
Effective specific impulse, lbf-sec/lbm 286.5
Burn time average thrust, lbf 5,500
Maximum thrust, lbf 6,720

NOZZLE

Initial throat diameter, in. 2.3
Exit diameter, in. 16.5
Expansion ratio, initial.....................................50.2:1

WEIGHTS, LBM

Total loaded 662.3
Propellant (including igniter propellant) 601.6
Case assembly 24.3
Nozzle assembly 12.5
Total inert 60.7
Burnout 58.6
Propellant mass fraction 0.91

TEMPERATURE LIMITS

Operation.. 40º-100°F
Storage..30º-110°F

SPIN EXPERIENCE, RPM 180

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL .... FIBER GLASS-EPOXY COMPOSITE

PRODUCTION STATUS....... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

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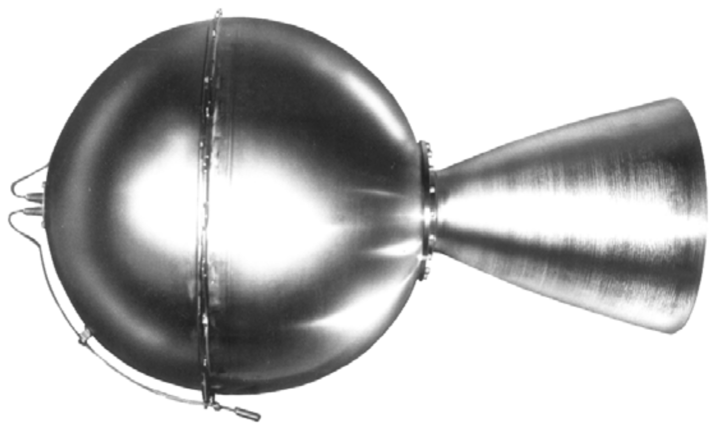
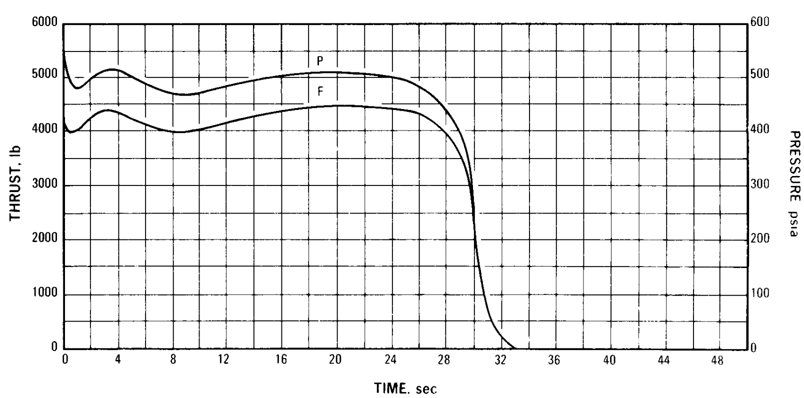
STAR 24
TE-M-640

NORTHROP GRUMMAN



The STAR 24 rocket motor was qualified in 1973 and flown as the apogee kick motor for the Skynet II satellite. The motor assembly uses a titanium case and carbon-phenolic exit cone. Different versions of this motor have been qualified for the Pioneer Venus mission (1978). The initial STAR 24 flight was in 1974 on Delta 100. The STAR 24 motor has flown from both the Eastern Test Range and Western Test Range.



MOTOR DIMENSIONS

Motor diameter, in.	24.5
Motor length, in.	40.5

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec	29.6/31.1
Ignition delay time, sec	0.03
Burn time average chamber pressure, psia	486
Maximum chamber pressure, psia	524
Total impulse, lbf-sec	126,000
Propellant specific impulse, lbf-sec/lbm	286.0
Effective specific impulse, lbf-sec/lbm	282.9
Burn time average thrust, lbf	4,170
Maximum thrust, lbf	4,420

NOZZLE

Initial throat diameter, in.	2.42
Exit diameter, in.	14.88
Expansion ratio, initial/average	37.8:1/36.7:1

WEIGHTS, LBM

Total loaded	481.0
Propellant (including igniter propellant)	440.6
Case	13.0
Nozzle assembly	13.1
Total inert	40.4
Burnout	35.6
Propellant mass fraction	0.92

TEMPERATURE LIMITS

Operation	0º-110°F
Storage	20º-110°F

SPIN EXPERIENCE, RPM 100

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL ....TITANIUM

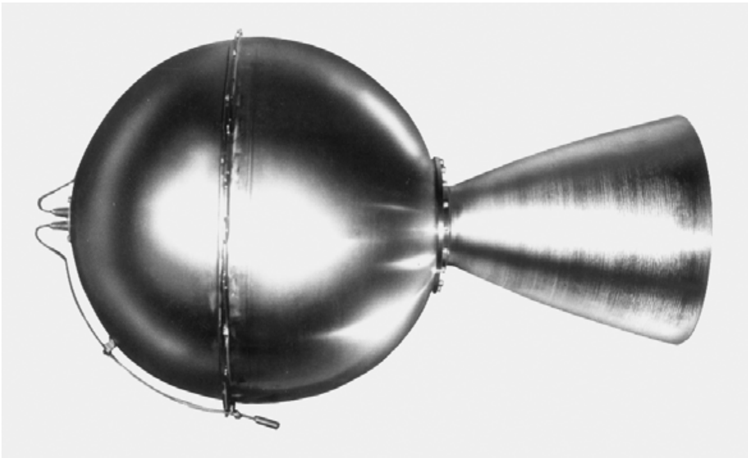
PRODUCTION STATUS....... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

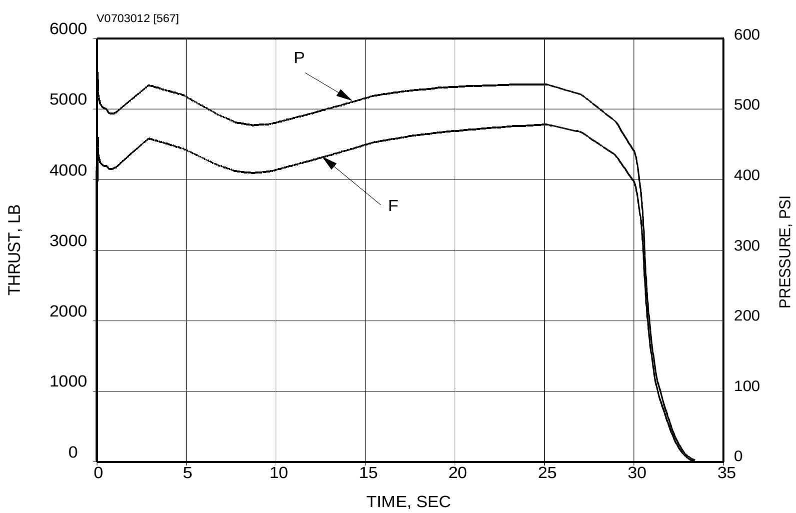
northropgumman.com

STAR 24C
TE-M-640-4

NORTHROP GRUMMAN



The STAR 24C was designed and qualified (in 1976) for launching NASA's International Ultraviolet Experiment (IUE) satellite in January 1978 from the Eastern Test Range on Delta 138. It operates at a slightly higher chamber pressure than earlier STAR 24 motors. The STAR 24C has an elongated cylindrical section and a larger nozzle throat to accommodate increased propellant loading.



MOTOR DIMENSIONS

Motor diameter, in. 24.5
Motor length, in. 42.0

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 28.0/29.6
Ignition delay time, sec 0.03
Burn time average chamber pressure, psia..........544
Maximum chamber pressure, psia 598
Total impulse, lbf-sec 138,000
Propellant specific impulse, lbf-sec/lbm............285.1
Effective specific impulse, lbf-sec/lbm 282.3
Burn time average thrust, lbf 4,650
Maximum thrust, lbf 4,800

NOZZLE

Initial throat diameter, in. 2.443
Exit diameter, in. 14.88
Expansion ratio, initial....................................37.1:1

WEIGHTS, LBM

Total loaded 527.5
Propellant (including 1.2 lbm igniter propellant)
....484.0
Case 14.1
Nozzle assembly 13.1
Total inert 43.5
Burnout 38.7
Propellant mass fraction 0.92

TEMPERATURE LIMITS

Operation...0º-110°F\
Storage ....20º-110°F

SPIN EXPERIENCE, RPM 100

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL ....TITANIUM

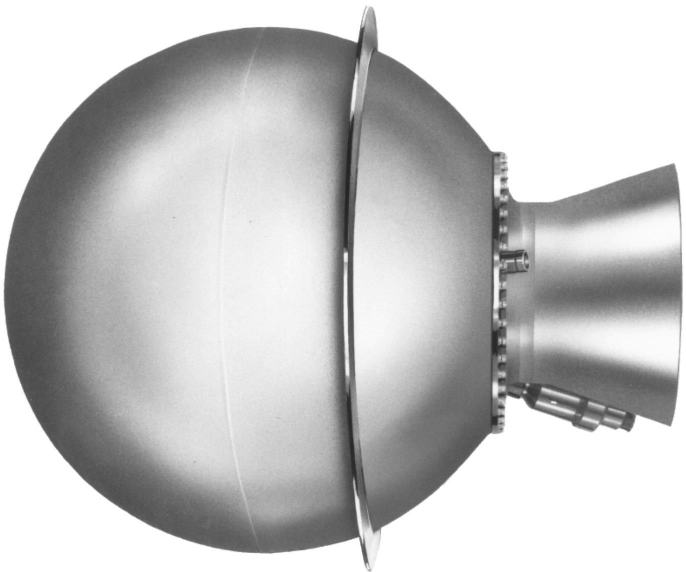
PRODUCTION STATUS
.... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

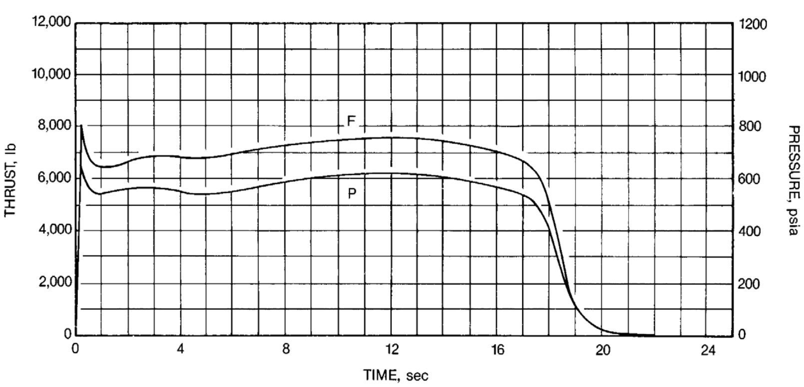
northropgumman.com

STAR 26
TE-M-442

NORTHROP GRUMMAN



The STAR 26 was qualified in 1964 for flight as an upper stage in the Sandia National Laboratories' Strypi IV vehicle. Similar in design to its predecessor, the STAR 24, this motor offers a higher thrust.



MOTOR DIMENSIONS

Motor diameter, in. 26.0

Motor length, in. 33.0

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 17.8/19.0

Ignition delay time, sec 0.06

Burn time average chamber pressure, psia 575

Maximum chamber pressure, psia 650

Total impulse, lbf-sec 138,500

Propellant specific impulse, lbf-sec/lbm 272.4

Effective specific impulse, lbf-sec/lbm 271.0

Burn time average thrust, lbf 7,500

Maximum thrust, lbf 8,000

NOZZLE

Initial throat diameter, in. 3.06

Exit diameter, in. 12.50

Expansion ratio, initial 16.7:1

WEIGHTS, LBM

Total loaded 594.0

Propellant (including 1.2 lbm igniter propellant) 508.5

Case assembly 39.6

Nozzle assembly 23.3

Total inert 85.5

Burnout 83.0

Propellant mass fraction 0.86

TEMPERATURE LIMITS

Operation .... 50º-90°F

Storage .... 40º-120°F

SPIN EXPERIENCE, RPM 400

PROPELLANT DESIGNATION TP-H-3114

CASE MATERIAL .... D6AC STEEL

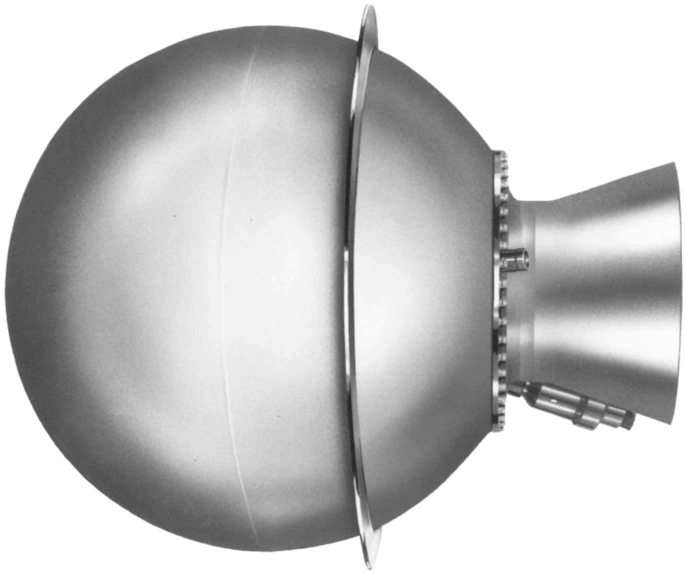
PRODUCTION STATUS

.... FLIGHT-PROVEN

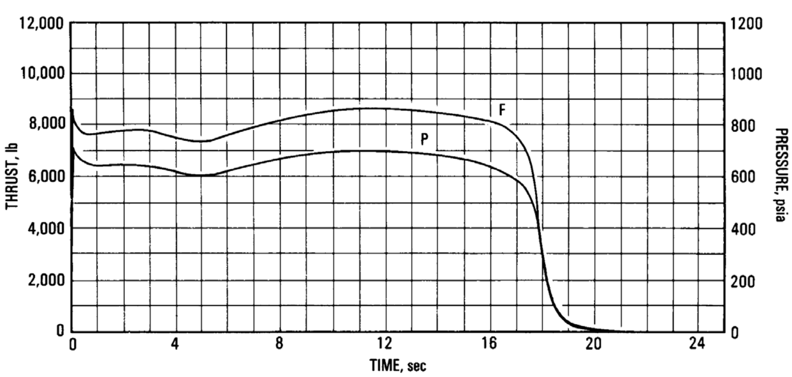
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 26B
TE-M-442-1



The STAR 26B is a version of the STAR 26 that is lightened by utilizing a titanium case. This weight savings has allowed increased propellant loading, resulting in extended performance. The STAR 26B was qualified in a 1970 test and was flown as an upper stage on the Burner IIA spacecraft for Boeing and the U. S. Air Force beginning in 1972.



MOTOR DIMENSIONS

Motor diameter, in. 26.1
Motor length, in. 33.1

MOTOR PERFORMANCE (70°F VACUUM,
Isp based on Burner IIA flight data) ....

Burn time/action time, sec 17.8/18.6
Ignition delay time, sec 0.06
Burn time average chamber pressure, psia 623
Maximum chamber pressure, psia 680
Total impulse, lbf-sec 142,760
Propellant specific impulse, lbf-sec/lbm 272.4
Effective specific impulse, lbf-sec/lbm 271.7
Burn time average thrust, lbf 7,784
Maximum thrust, lbf 8,751

NOZZLE

Initial throat diameter, in. 2.963
Exit diameter, in. 12.50
Expansion ratio, initial 17.8:1

WEIGHTS, LBM

Total loaded 575.6
Propellant (including 0.4 lbm igniter propellant) 524.0
Case assembly 23.5
Nozzle assembly 19.3
Total inert 51.6
Burnout 50.3
Propellant mass fraction 0.91

TEMPERATURE LIMITS

Operation .... 50º-90°F
Storage .... 40º-100°F

PROPELLANT DESIGNATION TP-H-3114

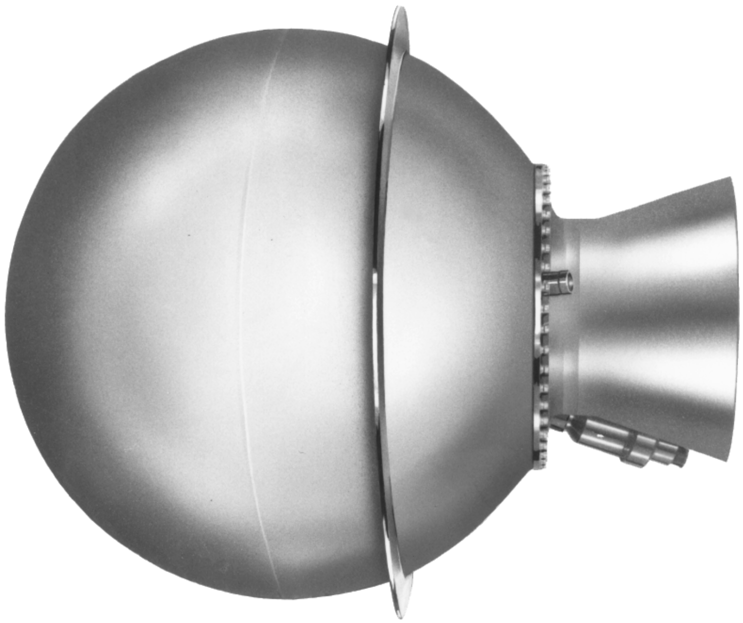
CASE MATERIAL ....TITANIUM

PRODUCTION STATUS ....FLIGHT-PROVEN

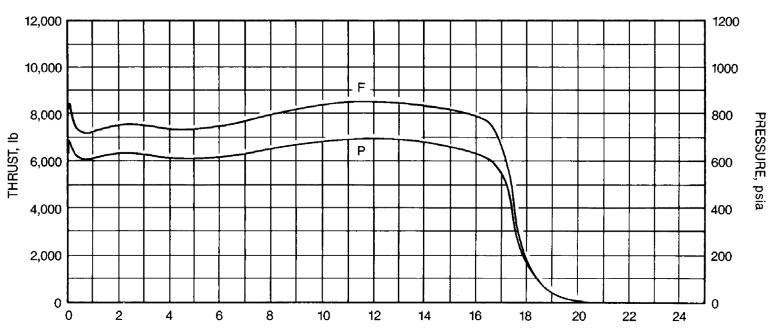
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 26C
TE-M-442-2



The STAR 26C employs the same titanium alloy case as the STAR 26B; however, the insulation is increased to accommodate high-spin-rate applications. The motor has been used as an upper stage for Sandia National Laboratories' Strypi IV vehicle and for applications for the U.S. Army.



MOTOR DIMENSIONS

Motor diameter, in.	26.1
Motor length, in.	33.1

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec	16.8/18.3
Ignition delay time, sec	0.06
Burn time average chamber pressure, psia	640
Maximum chamber pressure, psia	690
Total impulse, lbf-sec	139,800
Propellant specific impulse, lbf-sec/lbm	273.4
Effective specific impulse, lbf-sec/lbm	272.1
Burn time average thrust, lbf	7,870
Maximum thrust, lbf	8,600

NOZZLE

Initial throat diameter, in.	2.963
Exit diameter, in.	12.50
Expansion ratio, initial	17.8:1

WEIGHTS, LBM

Total loaded	579.0
Propellant (including igniter propellant)	511.4
Case assembly	23.6
Nozzle assembly	19.8
Total inert	67.6
Burnout	65.1
Propellant mass fraction	0.88

TEMPERATURE LIMITS

Operation	50º-90°F
Storage	40º-100°F

SPIN CAPABILITY, RPM 250

PROPELLANT DESIGNATION TP-H-3114

CASE MATERIAL .... TITANIUM

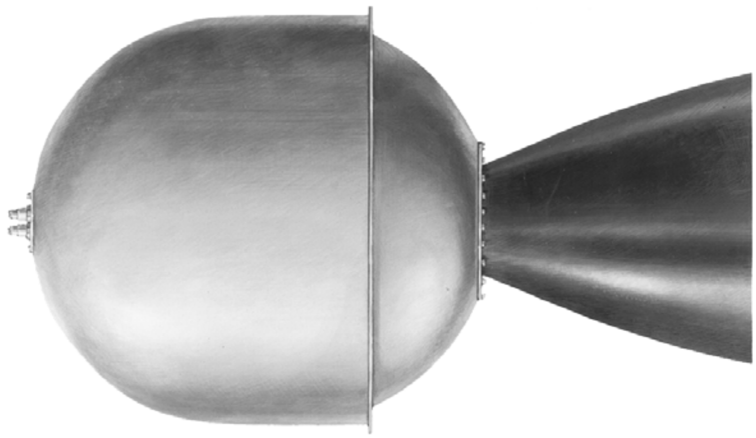
PRODUCTION STATUS....... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

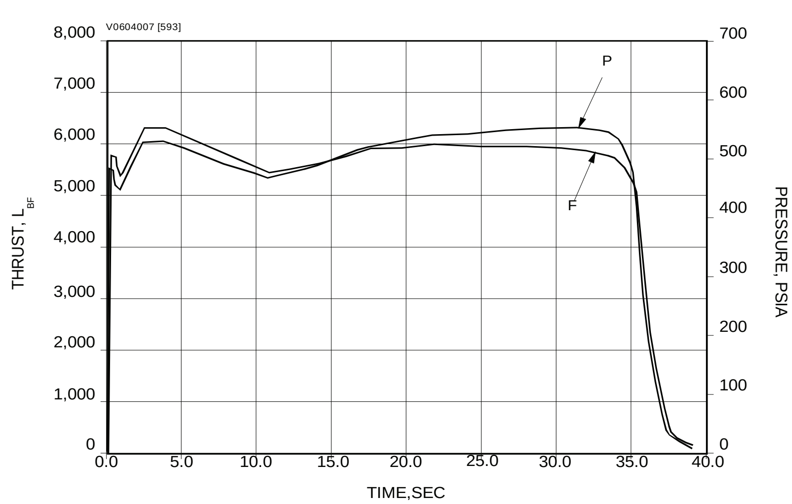
northropgumman.com

STAR 27
TE-M-616

NORTHROP GRUMMAN



The STAR 27 rocket motor was developed and qualified in 1975 for use as the apogee kick motor for the Canadian Communications Research Centre's Communications Technology Satellite. With its ability to accommodate various propellant loadings (9% offload flown) and explosive transfer assemblies, it has served as the apogee kick motor for various applications. The high-performance motor utilizes a titanium case and carbon-phenolic nozzle. The motor first flew in January 1976 on Delta 119. It has flown for Navigation Satellite Timing and Ranging (NAVSTAR) on Atlas vehicles launched from the Western Test Range, for Geosynchronous Orbiting Environmental Satellites (GOES), for the Japanese N-II vehicle from Tanagashima, and for the Geostationary Meteorological Satellite (GMS) series of weather satellites.



MOTOR DIMENSIONS

Motor diameter, in.	27.3
Motor length, in.	48.7

MOTOR PERFORMANCE (60°F VACUUM)*

Burn time/action time, sec	34.4/37.3
Ignition delay time, sec	0.076
Burn time average chamber pressure, psia	563
Maximum chamber pressure, psia	497
Total impulse, lbf-sec	213,790
Propellant specific impulse, lbf-sec/lbm	290.7
Effective specific impulse, lbf-sec/lbm	287.9
Burn time average thrust, lbf	5,720
Maximum thrust, lbf	6,340

NOZZLE

Initial throat diameter, in.	2.74
Exit diameter, in.	19.1
Expansion ratio, initial	48.8:1

WEIGHTS, LBM

Total loaded	796.2
Propellant (including 0.5 lbm igniter propellant)	735.6
Case assembly	23.6
Nozzle assembly	20.4
Total inert	60.6
Burnout	53.6
Propellant mass fraction	0.92

TEMPERATURE LIMITS

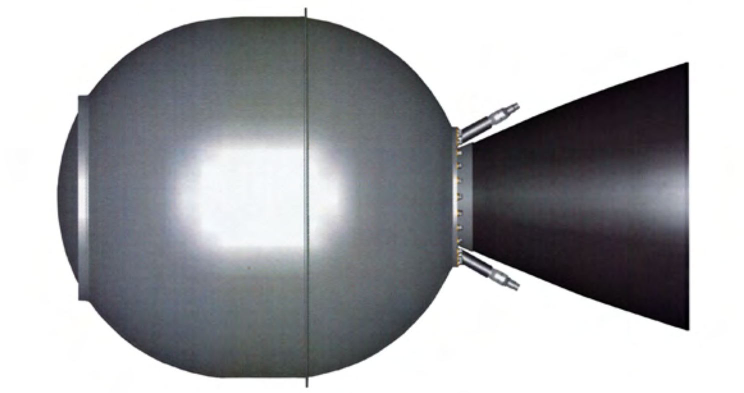
Operation	20 to 100°F
Storage	40 to 100°F

SPIN CAPABILITY, RPM	110
PROPELLANT DESIGNATION	TP-H-3135
CASE MATERIAL	TITANIUM
PRODUCTION STATUS	FLIGHT-PROVEN

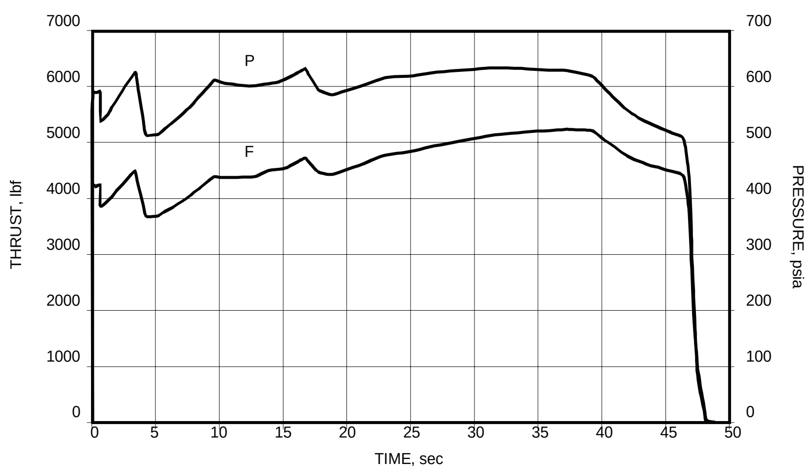
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 27H
TE-M-1157



The STAR 27H was developed as the apogee kick motor for NASA's Interstellar Boundary Explorer (IBEX) mission in 2006 and completed qualification testing in July 2007. The STAR 27H is an updated version of the previously qualified STAR 27 motor and features a titanium case with forward and meridional attach flanges and Northrop Grumman's space-qualified HTPB propellant. The nozzle design, which is also used on the STAR 30C motor, incorporates a contoured nozzle with an integral toroidal igniter and carbon-phenolic exit cone and has flown on over 20 successful missions.



MOTOR DIMENSIONS

Motor diameter, in. 27.3

Motor length, in. 48.0

MOTOR PERFORMANCE (70°F VACUUM)*

Burn time/action time, sec 46.3/47.3

Ignition delay time, sec 0.150

Burn time average chamber pressure, psia 596

Maximum chamber pressure, psia 633

Total impulse, lbf-sec 219,195

Propellant specific impulse, lbf-sec/lbm 294.3

Effective specific impulse, lbf-sec/lbm 291.4

Burn time average thrust, lbf 4,650

Maximum thrust, lbf 5,250

NOZZLE

Initial throat diameter, in. 2.20

Exit diameter, in. 19.89

Expansion ratio, initial 81.7:1

WEIGHTS, LBM

Total loaded 810.9

Propellant (including 0.5 lbm igniter propellant 744.8

Case assembly 21.8

Nozzle assembly 29.0

Total inert 66.1

Burnout 58.8

Propellant mass fraction 0.92

TEMPERATURE LIMITS

Operation .... 40 to 90°F

Storage .... 40 to 100°F

SPIN CAPABILITY, RPM 110

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL .... TITANIUM

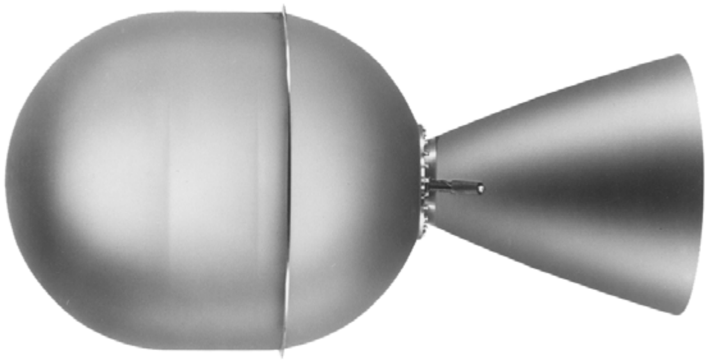
PRODUCTION STATUS .... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

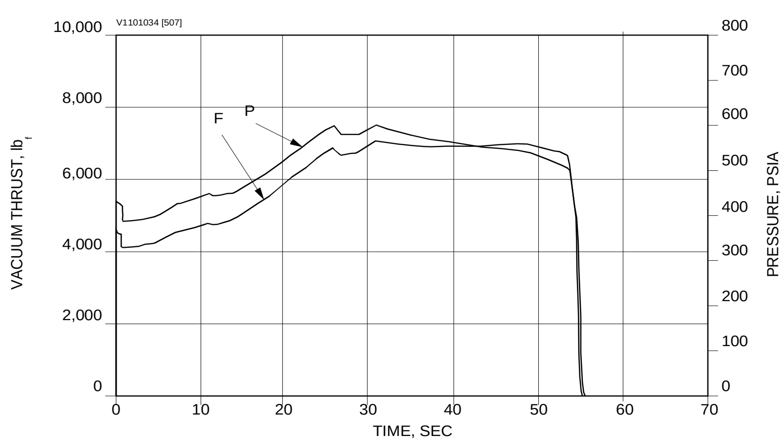
northropgumman.com

STAR 30 SERIES

STAR 30BP
TE-M-700-20



The STAR 30BP rocket motor serves as the apogee kick motor for several different satellite manufacturers such as RCA/GE/Lockheed Martin, Hughes/Boeing, and Northrop Grumman. The design incorporates an 89%-solids hydroxyl-terminated polybutadiene (HTPB) propellant in a 6Al-4V titanium case insulated with silica-filled ethylene propylene diene monomer (EPDM) rubber. This motor was the prototype for a head-end web grain design with an integral toroidal igniter incorporated into the submerged nozzle. The STAR 30BP was qualified in 1984 and has flown from Ariane, Space Shuttle, and Delta.



MOTOR DIMENSIONS

Motor diameter, in.	30.0
Motor length, in.	59.3

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec	54/55
Ignition delay time, sec	0.150
Burn time average chamber pressure, psia	514
Maximum chamber pressure, psia	595
Total impulse, lbf-sec	328,455
Propellant specific impulse, lbf-sec/lbm	294.9
Effective specific impulse, lbf-sec/lbm	292.3
Burn time average thrust, lbf	5,985
Maximum average thrust, lbf	6,945

NOZZLE

Initial throat diameter, in.	2.68
Exit diameter, in.	23.0
Expansion ratio, initial	73.7:1

WEIGHTS, LBM

Total loaded*	1,196.7
Propellant (including 0.6 lbm igniter propellant)	1,113.6
Case assembly	30.5
Nozzle/igniter assembly (excluding igniter propellant)	33.8
Total inert*	83.1
Burnout*	72.4
Propellant mass fraction*	0.93*

Excluding remote S&A/ETA

TEMPERATURE LIMITS

Operation	40º-90°F
Storage	40º-100°F

SPIN EXPERIENCE, RPM	100
PROPELLANT DESIGNATION	TP-H-3340
CASE MATERIAL	TITANIUM
PRODUCTION STATUS	FLIGHT-PROVEN

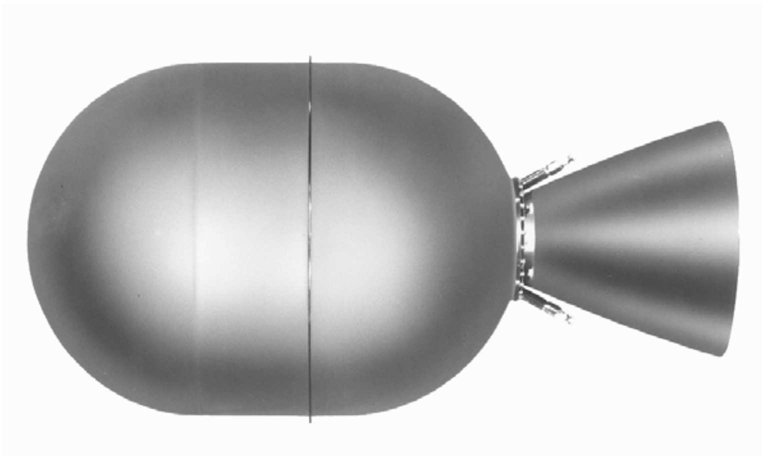
Note: Design has been ground tested with a 20% offload

For more information, contact:
starmotors@ngc.com.

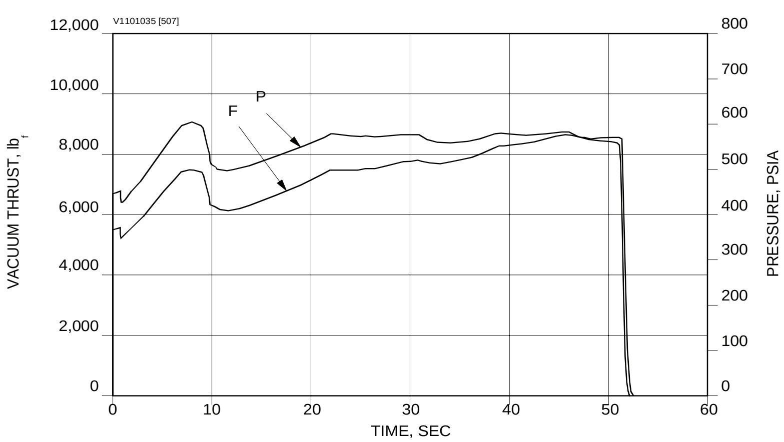
northropgumman.com

STAR 30C
TE-M-700-18

NORTHROP GRUMMAN



The STAR 30C was qualified in 1985 as an apogee kick motor for the RCA/GE/Lockheed Martin Series 3000 satellites. It currently serves on the Hughes/Boeing Satellite Systems HS-376 spacecraft. The case design incorporates an elongated cylindrical section, making the case 5 inches longer than the STAR 30BP case. Like the STAR 30BP, the STAR 30C uses an 89% solids HTPB propellant in a 6Al-4V titanium case insulated with silica-filled EPDM rubber. It has a contoured nozzle with an integral toroidal igniter and a carbon-phenolic exit cone. However, the nozzle is truncated 5 inches to maintain nearly the same overall length as the STAR 30BP. The STAR 30C has flown since 1985 from the Space Shuttle, Ariane, Long March, and Delta.



MOTOR DIMENSIONS

Motor diameter, in. 30.0
Motor length, in. 58.8

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 51/52
Ignition delay time, sec 0.15
Burn time average chamber pressure, psia..........552
Maximum chamber pressure, psia 604
Total impulse, lbf-sec 376,095
Propellant specific impulse, lbf-sec/lbm............288.8
Effective specific impulse, lbf-sec/lbm 286.4
Burn time average thrust, lbf 7,300
Maximum thrust, lbf 8,450

NOZZLE

Initial throat diameter, in. 2.89
Exit diameter, in. 19.7
Expansion ratio, initial.....................................46.4:1

WEIGHTS, LBM

Total loaded*..1,389.3
Propellant (including igniter propellant)
....1,302.5
Case assembly 35.7
Nozzle/igniter assembly
(excluding igniter propellant) ....
Total inert*..84.8
Burnout*...74.2
Propellant mass fraction*....................................0.94
*Excluding remote S&A/ETA

TEMPERATURE LIMITS

Operation.. 40º-90°F
Storage.. 40º-100°F

SPIN EXPERIENCE, RPM 100

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL ....TITANIUM

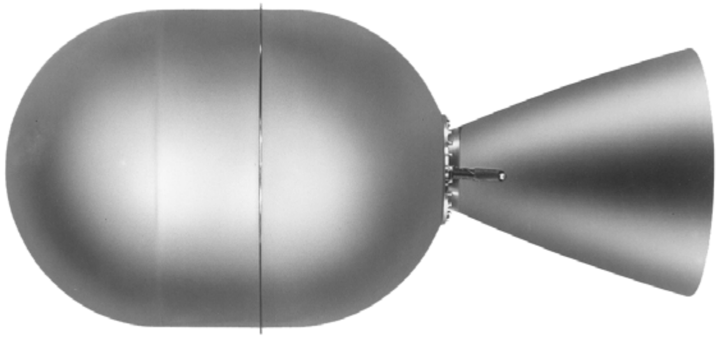
PRODUCTION STATUS....... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

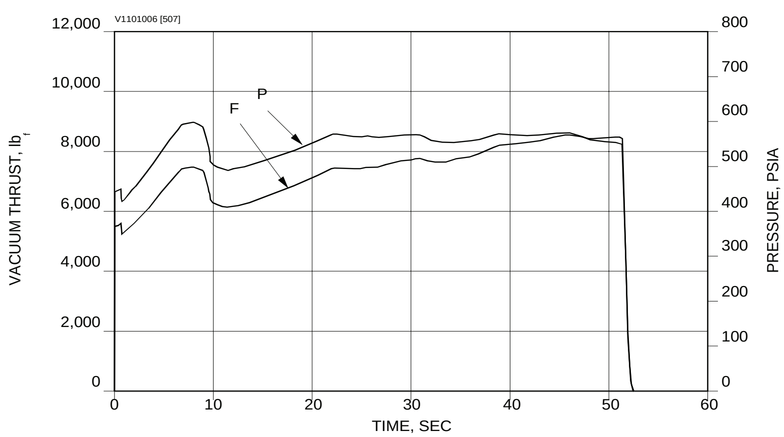
northropgumman.com

STAR 30C/BP
TE-M-700-25

NORTHROP GRUMMAN



The STAR 30C/BP rocket motor combines the flight-qualified STAR 30C motor case with the same flight-qualified nozzle assembly as the STAR 30BP and STAR 30E motors. No ground qualification test was performed before the first flight. This combination increases the overall motor length and improves the delivered specific impulse. The STAR 30C/BP has flown on the Hughes/BSS HS-376 and Orbital Sciences Start-1 Bus satellites. The design incorporates an 89% solids HTPB propellant in a 6Al-4V titanium case insulated with silica-filled EPDM rubber. It has a contoured nozzle with an integral toroidal igniter and a carbon-phenolic exit cone.



MOTOR DIMENSIONS
Motor diameter, in. 30.0
Motor length, in. 64.3

MOTOR PERFORMANCE (70°F VACUUM)
Burn time/action time, sec 51/52
Ignition delay time, sec 0.08
Burn time average chamber pressure, psia 552
Maximum chamber pressure, psia 604
Total impulse, lbf-sec 383,270
Propellant specific impulse, lbf-sec/lbm 294.2
Effective specific impulse, lbf-sec/lbm 291.8
Burn time average thrust, lbf 7,400
Maximum thrust, lbf 8,550

NOZZLE
Initial throat diameter, in. 2.89
Exit diameter, in. 23.0
Expansion ratio, initial/average 63.2:1

WEIGHTS, LBM
Total loaded* 1,393.6
Propellant (including 0.6 lbm igniter propellant) 1,302.5
Case assembly 35.7
Nozzle/igniter assembly (including igniter propellant) 34.5
Total inert* 90.6
Burnout* 79.6
Propellant mass fraction* 0.93
*Excluding remote S&A/ETA

TEMPERATURE LIMITS
Operation .... 40º-90°F
Storage .... 40º-100°F

SPIN EXPERIENCE, RPM 100

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL .... TITANIUM

PRODUCTION STATUS .... FLIGHT-PROVEN

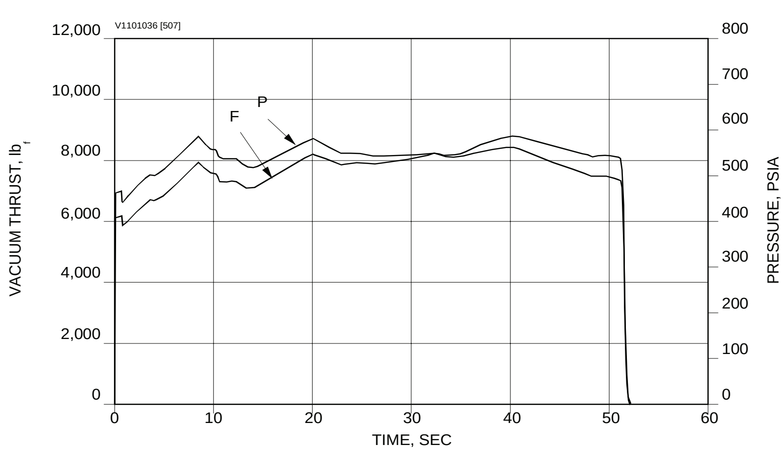
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 30E
TE-M-700-19

NORTHROP GRUMMAN

The STAR 30E serves as an apogee kick motor. Qualified in December 1985, the design incorporates a case cylinder that is 7 inches longer than the STAR 30BP and a nozzle assembly with the same length exit cone as the STAR 30BP. It utilizes an 89% solids HTPB propellant in a 6Al-4V titanium case insulated with silica-filled EPDM rubber. It has a contoured nozzle with an integral toroidal igniter and a carbon-phenolic exit cone. The STAR 30E first flew as an apogee kick motor for Skynet in a December 1988 launch from Ariane.



MOTOR DIMENSIONS
Motor diameter, in. 30.0
Motor length, in. 66.3

MOTOR PERFORMANCE (70°F VACUUM)
Burn time/action time, sec 51.1/51.8
Ignition delay time, sec 0.20
Burn time average chamber pressure, psia 537
Maximum chamber pressure, psia 590
Total impulse, lbf-sec 407,550
Propellant specific impulse, lbf-sec/lbm 292.8
Effective specific impulse, lbf-sec/lbm 290.4
Burn time average thrust, lbf 7,900
Maximum thrust, lbf 8,850

NOZZLE
Initial throat diameter, in. 3.0
Exit diameter, in. 23.0
Expansion ratio, initial 58.6:1

WEIGHTS, LBM
Total loaded* 1,485.7
Propellant (including 0.6 lbm igniter propellant) 1,392.0
Case assembly 37.9
Nozzle/igniter assembly
(excluding igniter propellant) 33.6
Total inert* 93.7
Burnout* 82.5
Propellant mass fraction* 0.93*
Excluding remote S&A/ETA

TEMPERATURE LIMITS
Operation .... 40º-90°F
Storage .... 40º-100°F

SPIN EXPERIENCE, RPM 100

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL .... TITANIUM

PRODUCTION STATUS .... FLIGHT-PROVEN

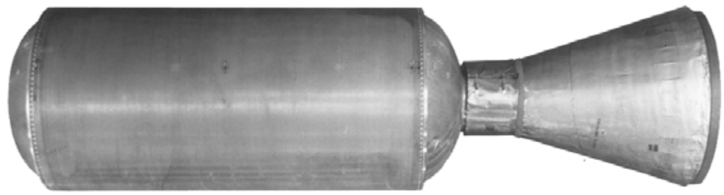
For more information, contact:
starmotors@ngc.com.

northropgumman.com

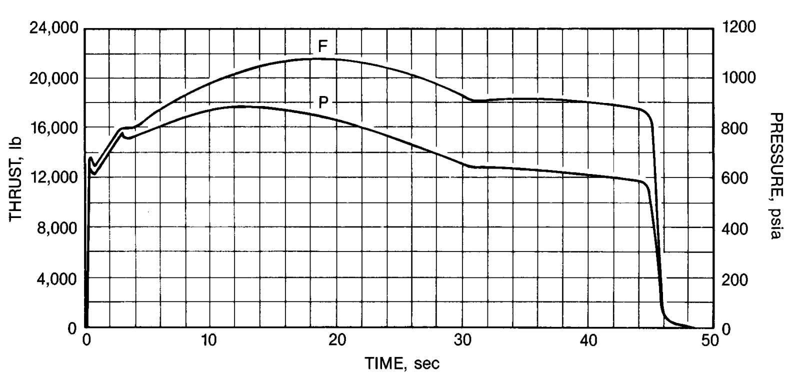
STAR 31 AND 37 SERIES

STAR 31
TE-M-762

NORTHROP GRUMMAN



The STAR 31 Antares III is a third-stage rocket motor developed and qualified (1978 to 1979) for Vought Corporation's Scout launch vehicle. The design incorporates an 89% solids HTPB propellant in a Kevlar® filament-wound case insulated with silica-filled EPDM rubber. The STAR 31 first flew from the Western Test Range in October 1979 to launch the MAGSAT satellite.



MOTOR DIMENSIONS

Motor diameter, in. 30.1
Motor length, in. 113

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 45/46
Ignition delay time, sec 0.14
Burn time average chamber pressure, psia 712
Maximum chamber pressure, psia 865
Total impulse, lbf-sec 840,000
Propellant specific impulse, lbf-sec/lbm 296.3
Effective specific impulse, lbf-sec/lbm 293.5
Burn time average thrust, lbf 18,500
Maximum thrust, lbf 21,500

NOZZLE

Initial throat diameter, in. 3.74
Exit diameter, in. 28.67
Expansion ratio, initial 58:1

WEIGHTS, LBM

Total loaded 3,072
Propellant (including igniter propellant) 2,835
Case assembly 92
Nozzle assembly 65.5
Total inert 237
Burnout 210
Propellant mass fraction 0.92/0.93
(with/without external insulation)

TEMPERATURE LIMITS

Operation .... 40°-90°F
Storage .... 20°-100°F

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL

.... KEVLAR-EPOXY COMPOSITE

PRODUCTION STATUS

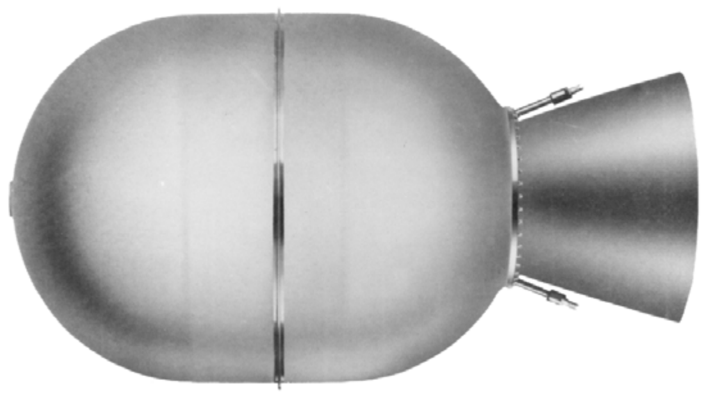
.... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

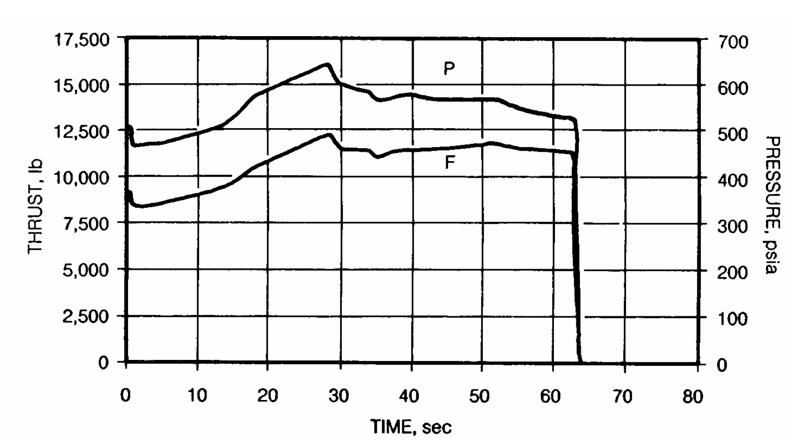
northropgumman.com

STAR 37FM
TE-M-783

NORTHROP GRUMMAN



The STAR 37FM rocket motor was developed and qualified (1984) for use as an apogee kick motor on TRW FLTSATCOM, NASA ACTS, GE/LM, and GPS Block IIR satellites and served as the third stage on Boeing's Delta II Med-Lite launch vehicle. The motor design features a titanium case, a 3-D carbon-carbon throat, and a carbon-phenolic exit cone. The first flight of the STAR 37FM occurred in 1986.



MOTOR DIMENSIONS

Motor diameter, in. 36.8
Motor length, in. 66.5

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 62.7/63.3
Ignition delay time, sec 0.13
Burn time average chamber pressure, psia 540
Maximum chamber pressure, psia 642
Total impulse, lbf-sec 686,145
Propellant specific impulse, lbf-sec/lbm 291.9
Effective specific impulse, lbf-sec/lbm 289.8
Burn time average thrust, lbf 10,827
Maximum thrust, lbf 12,325

NOZZLE

Initial throat diameter, in. 3.52
Exit diameter, in. 24.45
Expansion ratio, initial 48.2:1

WEIGHTS, LBM

Total loaded* 2,530.8
Propellant (including igniter propellant) 2,350.1
Case assembly 71.1
Nozzle assembly/igniter assembly (excluding igniter propellant) 75.0
Total inert 180.1
Burnout* 162.5
Propellant mass fraction 0.93
*Excluding ETA lines and S&A

TEMPERATURE LIMITS

Operation .... 20°-110°F
Storage .... 40°-110°F

SPIN EXPERIENCE, RPM 60

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL .... TITANIUM

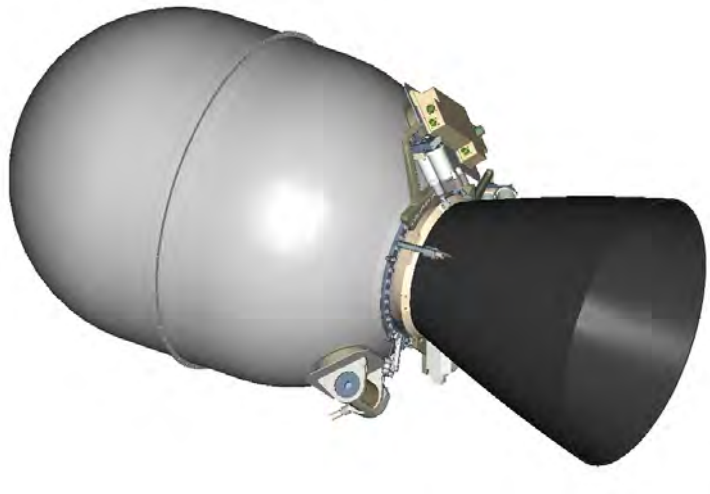
PRODUCTION STATUS .... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

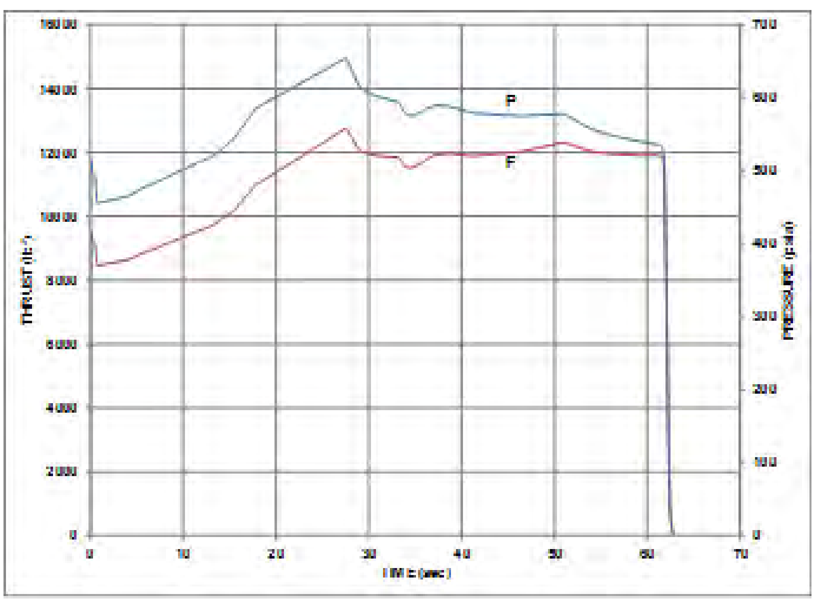
northropgumman.com

STAR 37FMV
TE-M-1139

NORTHROP GRUMMAN



The STAR 37FMV rocket motor was developed for use as an upper stage motor for missions requiring three-axis control. The motor design features a titanium case, a 3-D carbon-carbon throat, a carbon-phenolic exit cone, and an electromechanically actuated flexseal thrust vector control nozzle.



MOTOR DIMENSIONS

Motor diameter, in. 36.8

Motor length, in. 75.5

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 62.7/63.3

Ignition delay time, sec 0.13

Burn time average chamber pressure, psia 540

Maximum chamber pressure, psia 642

Total impulse, lbf-sec 694,680

Propellant specific impulse, lbf-sec/lbm 296.6

Effective specific impulse, lbf-sec/lbm 293.7

Burn time average thrust, lbf 10,980

Maximum thrust, lbf 12,500

NOZZLE

Initial throat diameter, in. 3.52

Exit diameter, in. 29.46

Expansion ratio, initial 70.0:1

Type .... VECTORABLE ± 4 DEG

WEIGHTS, LBM

Total loaded* 2,578.8

Propellant (including igniter propellant) 2,345.3

Case assembly 71.1

Nozzle assembly/igniter assembly
(excluding igniter propellant) 99.0

Total inert 236.7

Burnout* 216.9

Propellant mass fraction 0.91

*Excluding ETA lines and S&A

TEMPERATURE LIMITS

Operation .... 40°-90°F

Storage .... 40°-110°F

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL ....TITANIUM

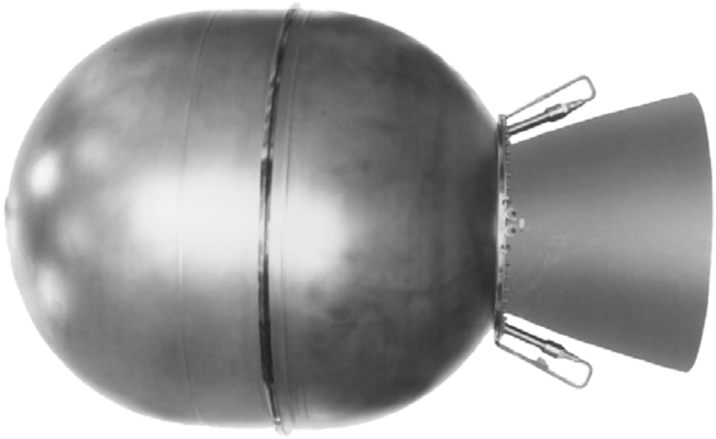
PRODUCTION STATUS......... DEVELOPMENT

For more information, contact:
starmotors@ngc.com.

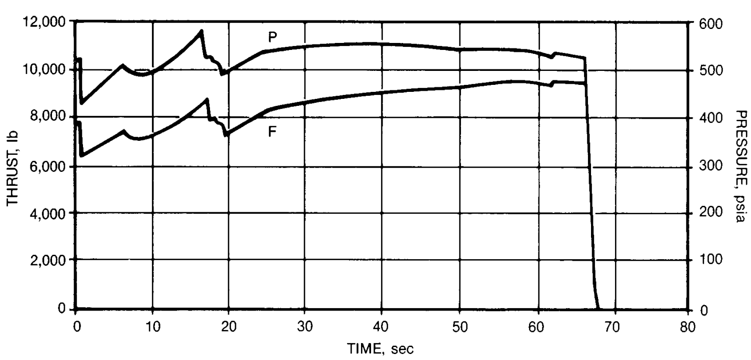
northropgumman.com

STAR 37XFP
TE-M-714-16/-17

NORTHROP GRUMMAN



The STAR 37XFP TE-M-714-16 configuration was qualified as the orbit insertion motor for the Rockwell/Boeing Global Positioning System Block II as well as for low earth orbit insertion for RCA/GE/Lockheed Martin's Television Infrared Observation Satellite (TIROS) and the Defense Meteorological Satellite Program (DMSP), and as an apogee motor for RCA/GE/Lockheed Martin series-4000 satellites. The TE-M-714-17 configuration was qualified as the apogee motor for the RCA SATCOM KuBand satellite. The STAR 37XFP motor can be used as a replacement for the STAR 37F motor, which has been discontinued. It features a titanium case, 3-D carbon-carbon throat, carbon-phenolic exit cone, and a head-end web grain design. This motor first flew from the Space Shuttle as an apogee kick motor for SATCOM in 1985 and has also been launched from Ariane and Delta launch vehicles.



MOTOR DIMENSIONS

Motor diameter, in. 36.7
Motor length, in. 59.2

MOTOR PERFORMANCE (55°F VACUUM)

Burn time/action time, sec 66/67
Ignition delay time, sec 0.12
Burn time average chamber pressure, psia 527
Action time average chamber pressure, psia 523
Maximum chamber pressure, psia 576
Total impulse, lbf-sec 570,450
Propellant specific impulse, lbf-sec/lbm 292.6
Effective specific impulse, lbf-sec/lbm 290.0
Burn time average thrust, lbf 8,550
Action time average thrust, lfb 8,480
Maximum thrust, lbf 9,550

NOZZLE

Initial throat diameter, in. 3.18
Exit diameter, in. 23.51
Expansion ratio, initial/average 54.8/48.7
Type .... FIXED, CONTOURED

WEIGHTS, LBM (EXCLUDING REMOTE S&A/ETA)

Total loaded 2,107.1
Propellant (including igniter propellant) 1,948.2
Case assembly 58.1
Nozzle assembly (excluding igniter propellant) 70.0
Internal insulation 26.8
Liner 1.2
Miscellaneous 2.8
Total inert (excluding igniter propellant) 159.6
Burnout 140.3
Propellant mass fraction 0.925
S&A/ETA 4.2

TEMPERATURE LIMITS

Operation .... -32°-100°F
Storage .... -40°-90°F

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL .... 6Al-4V TITANIUM

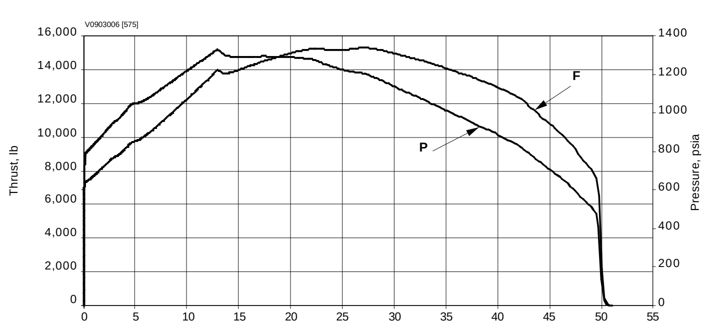
PRODUCTION STATUS .... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 37GV
TE-M-1007-1

The STAR 37GV composite case rocket motor was designed to provide increased specific impulse and reduced inert mass to achieve a high mass fraction. It incorporates an electromechanical flexseal thrust vector control system that provides ±4-degree vectorability using electromechanical actuators. Mid-cylinder, head end, aft end, or custom skirts can be implemented easily to meet specific interface requirements. The STAR 37GV was demonstrated in a successful December 1998 static firing.



MOTOR DIMENSIONS
Motor diameter, in. 35.2
Motor length, in. 66.2

MOTOR PERFORMANCE (70°F, vacuum)**
Burn time/action time, sec 49.0/50.2
Ignition delay time, sec 0.16
Burn time average chamber pressure, psia....... 1,050
Maximum chamber pressure, psia 1,350
Total impulse, lbf-sec 634,760
Propellant specific impulse, lbf-sec/lbm............ 295.5
Effective specific impulse, lbf-sec/lbm 293.5
Burn time average thrust, lbf 12,800
Maximum thrust, lbf 15,250

NOZZLE
Initial throat diameter, in. 2.5
Exit diameter, in. 23.4
Expansion ratio, initial.................................... 88.2:1
Type.................................. VECTORABLE, ±4 DEG

WEIGHTS, LBM*
Total loaded 2,391
Propellant 2,148
Case assembly 153.5
Nozzle assembly 75.6
Total inert 243.0
Burnout 228.6
Propellant mass fraction 0.90

TEMPERATURE LIMITS
Operation.. 40°- 90°F
Storage .... 40°-100°F

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL
....................GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS......... DEVELOPMENT

* Weights do not include TVA system hardware (actuators, brackets, controller, etc.) and reflect test motor configuration

** Motor performance reflects test motor configuration. By optimizing the case design and increasing the operating pressure, we estimate that the flight weight motor will result in a 15% performance increase

For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 48 SERIES

STAR 48A
TE-M-799-1

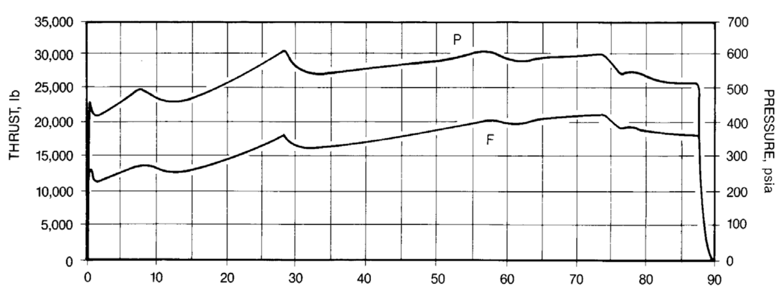
NORTHROP GRUMMAN

SHORT NOZZLE

The STAR 48A motor was designed and tested in 1984 as an increased payload capability version of the basic STAR 48 by incorporating an 8-inch stretch of the motor case. The short nozzle version is designed to fit within the same 80-inch envelope as the long nozzle versions of the STAR 48 and 48B.

The design uses a high-energy propellant and high-strength titanium case. The submerged nozzle uses a carbon-phenolic exit cone and a 3-D carbon-carbon throat.

The case features forward and aft mounting flanges and multiple tabs for attaching external hardware that can be relocated or modified for varying applications without requalification.



MOTOR DIMENSIONS

Motor diameter, in. 49.0
Motor length, in. 80.0

MOTOR PERFORMANCE (75°F VACUUM)**

Burn time/action time, sec 87.2/88.2
Ignition delay time, sec 0.100
Burn time average chamber pressure, psia 543
Maximum chamber pressure, psia 607
Total impulse, lbf-sec 1,528,400
Propellant specific impulse, lbf-sec/lbm 285.3
Effective specific impulse, lbf-sec/lbm 283.4
Burn time average thrust, lbf 17,350
Maximum thrust, lbf 21,150

NOZZLE

Initial throat diameter, in. 4.49
Exit diameter, in. 25.06
Expansion ratio, initial 31.2:1

WEIGHTS, LBM

Total loaded* 5,673.7
Propellant (including igniter propellant) 5,357.2
Case assembly 153.6
Nozzle assembly (excluding igniter propellant) 84.4
Total inert 316.5
Burnout* 280.0
Propellant mass fraction* 0.94
*Excluding remote S&A/ETA

TEMPERATURE LIMITS

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

SPIN EXPERIENCE, RPM 80

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL ....TITANIUM

**Calculated thrust and impulse based on static test data

For more information, contact:
starmotors@ngc.com.

northropgumman.com

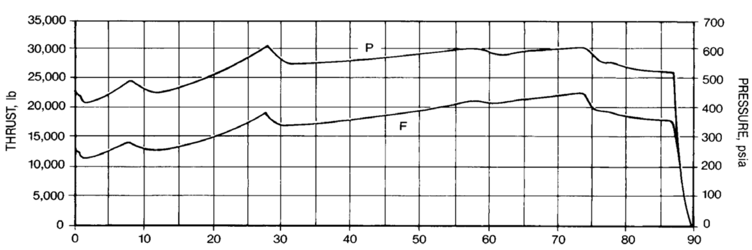
STAR 48A
TE-M-799

LONG NOZZLE

The STAR 48A motor is designed as an increased payload capability version of the basic STAR 48 by incorporating an 8-inch stretch of the motor case. The long nozzle version maximizes performance by also incorporating an 8-inch-longer exit cone, resulting in a longer overall envelope.

The design uses a high-energy propellant and high-strength titanium case. The submerged nozzle uses a carbon-phenolic exit cone and a 3-D carbon-carbon throat.

The case features forward and aft mounting flanges and multiple tabs for attaching external hardware that can be relocated or modified for varying applications without requalification.



MOTOR DIMENSIONS
Motor diameter, in. 49.0
Motor length, in. 88.0

MOTOR PERFORMANCE (75°F VACUUM)
Burn time/action time, sec 87.2/88.2
Ignition delay time, sec 0.100
Burn time average chamber pressure, psia 543
Maximum chamber pressure, psia 607
Total impulse, lbf-sec 1,563,760
Propellant specific impulse, lbf-sec/lbm 291.9
Effective specific impulse, lbf-sec/lbm 289.9
Burn time average thrust, lbf 17,750
Maximum thrust, lbf 21,650

NOZZLE
Initial throat diameter, in. 4.49
Exit diameter, in. 29.5
Expansion ratio, initial 43.1:1

WEIGHTS, lbm
Total loaded* 5,691.1
Propellant (including igniter propellant) 5,357.2
Case assembly 153.6
Nozzle assembly (excluding igniter propellant) 101.8
Total inert 333.9
Burnout* 294.3
Propellant mass fraction* 0.94
*Excluding remote S&A/ETA

TEMPERATURE LIMITS
Operation .... 30°-100°F
Storage .... 30°-100°F

SPIN EXPERIENCE, RPM 80

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL .... TITANIUM

PRODUCTION STATUS .... DEVELOPMENT

For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 48B
TE-M-711-17

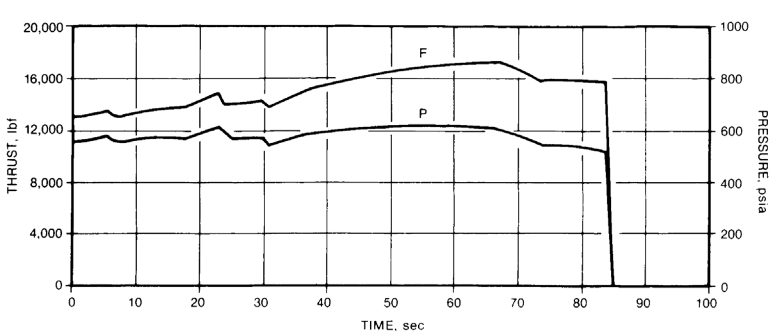
NORTHROP GRUMMAN

SHORT NOZZLE

The short nozzle STAR 48B was qualified in 1984 as a replacement for the short nozzle STAR 48 used on the Space Shuttle Payload Assist Module (PAM). The short nozzle configuration first flew from the Space Shuttle in June 1985 for ARABSAT.

The design uses a high-energy propellant and high-strength titanium case. The submerged nozzle uses a carbon-phenolic exit cone and a 3-D carbon-carbon throat.

The case features forward and aft mounting flanges and multiple tabs for attaching external hardware that can be relocated or modified for varying applications without requalification.



MOTOR DIMENSIONS

Motor diameter, in.	49.0
Motor length, in.	72.0

MOTOR PERFORMANCE (75°F VACUUM)

Burn time/action time, sec	84.1/85.2
Ignition delay time, sec	0.100
Burn time average chamber pressure, psia	579
Maximum chamber pressure, psia	618
Total impulse, lbf-sec	1,275,740
Propellant specific impulse, lbf-sec/lbm	287.9
Effective specific impulse, lbf-sec/lbm	286.0
Burn time average thrust, lbf	15,100
Maximum thrust, lbf	17,110

NOZZLE

Initial throat diameter, in.	3.98
Exit diameter, in.	25.06
Expansion ratio, initial	39.6:1

WEIGHTS, LBM

Total loaded*	4,705.4
Propellant (including igniter propellant)	4,431.2
Case assembly	128.5
Nozzle assembly (excluding igniter propellant)	81.2
Total inert*	274.2
Burnout*	245.4
Propellant mass fraction*	0.94

*Excluding remote S&A/ETA

TEMPERATURE LIMITS

Operation	30°-100°F
Storage	30°100°F

SPIN EXPERIENCE, RPM 80

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL ....TITANIUM

PRODUCTION STATUS....... FLIGHT-PROVEN

For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 48B
TE-M-711-18

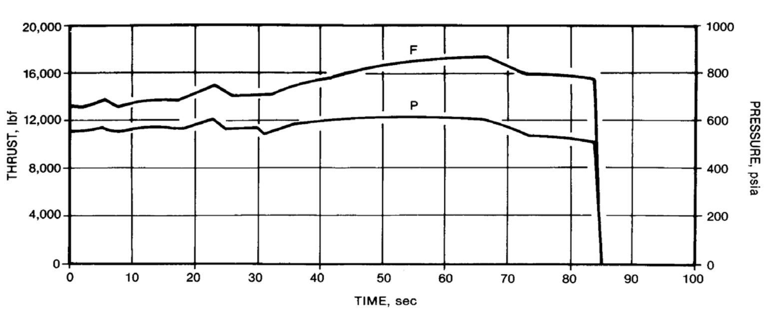
NORTHROP GRUMMAN

LONG NOZZLE

The long nozzle STAR 48B was qualified in 1984 as a replacement for the long nozzle STAR 48 for the Delta II launch vehicle third stage Payload Assist Module (PAM)-Delta. The long nozzle version first flew in June 1985 from the Space Shuttle to place the Morelos satellite in orbit.

The design uses a high-energy propellant and high-strength titanium case. The submerged nozzle uses a carbon-phenolic exit cone and a 3-D carbon-carbon throat.

The case features forward and aft mounting flanges and multiple tabs for attaching external hardware that can be relocated or modified for varying applications without requalification.



MOTOR DIMENSIONS

Motor diameter, in. 49.0
Motor length, in. 80.0

MOTOR PERFORMANCE (75°F vacuum)

Burn time/action time, sec 84.1/85.2
Ignition delay time, sec 0.100
Burn time average chamber pressure, psia..........579
Maximum chamber pressure, psia 618
Total impulse, lbf-sec 1,303,700
Propellant specific impulse, lbf-sec/lbm............294.2
Effective specific impulse, lbf-sec/lbm 292.1
Burn time average thrust, lbf 15,430
Maximum thrust, lbf 17,490

NOZZLE

Initial throat diameter, in. 3.98
Exit diameter, in. 29.5
Expansion ratio, initial.....................................54.8:1

WEIGHTS, LBM

Total loaded 4,720.8
Propellant (including igniter propellant) 4,431.2
Case assembly 128.5
Nozzle assembly (excluding igniter propellant) ...96.6
Total inert*..289.6
Burnout*...257.8
Propellant mass fraction*....................................0.94
*Excluding remote S&A/ETA

TEMPERATURE LIMITS

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

SPIN EXPERIENCE, RPM 80

PROPELLANT DESIGNATION TP-H-3340

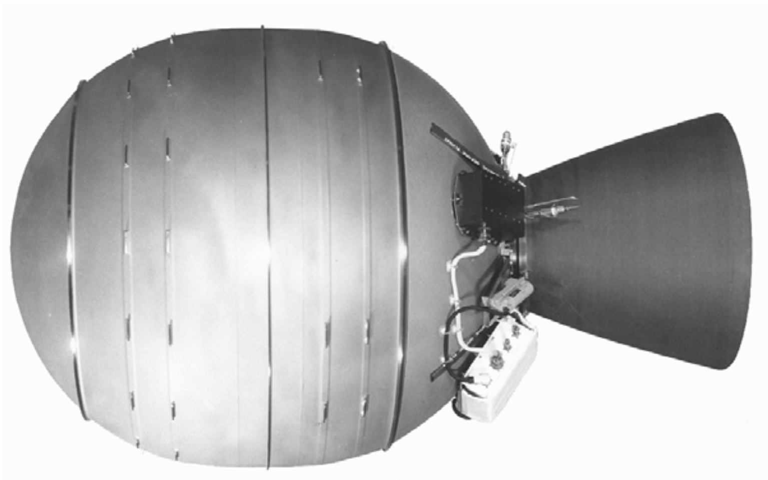
CASE MATERIAL ....TITANIUM

PRODUCTION STATUS....... FLIGHT-PROVEN

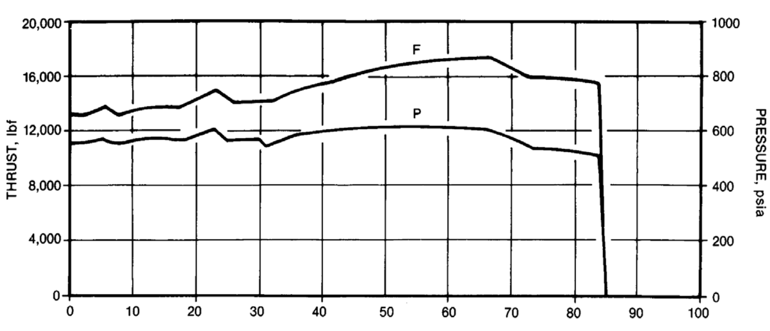
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 48BV
TE-M-940-1



The STAR 48BV has been qualified (1993) as an upper stage for EER System's Conestoga Vehicle. The STAR 48V is derived from the highly successful STAR 48B (TE-M-711 series) rocket motor. The STAR 48V provides the same range of total impulse as the STAR 48B with the long exit cone and includes an electromechanically actuated flexseal nozzle thrust vector control system for use on a nonspinning spacecraft. Case attachment features can be modified or relocated for varying applications without requalification.



MOTOR DIMENSIONS

Motor diameter, in.	49.0
Motor length, in.	81.7

MOTOR PERFORMANCE (70°F vacuum)

Burn time/action time, sec	84.1/85.2
Ignition delay time, sec	0.100
Burn time average chamber pressure, psia	579
Maximum chamber pressure, psia	618
Total impulse, lbf-sec	1,303,700
Propellant specific impulse, lbf-sec/lbm	294.2
Effective specific impulse, lbf-sec/lbm	292.1
Burn time average thrust, lbf	15,430
Maximum thrust, lbf	17,490

NOZZLE

Initial throat diameter, in.	3.98
Exit diameter, in.	29.43
Expansion ratio, initial	54.8:1
Type	VECTORABLE, ±4 DEG

WEIGHTS, LBM

Total loaded	4,772.0
Propellant	4,431.2
Case assembly	128.5
Nozzle assembly	116
Total inert	339.8
Burnout	305.5
Propellant mass fraction	0.93

TEMPERATURE LIMITS

Operation	30°-100°F
Storage	30°-100°F

PROPELLANT DESIGNATION TP-H-3340

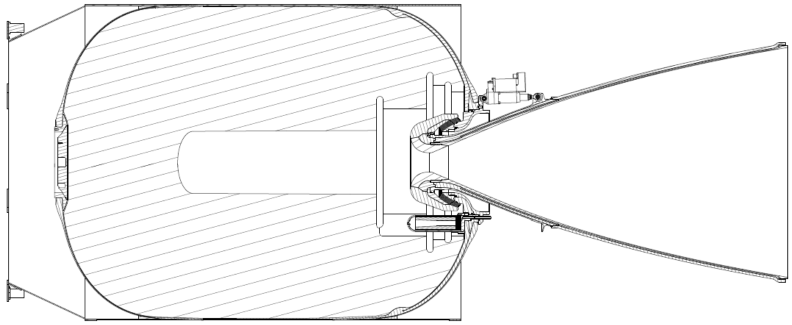
CASE MATERIAL ....TITANIUM

PRODUCTION STATUS....... FLIGHT-PROVEN

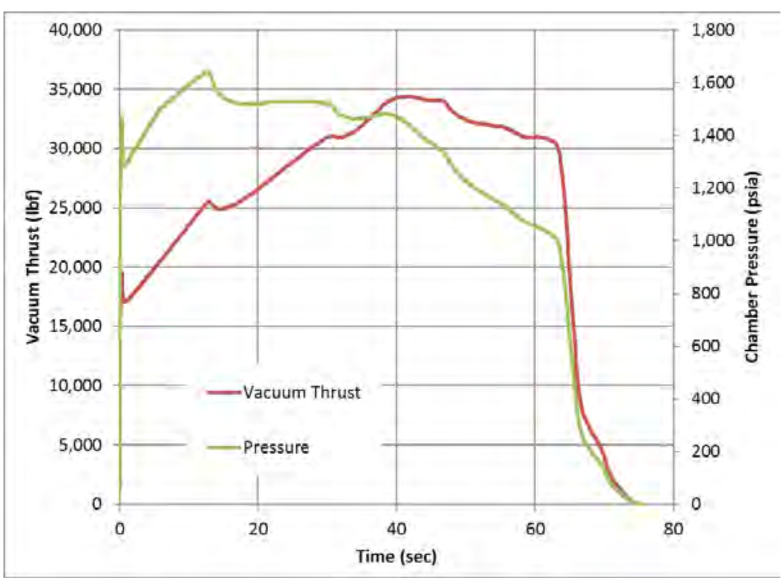
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 48GXV



The STAR 48GXV was conceived and demonstrated as a high-performance upper stage for the Parker Solar Probe program. This motor builds on the heritage STAR 48 family and significantly improves the overall performance by incorporating a composite case, a significant propellant upload and a very high expansion ratio nozzle. A successful demonstration firing was conducted at sea-level conditions in December 2013.



MOTOR DIMENSIONS

Motor diameter, in.	49.0
Motor length, in.	120.0

MOTOR PERFORMANCE (70°F vacuum)

Burn time, sec.	63.2
Burn time average chamber pressure, psia	1,400
Maximum chamber pressure, psia	1,644
Total impulse, lbf-sec	1,911,070
Propellant specific impulse, lbf-sec/lbm	307.7
Effective specific impulse, lbf-sec/lbm	306.0
Burn time average thrust, lbf	29,100
Maximum thrust, lbf	34,380

NOZZLE

Initial throat diameter, in.	2.98
Exit diameter, in.	35.88
Expansion ratio, average	88:1

WEIGHTS, LBM

Total loaded	6,768
Propellant	6,205
Insulated case assembly	339
Nozzle	184
Igniter	2.4
Burnout*	528

*Excludes S&A

TEMPERATURE LIMITS

Operation	50°-100°F
Storage	-30°-100°F

PROPELLANT DESIGNATION TP-H-3532

CASE MATERIAL GRAPHITE EPOXY COMPOSITE

PRODUCTION STATUS.................DEVELOPMENT

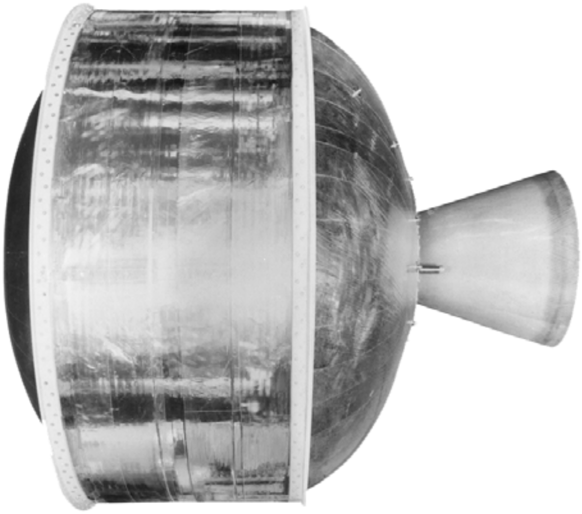
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 63 SERIES

STAR 63D
TE-M-936

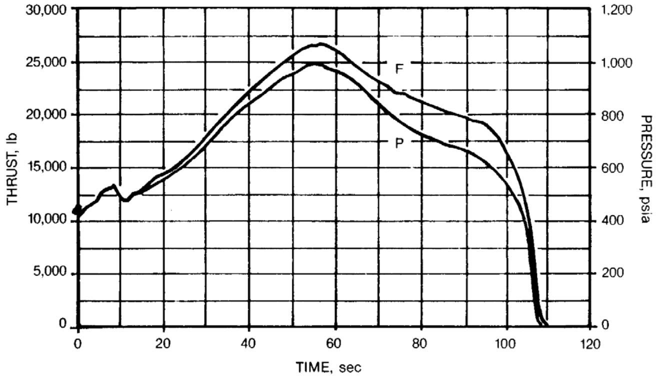
NORTHROP GRUMMAN



The STAR 63, as part of the PAM DII upper stage, was flown from the Space Shuttle. The motor utilizes a head-end web and a carbon-phenolic nozzle. The case material is a Kevlar-epoxy composite, although future motors would be made using a graphite-epoxy composite. Testing of STAR 63 series motors began in 1978 with completion of the PAM DII motor qualification in 1985. The first STAR 63D flight was from the Shuttle in November 1985 to place a defense communication satellite in orbit.

The motor derives its heritage from the Advanced Space Propellant Demonstration (ASPD) and the Improved-Performance Space Motor II (IPSM) programs. On the ASPD program, a delivered specific impulse of over 314 lbf-sec/lbm was demonstrated at Arnold Engineering Development Center (AEDC). On the IPSM II program, a dual-extending exit cone with a gas-deployed skirt was demonstrated at AEDC.

In 1994, an 8-year-old STAR 63D motor was tested with a flexseal nozzle. Designated the STAR 63DV, the motor successfully demonstrated performance of the 5-degree thrust vector control nozzle and electromechanical actuation system.



MOTOR DIMENSIONS

Motor diameter, in.	63.0
Motor length, in.	70.0

MOTOR PERFORMANCE (77°F VACUUM)

Action time, sec	108
Ignition delay time, sec	0.300
Action time average chamber pressure, psia	607
Maximum chamber pressure, psia	957
Total impulse, lbf-sec	2,042,450
Propellant specific impulse, lbf-sec/lbm	285.0
Effective specific impulse, lbf-sec/lbm	283.0
Action time average thrust, lbf	19,050
Maximum thrust, lbf	26,710

NOZZLE

Initial throat diameter, in.	4.174
Exit diameter, in.	21.82
Expansion ratio, initial	27.3:1

WEIGHTS, LBM

Total loaded	7,716.0
Propellant (including igniter propellant)	7,166.5
Case assembly	233.5
Nozzle assembly	134.0
Total inert	550.0
Burnout	508.0
Propellant mass fraction	0.93

TEMPERATURE LIMITS

Operation	30°-100°F
Storage	30°-100°F

SPIN EXPERIENCE, RPM 85

PROPELLANT DESIGNATION TP-H-1202

CASE MATERIAL
....KEVLAR-EPOXY COMPOSITE*

PRODUCTION STATUS.... FLIGHT-PROVEN

* to be replaced with a graphite composite

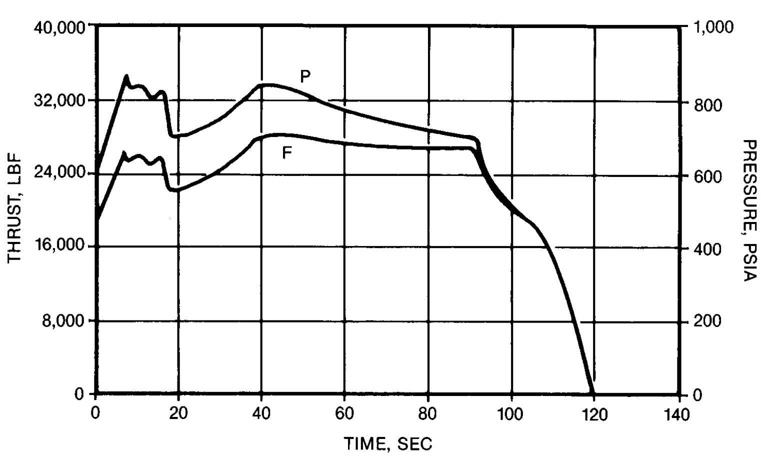
For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 63F
TE-M-963-2

NORTHROP GRUMMAN

The STAR 63F successfully completed qualification in 1990. It has been utilized as a stage for the Long March launch vehicle. The motor is an extended-case version of the STAR 63D to increase the propellant weight. With the addition of a larger nozzle, the STAR 63F delivers nearly a 300 lbf-sec/lbm specific impulse. Like the STAR 63D, the motor case material was qualified with Kevlar-epoxy composite and requires a change to graphite-epoxy composite.



MOTOR DIMENSIONS

Motor diameter, in. 63.1
Motor length, in. 106.7

MOTOR PERFORMANCE (77°F VACUUM)

Action time, sec 120
Ignition delay time, sec 0.335
Action time average chamber pressure, psia 680
Maximum chamber pressure, psia 874
Total impulse, lbf-sec 2,816,700
Propellant specific impulse, lbf-sec/lbm 299.6
Effective specific impulse, lbf-sec/lbm 297.1
Action time average thrust, lbf 23,520
Maximum thrust, lbf 28,160

NOZZLE

Initial throat diameter, in. 4.45
Exit diameter, in. 39.4
Expansion ratio, initial 78:4:1

WEIGHTS, LBM

Total loaded 10,122.9
Propellant (including igniter propellent) 9,401.6
Case assembly 283.3
Nozzle assembly 211.4
Total inert 721.3
Burnout 643.3
Propellant mass fraction 0.93

TEMPERATURE LIMITS

Operation .... 35°-95°F
Storage .... 35°-95°F

SPIN EXPERIENCE, RPM 85

PROPELLANT DESIGNATION TP-H-1202

CASE MATERIAL
.......................KEVLAR-EPOXY COMPOSITE*

PRODUCTION STATUS....... FLIGHT-PROVEN

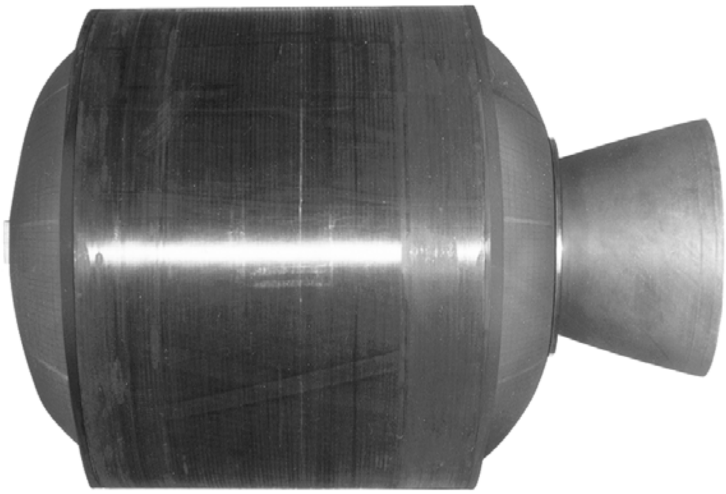
* to be replaced with a graphite composite

For more information, contact:
starmotors@ngc.com.

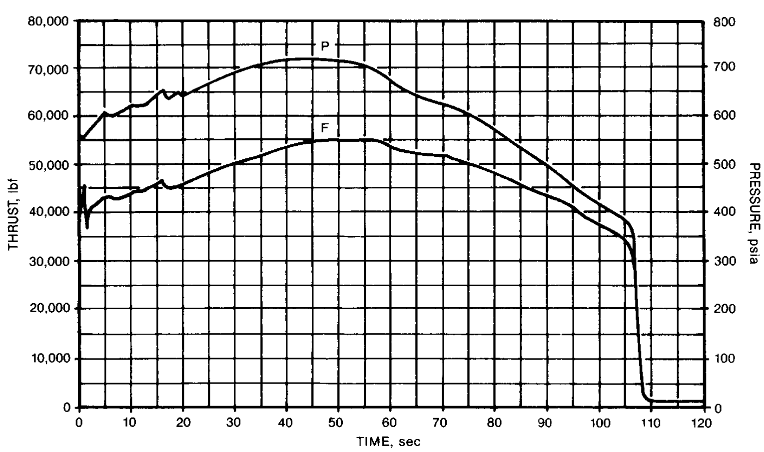
northropgumman.com

STAR 75 SERIES

STAR 75
TE-M-775-1



The STAR 75 demonstration motor was made and tested in December 1985 as a first step in the development and qualification of perigee kick motors in the 9,000- to 17,500-lbm propellant range. The STAR 75 includes many design features and materials proven on previous Northrop Grumman space motors: a slotted, center-perforate propellant grain housed in a graphite-epoxy, filament-wound case and a submerged nozzle with a carbon-phenolic exit cone.



MOTOR DIMENSIONS

Motor diameter, in. 75.0
Motor length, in. 102.0**

MOTOR PERFORMANCE (75°F)

Burn time/action time, sec 105/107
Ignition delay time, sec 0.42
Burn time average chamber pressure, psia 616
Maximum chamber pressure, psia 719
Total impulse, lbf-sec 4,797,090*
Propellant specific impulse, lbf-sec/lbm........... 290.0*
Effective specific impulse, lbf-sec/lbm 288.0*
Burn time average thrust, lbf 45,000*
Maximum thrust, lbf 55,000*

NOZZLE

Initial throat diameter, in. 6.8
Exit diameter, in. 28.5**
Expansion ratio, sea level, initial 17.7:1**

WEIGHTS, LBM

Total loaded 17,783
Propellant (including 4.71 lbm igniter propellant) ....
.... 16,542
Case assembly 864
Nozzle assembly 260
Total inert 1,126.4
Propellant mass fraction 0.93

TEMPERATURE LIMITS

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

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL .... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS...... DEMONSTRATED

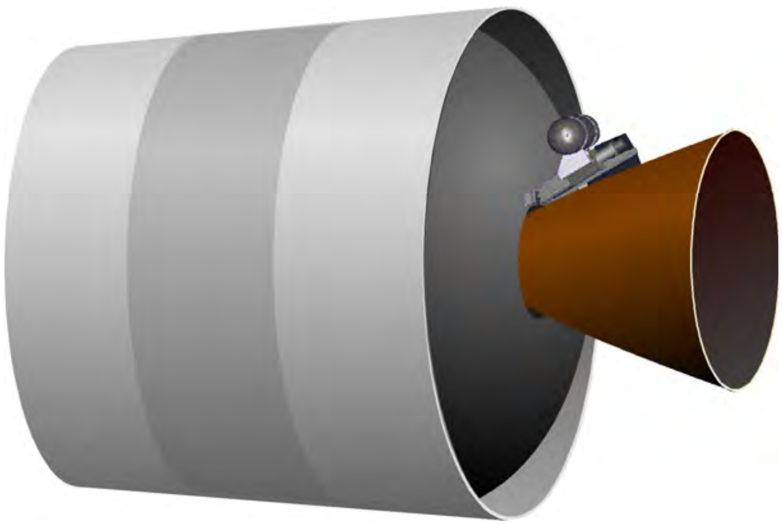
*Predictions under vacuum with flight exit cone
**Demonstration motor

For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR 92 SERIES

STAR 92



The STAR 92 is a derivative of our successful STAR and CASTOR® series of motors. It incorporates the motor heritage of both systems and can be used in either a third-stage or an upper-stage application. This design progressed to the point at which a preliminary design review was held.

MOTOR DIMENSIONS

Motor diameter, in. 93.0
Motor length, in. 143.0

MOTOR PERFORMANCE (75°F VACUUM)

Burn time, sec. 175.6
Average chamber pressure, psia 791
Total impulse, lbf-sec 10,120,100
Propellant specific impulse, lbf-sec/lbm 290.1
Effective specific impulse, lbf-sec/lbm 287.7
Burn time average thrust, lbf 57,570

NOZZLE

Exit diameter, in. 42.4
Expansion ratio, average 39.0:1

WEIGHTS, LBM

Total loaded 37,119
Propellant 34,879
Case 1,418
Nozzle 634
Other 188
Total inert 2,240
Burnout 1,939
Mass fraction 0.94

TEMPERATURE LIMITS

Operation ....30 to 95°F
Storage ....30 to 95°F

PROPELLANT DESIGNATION TP-H-8299

CASE MATERIAL .... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS
............DESIGN CONCEPT (THROUGH PDR)

For more information, contact:
starmotors@ngc.com.

northropgumman.com

STAR STAGES

Northrop Grumman offers a family of modular, high-performance upper stages based on our STAR motor series. By employing common, flight-proven subsystems with available STAR motor assemblies, Northrop Grumman provides customers with optimized upper stages at low development risk. The broad range of available STAR motor sizes and performance, combined with our common avionics and mission-specific structures, allows exceptional flexibility in configuring STAR-based stages to meet mission requirements.

The STAR stage architecture is compatible for use on a variety of launch vehicle applications and can be provided in either a spin or three-axis stabilized configuration. The three-axis stabilized stages include a gimbaled motor nozzle and electromechanical thrust vector control while spin stabilized stages include a fixed motor nozzle and, as required, spin-up, spin-down, and nutation control.

Northrop Grumman uses avionics and pneumatic components, as well as flight software, that are common with our launch vehicle programs to provide the STAR stage with the following onboard capabilities:

- Guidance, navigation, and control
- Mission sequencing
- Attitude control
- Power
- Ordnance initiation
- Telemetry
- Post-separation collision and contamination maneuvers
- Flight termination system (if required)

The mechanical assemblies and interfaces of the STAR stage are designed and qualified to meet the unique requirements of a particular mission. Northrop Grumman provides the structures that interface with the launch vehicle; house the electrical, ordnance, and attitude control subsystems; and support the customer's spacecraft. Depending on the application, the motor can either be part of the primary load path or can be housed within an interstage structure. Northrop Grumman also provides the systems to separate the STAR stage from the launch vehicle as well as to separate the STAR stage from the customer's spacecraft, if required.

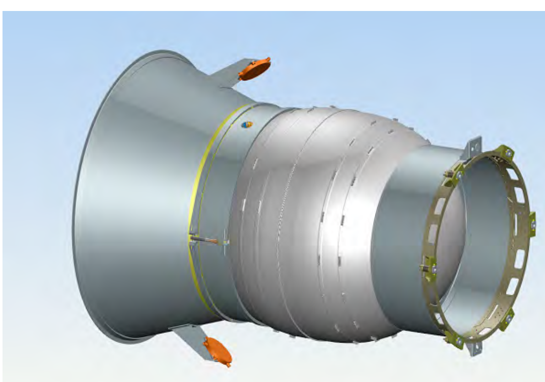
STAR Stage 3700S
for NASA's Lunar Prospector

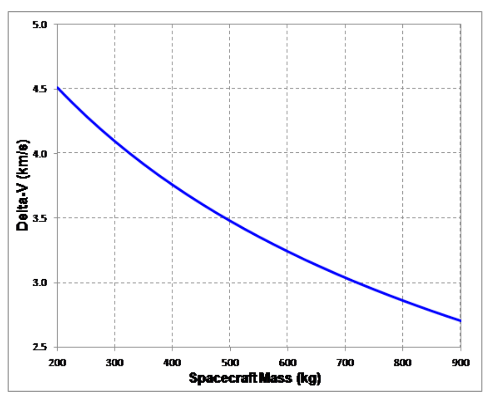
Northrop Grumman has successfully incorporated STAR motor-based stages onto existing Northrop Grumman launch platforms including Pegasus and Minotaur, and configured stages for mating directly with the spacecraft as shown for the Lunar Prospector trans-luner injection stage.

Northrop Grumman is currently developing a STAR stage based on the STAR 48BV motor for a 2018 mission. This mass efficient, three-axis stabilized stage and its capability are shown below. The STAR 48BV stage provides guidance, control, sequencing, and electrical support throughout stage operation. In this application, the STAR 48BV motor is part of the primary load path to optimize mass efficiency. Northrop Grumman provides an adapter to interface the stage with the launch vehicle as well as an avionics assembly that houses the electrical and attitude control systems and provides the interface to the spacecraft. Both the launch vehicle adapter and the spacecraft structural interface can be updated to support a wide array of mechanical interface options.

With the flexibility inherent with our STAR motor performance and our common avionics approach, Northrop Grumman can deliver a STAR stage solution optimized to meet specific mission requirements with low development risk and non-recurring effort.

Inquiries regarding Star Stages motor products should be directed to our business development representatives at starmotors@ngc.com.

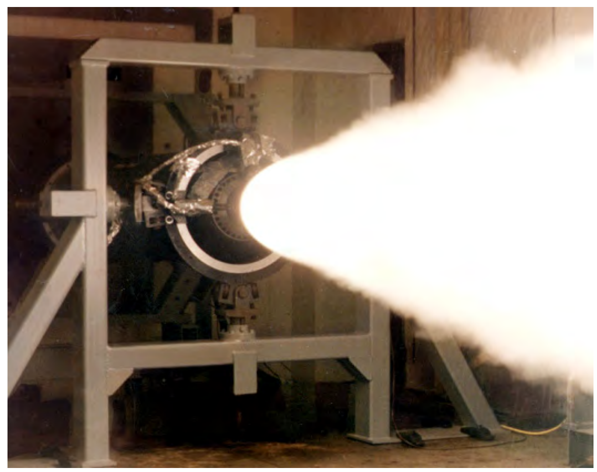




Example Stage Design Based on the STAR 48BV Motor

ADVANCED SOLID AXIAL STAGE (ASAS™) MOTORS

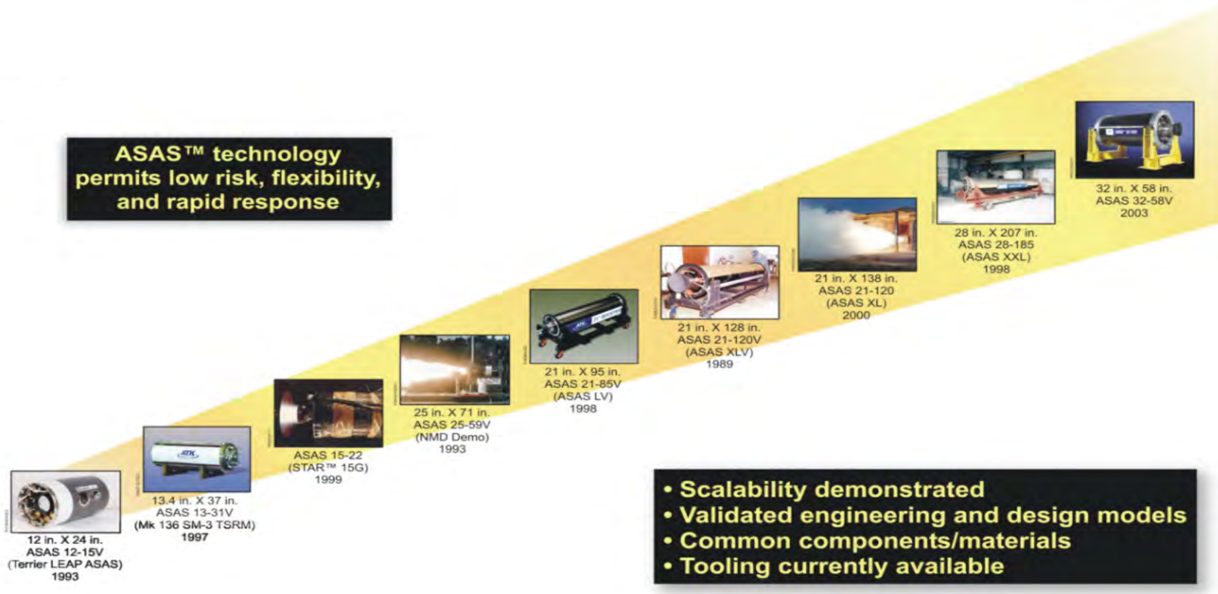
Northrop Grumman's ASAS family of high-performance solid propellant motors is adaptable to a wide variety of applications. These designs incorporate proven design concepts, materials technology, and manufacturing techniques that provide enhanced operational performance. The technologies reflected in these motor designs were identified and developed in more than 425 tests performed as part of technology programs conducted between 1985 and 2003 for the U. S. Air Force and the Missile Defense Agency.



ASAS 21-in. Motor Firing (1998)

The ASAS family of motors employs, as appropriate, design features including the following:

- High-strength, high-stiffness graphite-epoxy composite cases permitting increased operating pressure to increase expansion ratio and enhance motor performance, particularly for demanding interceptor applications
- Carbon-carbon throat materials that minimize throat erosion and related performance losses
- Erosion-resistant Kevlar-filled elastomeric insulation to provide thermal protection at minimum weight
- High-performance conventional and advanced composite solid propellant formulations providing required energy, temperature capability, and insensitive munitions characteristics for each of the motor designs
- Electromechanically actuated, flexseal, or trapped ball thrust vector control nozzle technology
- Mission-specific component technology, including carbon-carbon exit cones, consumable igniters, semiconductor bridge-based ignition systems, integrated hybrid warm/cold-gas attitude control systems, and isolation of multiple pulses with a barrier (rather than bulkhead) insulation system



ASAS component and materials technology is mature, design scalability has been demonstrated, related engineering design models have been validated, and common components and materials are used in all of these booster configurations. These component technologies have been successfully demonstrated in sea level and simulated altitude tests and in successful flight tests.

By applying these proven technologies to new motor designs, Northrop Grumman offers:

1. Reductions in design, analysis, and development cost and schedule with streamlined component- and motor-level test programs

2. Off-the-shelf component and materials technologies with proven scalability across a range of booster configurations. This reduces development risk and ensures that performance meets design specifications

3. Established tooling, manufacturing, and inspection techniques that provide reproducible, high-quality products

The development philosophy for these motors has been to test a somewhat heavyweight prototype or development unit to confirm design margins without risking failure. This first firing is generally conducted at sea level. Scalability of ASAS design concepts and material technology has been demonstrated in motors ranging from 4 to 32 inches in diameter and will soon be demonstrated in a motor at 40-inches diameter.

Graphite-Epoxy Composite Case Winding (21-in. booster)

Flexseal TVC Nozzle Assembly

Motor Static Firing at Simulated Altitude (ASAS AKS-2 Qualification Motor)

SM-3 FTR-1A Missile Launch with ATK TSRM (January 25, 2001)

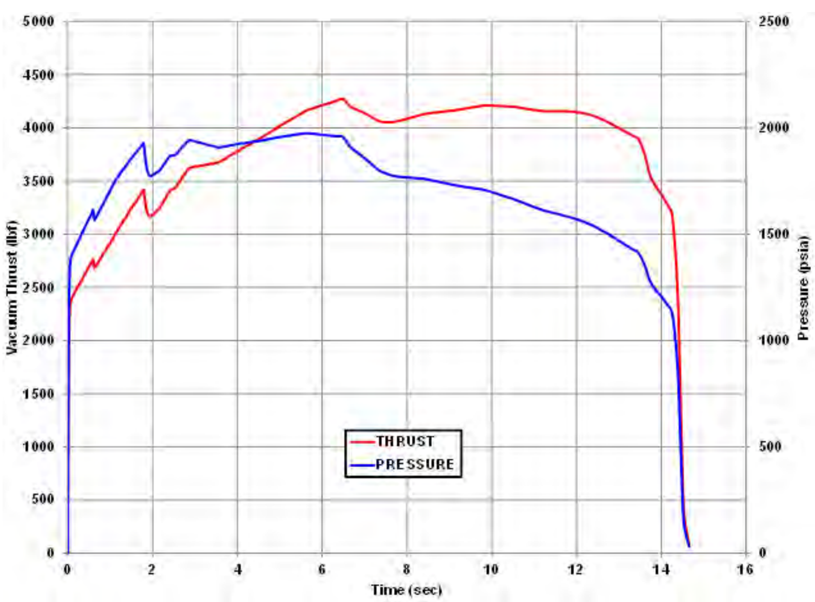
Inquiries regarding ASAS motor products should be directed to our business development representatives at [starmotors@ngc.com.](mailto:starmotors@ngc.com)

ASAS 13-30V

NORTHROP GRUMMAN

FIXED AND VECTORABLE UPPER STAGE MOTOR

The Advanced Solid Axial Stage (ASAS) 13-30V is a high-performance upper-stage motor derived from the Mk 136 Standard Missile 3 Block IA/IB Third Stage Rocket Motor. The motor is 39.3 inches long and nominally designed as an upper-stage motor. The motor uses a pyrogen igniter for highly repeatable ignition performance. The motor incorporates a ± 5-degree nozzle powered by a Northrop Grumman Thrust Vector Electronic Control System (TVECS™) thrust vector actuation system using electromechanical actuators.



MOTOR DIMENSIONS

Motor diameter, in. 13.5
Motor length, in. 39.3

MOTOR PERFORMANCE (70°F VACUUM)

Burn time, sec. 14.3
Burn time average chamber pressure, psia 1,730
Maximum chamber pressure, psia 1,975
Total impulse, lbf-sec 55,180
Propellant specific impulse, lbf-sec/lbm 281.8
Effective specific impulse, lbf-sec/lbm 279.5
Burn time average thrust, lbf 3,825
Maximum thrust, lbf 4,275

NOZZLE

Initial throat diameter, in. 1.1
Exit diameter, in. 6.8
Expansion ratio, initial 38.3:1

WEIGHTS, LBM

Total loaded* 250.9
Propellant 195.8
Case 40.2
Nozzle 7.2
Total inert 55.1
Burnout* 53.5

TEMPERATURE LIMITS

Operation .... 45°-120°F
Storage .... 30°-120°F

PROPELLANT DESIGNATION TP-H-3340A

CASE MATERIAL

.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS .... FLIGHT-PROVEN

*Excludes ETA lines, safe and arm device, battery, and controller

For more information, contact:
starmotors@ngc.com.

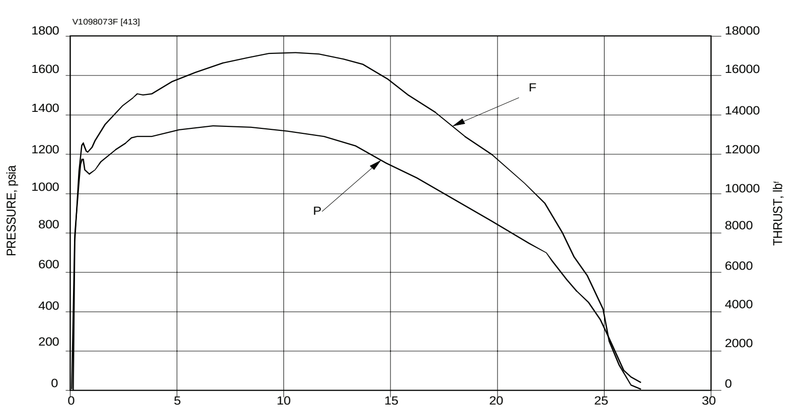
northropgumman.com

ASAS 21-85V
TE-M-1031-1

NORTHROP GRUMMAN

The ASAS 21-85V is a solid rocket motor with a graphite-composite case that was developed for sounding rockets and high-performance guided booster applications. The initial 21-inch motor static test was conducted to demonstrate application and scaling of ASAS technology to vertical launch system-compatible large booster designs in April 1998. The design incorporated a 4.5-degree thrust vector control nozzle and a low-temperature capable propellant.

Early test efforts led to a June 1999 test for the Air Force Research Laboratory that incorporated a fixed nozzle (blast tube) arrangement to evaluate the use of low-cost materials and design concepts. The ASAS II version of the motor also incorporated a new propellant (TP-H-3516A) with 20% aluminum, 88.5% total solids, and 1% plasticizer.



MOTOR DIMENSIONS

Motor diameter, in.	20.4
Motor length, in.	95.5

MOTOR PERFORMANCE (75°F SEA LEVEL)

Burn time/action time, sec	24.4/25.7
Ignition delay time, sec	0.012
Burn time average chamber pressure, psia	1,100
Maximum chamber pressure, psia	1,350
Total impulse, lbf-sec	347,400
Propellant specific impulse, lbf-sec/lbm	240.6
Burn time average thrust, lbf	14,000
Maximum thrust, lbf	17,250

NOZZLE

Initial throat diameter, in.	3.1
Exit diameter, in.	11.6
Expansion ratio, initial	13.9:1
TVC, deg	±4.5

WEIGHTS, LBM

Total loaded	1,656
Propellant	1,444
Case assembly	129
Nozzle assembly	33
Total inert	212
Propellant mass fraction	0.87

TEMPERATURE LIMITS

Operation	-10°-130°F
Storage	-20°-130°F

PROPELLANT DESIGNATION TP-H-3514A

CASE MATERIAL
.... GRAPHITE-EPOXY COMPOSITE

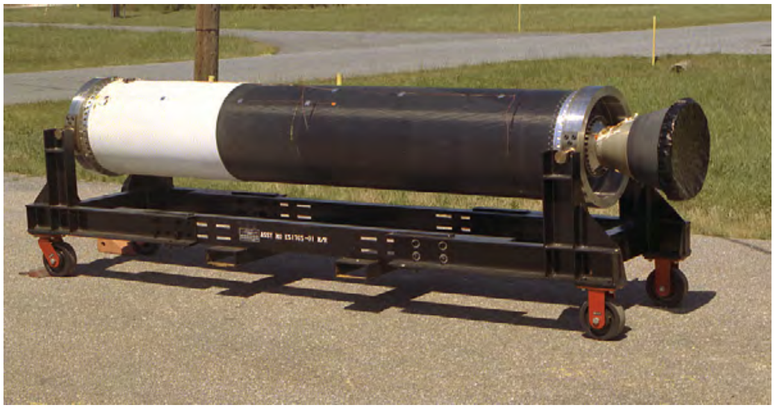
PRODUCTION STATUS .... DEVELOPMENT

For more information, contact:
starmotors@ngc.com.

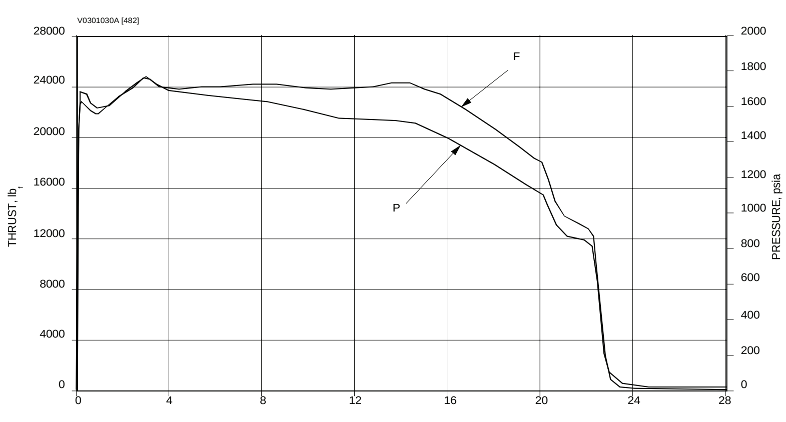
northropgumman.com

ASAS 21-120
TE-M-1059-1

NORTHROP GRUMMAN



The ASAS 21-120 is a solid rocket motor with a graphite-composite case that was developed in 2000 for vertical launch system, target, and sounding rocket applications. This is a fixed nozzle version of the ASAS 21-120V motor.



MOTOR DIMENSIONS

Motor diameter, in. 20.5
Motor length, in. 138.0

MOTOR PERFORMANCE (75°F SEA LEVEL)

Burn time/action time, sec 22.1/22.8
Ignition delay time, sec 0.012
Burn time average chamber pressure, psia 1,480
Maximum chamber pressure, psia 1,760
Total impulse, lbf-sec 497,600
Propellant specific impulse, lbf-sec/lbm 244.4
Burn time average thrust, lbf 22,300
Maximum thrust, lbf 24,700

NOZZLE

Initial throat diameter, in. 3.36
Exit diameter, in. 16.80
Expansion ratio, initial 25:1

WEIGHTS, LBM

Total loaded 2,323
Propellant 2,036
Case assembly* 254
Nozzle assembly 32
Total inert 286
Propellant mass fraction 0.88
*Includes igniter without 1.08 lbm propellant

TEMPERATURE LIMITS

Operation .... 40°-100°F
Storage .... 0°-100°F

PROPELLANT DESIGNATION TP-H-3516A

CASE MATERIAL

.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS .... DEVELOPMENT

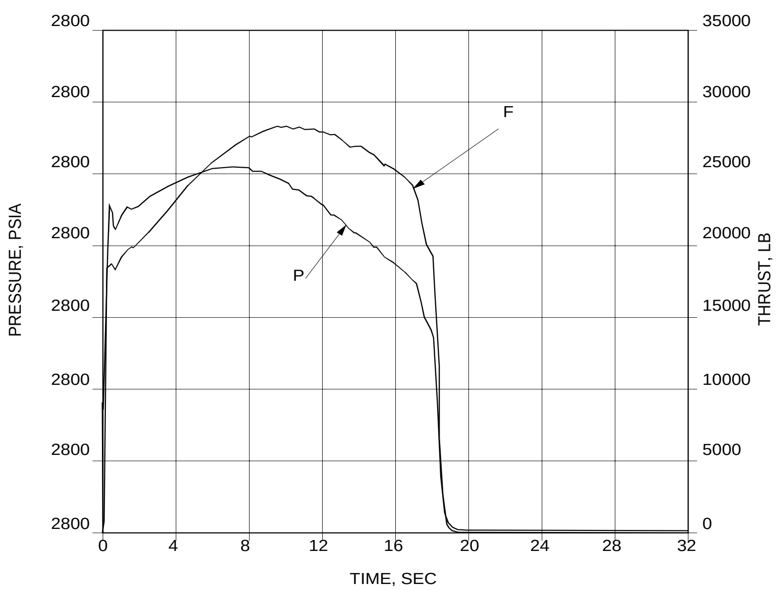
For more information, contact:
starmotors@ngc.com.

northropgumman.com

ASAS 21-120V
TE-M-909-1

NORTHROP GRUMMAN

The ASAS 21-120V solid rocket motor was designed, fabricated, and tested in just four and one-half months after program start. It features a 5 -degree flexseal thrust vector control nozzle with a carbon phenolic exit cone. This successful test led to receipt of the Strategic Defense Initiative Office Director's Award in recognition of outstanding achievement. The ASAS 21-120V configuration is applicable to vertical launch system, target, sounding rocket, and high-performance guided booster applications.



MOTOR DIMENSIONS
Motor diameter, in. 20.5
Motor length, in. 130.0

MOTOR PERFORMANCE (70°F SEA LEVEL)*
Burn time/action time, sec 17.9/18.6
Ignition delay time, sec 0.005
Burn time average chamber pressure, psia 1,800
Maximum chamber pressure, psia 2,050
Total impulse, lbf-sec 454,700
Propellant specific impulse, lbf-sec/lbm 250.8
Burn time average thrust, lbf 24,900
Maximum thrust, lbf 28,600

NOZZLE
Initial throat diameter, in. 3.0
Exit diameter, in. 14.0
Expansion ratio, initial 20:1
TVC, deg .... ±5.0

WEIGHTS, LBM
Total loaded 2,236
Propellant (less igniter propellant) 1,813
Case assembly* 363
Nozzle assembly 32
Total inert (including TVA) 423
Propellant mass fraction 0.81
*Includes igniter without 1.08 lbm propellant

TEMPERATURE LIMITS
Operation .... 40°-100°F
Storage .... 0°-100°F

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL
.... GRAPHITE-EPOXY COMPOSITE

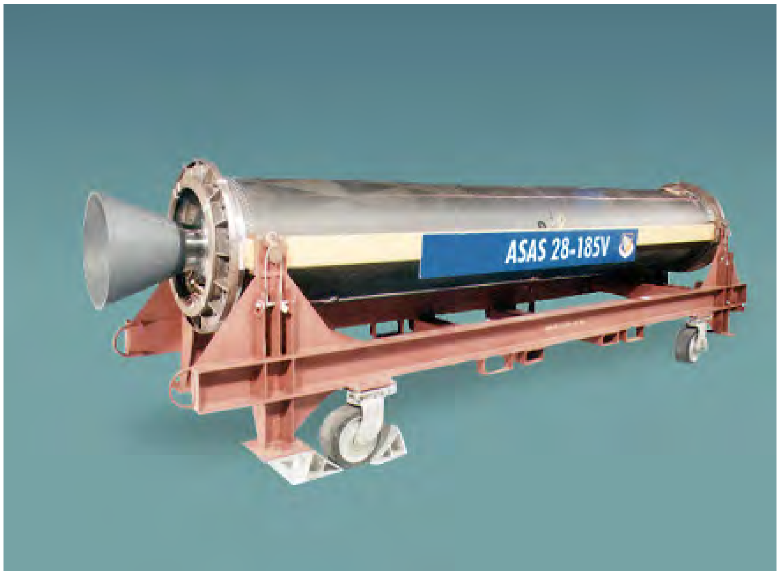
PRODUCTION STATUS .... DEVELOPMENT
*Development motor values. Flight design mass fraction is 0.89 with total impulse improvement of approximately 15%.

For more information, contact:
starmotors@ngc.com.

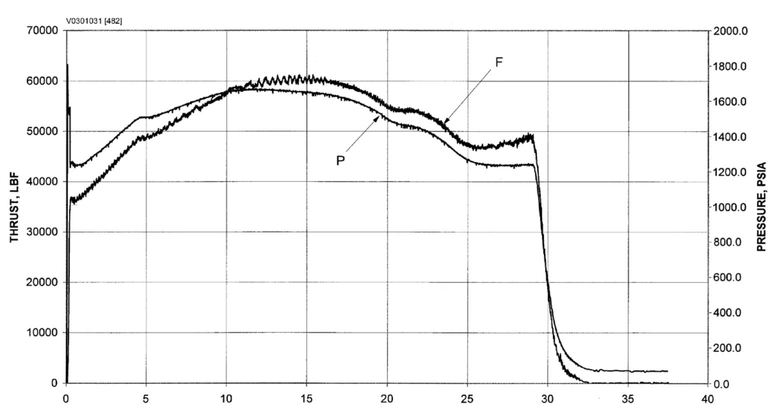
northropgumman.com

ASAS 28-185/185V
TE-T-1032

NORTHROP GRUMMAN



The ASAS 28-185 motor is a graphite composite case, fixed nozzle, solid rocket motor applicable to guided first-stage, sounding rocket, and target applications. With a thrust vector control nozzle, the motor is designated ASAS 28-185V. The motor was tested on September 30, 1998, and confirmed scaling of ASAS technology from smaller motors to a 28.5-inch-diameter motor configuration with extended burn time. Motor ignition was successfully achieved with a prototype electro-optical safe-and-arm device and a semiconductor bridge initiator. The motor incorporated a thrust vector control nozzle simulator to evaluate thermal response for simulated flexseal components, but the test nozzle was not vectorable by design.



MOTOR DIMENSIONS

Motor diameter, in. 28.5
Motor length, in. 207

MOTOR PERFORMANCE (75°F SEA LEVEL)

Burn time/action time, sec 29.2/31.2
Ignition delay time, sec 0.010
Burn time average chamber pressure, psia....... 1,470
Maximum chamber pressure, psia 1,660
Total impulse, lbf-sec 1,559,050
Propellant specific impulse, lbf-sec/lbm............ 252.6
Burn time average thrust, lbf 52,100
Maximum thrust, lbf 61,200

NOZZLE

Initial throat diameter, in. 5.0
Exit diameter, in. 21.3
Expansion ratio, initial..................................... 18.3:1
TVC, deg (design capability) .... ±5

WEIGHTS, LBM*

Total loaded 6,901
Propellant 6,172
Case assembly 608
Nozzle assembly 121
Total inert 729
Burnout 696
Propellant mass fraction 0.89
*weights without TVC

TEMPERATURE LIMITS

Operation... 40°-90°F
Storage .... 20°-110°F

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL

.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS .... DEVELOPMENT

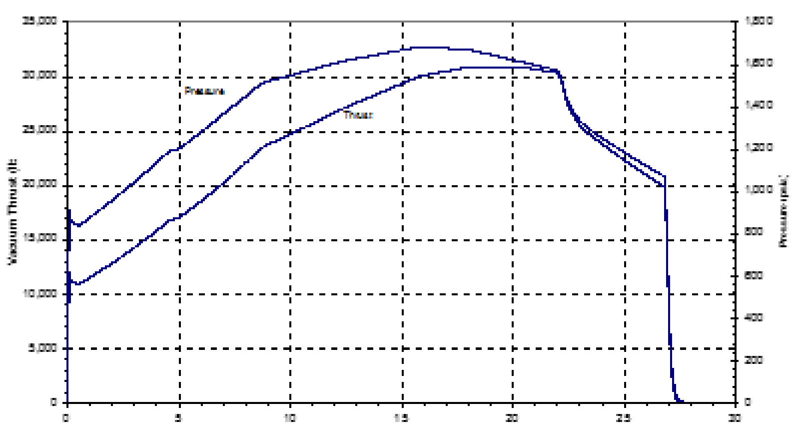
For more information, contact:
starmotors@ngc.com.

northropgumman.com

ASAS 32-58V (RAVEN) TE-M-1106-1

NORTHROP GRUMMAN

Static tested on September 16, 2003, the ASAS 32-58V RApid VEctoring Nozzle (RAVEN) design demonstrated an enhanced slew rate with a trapped ball nozzle using electromechanical actuation. The nozzle was tested on a 32-inch-diameter composite case motor representative of a future missile defense interceptor second stage. The motor was ignited with an Northrop Grumman Missile Products electronic safe-and-arm device and pyrotechnic igniter. Motor design, analysis, fabrication, and successful static test efforts were completed in a five and one-half-month period.



MOTOR DIMENSIONS

Motor diameter, in. 32
Motor length, in. 74.8

MOTOR PERFORMANCE (70°F VACUUM)

Burn time/action time, sec 26.6/28.1
Ignition delay time, sec 0.057
Burn time average chamber pressure, psia.......1,390
Maximum chamber pressure, psia 1,690
Total impulse, lbf-sec 640,580
Propellant specific impulse, lbf-sec/lbm............279.0
Effective specific impulse, lbf-sec/lbm 277.3
Burn time average thrust, lbf 23,900
Maximum thrust, lbf 30,880

NOZZLE

Initial throat diameter, in. 3.2
Exit diameter, in. 16.9
Expansion ratio, initial...28:1
Expansion cone half angle, exit, deg..................22.5
Type..Contoured
TVC, deg ....± 12

WEIGHTS, LBM

Total loaded 2,618
Propellant 2,296
Case assembly 209
Nozzle assembly (including actuators) 104
Igniter assembly (including ESA)..............................9
Total inert..322
Burnout 308
Propellant mass fraction 0.88

TEMPERATURE LIMITS

Operation..45°-90°F
Storage ....-20°-140°F

PROPELLANT DESIGNATION TP-H-3527A

CASE MATERIAL
.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS ....DEVELOPMENT

For more information, contact:
starmotors@ngc.com.

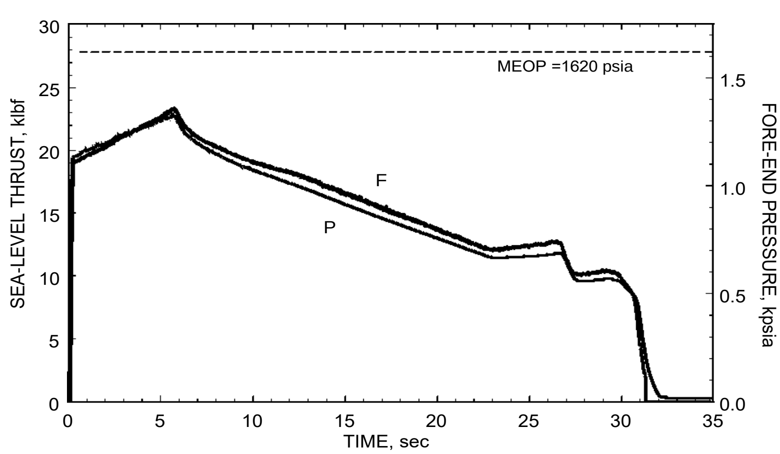
northropgumman.com

ORIOLE

The Oriole is a 22-inch-diameter, high-performance, low-cost rocket motor used as a first, second, or upper stage for sounding rockets, medium-fidelity target vehicles, and other trans-atmospheric booster and sled test applications. The motor was developed in the late 1990s as a next-generation, high-performance sounding rocket motor and was first successfully static tested in 2000. Five successful flight tests have been completed to date using the Oriole as a second stage. The nozzle has been optimized for high-altitude applications and the graphite-epoxy case and modern high-performance propellant combine to provide a high-mass-fraction and cost-effective design.

Future Oriole variants are in concept development. These include a version, for use as a booster in experimental scramjet or other similar applications, that has extra external insulation, allowing for extended flight times within the atmosphere. There is also a shorter burn time, first-stage booster specific version, which would be an ideal replacement for Talos/Taurus class motors and would yield greater performance. The first stage incorporates a low altitude optimized nozzle and has a burn time in the 12- to 15-second range.

The Oriole motor also has the flexibility to accommodate a thrust vector control system for high-fidelity target or orbital mission applications. In addition, a subscale version, called the Cardinal motor, is suitable for upper-stage applications with Oriole or other motors in the lower stage(s). The Cardinal motor would be about half the size and weight of the full-scale Oriole motor and take advantage of many similar proven components and processes to provide maturity and low-cost benefits.



MOTOR DIMENSIONS
Motor diameter, in. 22
Motor length, in. 154.68

MOTOR PERFORMANCE (70°F VACUUM)
Burn time/action time, sec 30.0/28.85
Ignition delay time, sec 0.025
Burn time average chamber pressure, psia....944
Maximum chamber pressure, psia 1,410
Total impulse, lbf-sec....624,290
Propellant specific impulse, lbf-sec/lbm....288.5
Burn time average thrust, lbf 20,790
Maximum thrust, lbf 29,570

NOZZLE
Initial throat diameter, in. 3.72
Exit diameter, in. 19.82
Expansion ratio, initial....28.4:1
TVC, deg ....N/A

WEIGHTS, LBM
Total loaded 2,588
Propellant (less igniter propellant)....2,152
Case assembly....214
Nozzle assembly 145
Total inert....436
Propellant mass fraction....0.83

TEMPERATURE LIMITS
Operation....0°-120°F
Storage....-10°-125°F

PROPELLANT DESIGNATION
....QDL/SAA-144 ALUMINIZED HTPB

CASE MATERIAL
.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS....IN PRODUCTION

For more information, contact:
starmotors@ngc.com.

northropgumman.com

ELECTROMECHANICAL THRUST VECTOR ACTUATION SYSTEM

Northrop Grumman has developed the first in a family of thrust vector actuation systems that is designed for low-cost modularity. The controller uses state-of-the-art electronics packaged in a rugged and lightweight mechanical enclosure. Two-axis digital loop closure, communication, and housekeeping functions are performed with less than half the electronic piece part count found in similar thrust vector actuation designs. An innovative, patented, digital design enables this low-cost flexibility.

Derivative controller designs with different maximum output power capability of up to 33 Hp (without torque summing) can be produced from the same basic architecture. This is also true for the actuator design, which can easily be scaled up or down to accommodate almost any combination of output force and speed required.

Inquiries regarding EM TVA products should be directed to our business development representatives at starmotors@ngc.com.

TVECS™ Model TE-A-1154-1 Electromechanical Thrust Vector Actuation System

Product Description:

- Two-channel, linear output electromechanical actuation system
- Brushless DC motors
- Linear variable displacement transducer position feedback
- Resolver rate feedback
- Digital loop closure (position and rate)
- RS-422 communication
- Externally programmable for custom compensation

Options:

- Other stroke and null lengths available with minor actuator modifications (linear variable displacement transducer, ball screw, housing lengths)
- Other communication protocols are available (RS-485, MIL-STD-1553, CAN, analog, etc.); communication digital format is flexible
- Controller mounting provisions and cable lengths can be modified, as required
- Ability to reconfigure digital logic through main communication interface
- Enhanced reliability screening available (JANTXV, Class B, Class H, minimum, and space level)
- Radiation tolerance
- Military temperature range

Product Characteristics

Main Power	80 VDC / 30 A (per channel)
Logic Power	28 VDC / 1A
Rated Speed	7.5 in/sec
Rated Load	1,600 lbf
Total Stroke	2.0 in
Null Length	8.394 in
Null Length Adjustment	0.2 in
Weight (not including battery)	21 lb

Design Capability

Operating Voltage, Main (max)	270 VDC
Current Limit, Main (max)	50 A
Maximum Output Force	3,500 lbf
Maximum Rated Speed	13 in/sec
Maximum Power Output	6 HP

ORDNANCE PRODUCTS

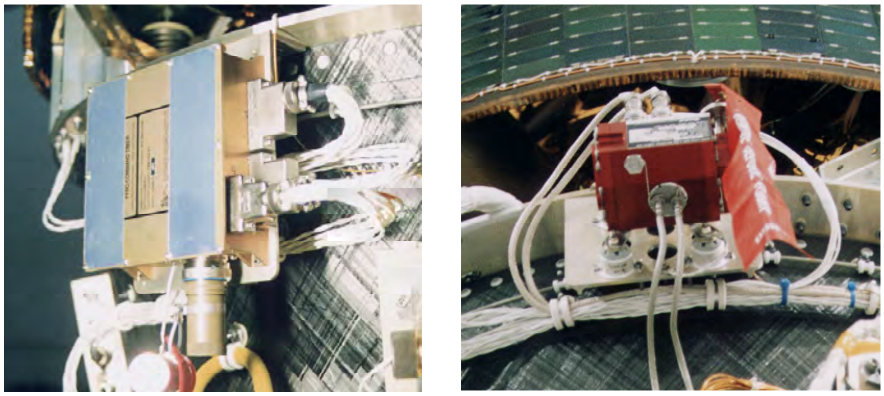
Northrop Grumman Missile Products has produced a wide variety of ordnance products since the 1960s including:

- Conventional electromechanical safe-and-arm devices for STAR series space motor initiation and launch vehicle/stage destruct functions
- Conical-shaped charge assemblies for booster destruct applications on STAR, CASTOR, Titan, Atlas, and Delta
- Semiconductor bridge-based initiators for precise control of ordnance events for military applications such as the universal water activated release system for the U.S. Air Force
- Advanced electronics-based ordnance systems providing reductions in weight, enhanced event control, and system health monitoring

Several of these products are illustrated below and provide an overall heritage of proven reliability while providing flexibility to meet evolving customer needs.

SCB Initiator

Northrop Grumman ordnance production facilities at Missile Products include equipment for safe and arm assembly, initiator manufacturing, igniter manufacture, pyrotechnic and explosives loading, and laser welding. In addition to ordnance manufacture, Northrop Grumman has facilities at Missile Products to perform nondestructive testing, including X-ray, random vibration, shock and thermal environments, functional testing, and associated live material and product storage.



Lunar Prospector Command Timer and S&A Integration Conducted by Northrop Grumman

Electromechanical Safe and Arm Devices. The development and production heritage for electromechanical safe and arm devices represents more than 40 years of product maturity as illustrated below. These devices provide positive control of ordnance events in nonfragmenting and non-outgassing designs that provide external status indication and a safety pin to inhibit operation when desired. The current production Model 2134B is routinely used to initiate STAR series space motors (next page) and for destruct on Atlas IIAS and Titan IVB. The Model 2134B has supported more than 300 flights since 1989 with a 100% operational success rate. It is Eastern-Western Range 127-1 compliant and has flown successfully from Eastern Test Range, Western Test Range, and Kourou and on vehicles such as Titan, Delta, Ariane, and Space Shuttle.

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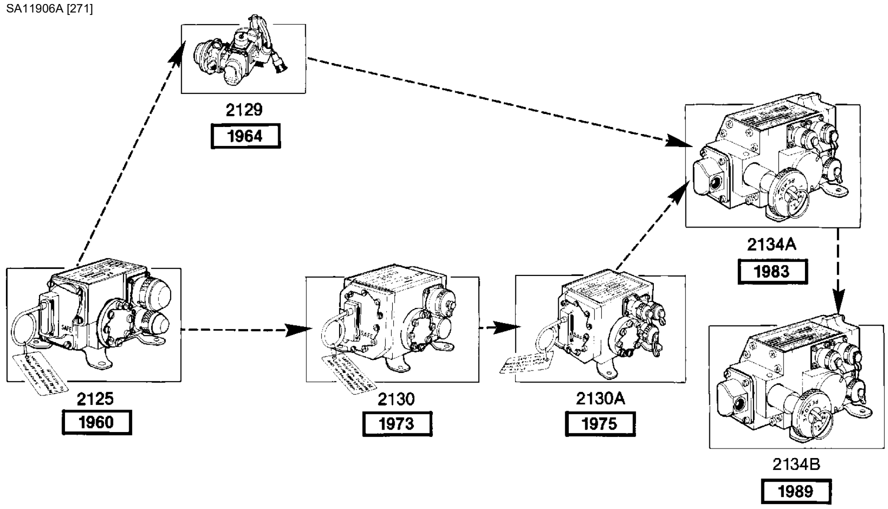
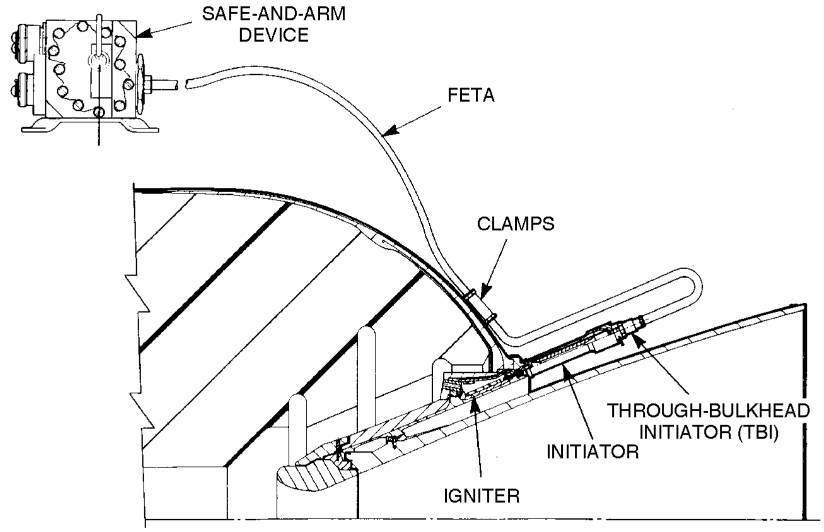


S&A Development Heritage Supports Product Reliability in Operation



Typical STAR Series Space Motor Ordnance Train to Provide On-Command Ignition

Northrop Grumman also supports safe and arm and ordnance system development having updated the documentation package and manufacturing instructions for the Space Shuttle S&A device. Northrop Grumman also developed and qualified the Army Tactical Missile Systems (TACMS) arm/fire device for motor ignition and the safe and arm device for Army TACMS warhead initiation and has rebuilt or refurbished existing Minuteman III arm/disarm switches for the U. S. Air Force. For the Minuteman III arm/disarm switch, six-sigma principles were employed to design and implement a manufacturing plan that features manufacturing cells and dedicated production stations. Trained technicians individually evaluate, rebuild, and then retest each arm/disarm switch. In addition, Northrop Grumman has integrated complete ordnance systems, which include Missile Products-fabricated wiring harnesses for missile defense boosters such as the Terrier lightweight exoatmospheric projectile Advanced Solid Axial Stage and the SM-3 Mk 136 Third Stage Rocket Motor. In the area of upper stages, Northrop Grumman conducted the design activity for the Lunar Prospector trans-lunar injection stage. This upper stage used customer-supplied command timer/sequence to control all ordnance functions including initiation of spin motors, separation systems, primary axial propulsion, separation systems, and destruct functions (see below).

Laser Welding Equipment

SCB Initiator Semi automated Manufacturing Line

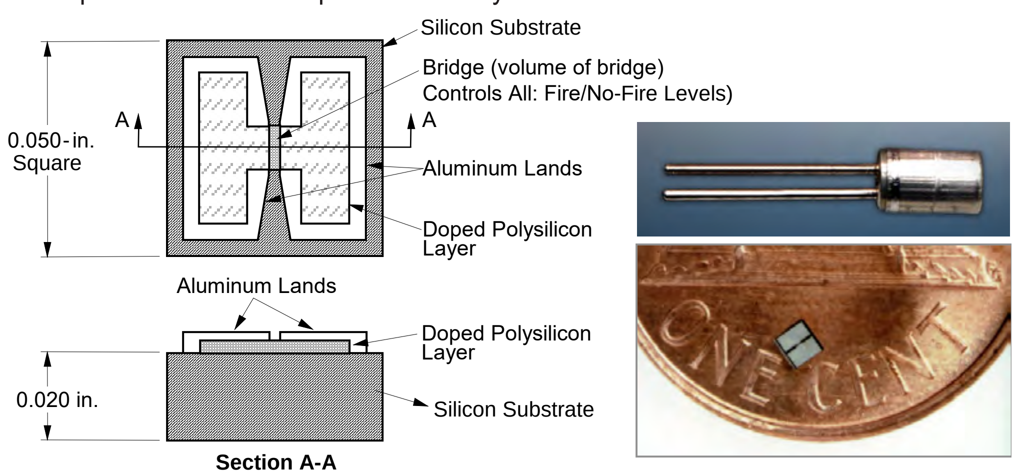
Conical-Shaped Charge Assemblies. Conical-shaped charges produced at Northrop Grumman provide a concentrated destructive jet of energy for flight termination applications on a variety of propulsion systems, including boosters used on Titan and Atlas as well as CASTOR and STAR series motors. Northrop Grumman conducts in-house testing for conical-shaped charge lot acceptance and has integrated destruct ordnance for stages including Lunar Prospector for Lockheed Martin and NASA. Conical-shaped charges produced at Northrop Grumman are reviewed and approved by the Eastern and Western Ranges for each application and meet the requirements of EWR 127-1. Photos below show two past uses of the conical-shaped charge.

CSC Installed on Lunar Prospector TLI Stage

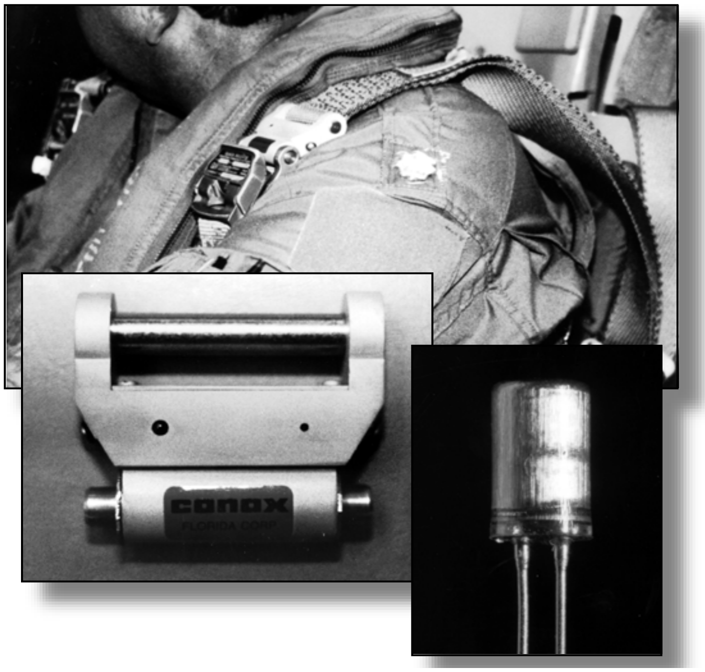
STAR 48 Destruct Test Using Model 2011 CSC

Semi-conductor Bridge (SCB) Initiators. Since 1989, Northrop Grumman has produced more than 60,000 SCB initiators for application in automotive airbags, the mining industry, for parachute release, tank rounds, and for motor and ordnance event initiation. The majority of this production has supported the Universal Water Activated Release System program following qualification of the device in 1994 (figure on following page). The flexibility and robustness of the basic SCB initiator configuration enables Northrop Grumman to tailor pin designs, output charges, and design features for specific applications.

The SCB initiator provides advantages over other initiator technologies by providing low, consistent initiation energy with fast and highly repeatable function times. These devices enhance safety by readily passing no-fire requirements (>1 amp/1 watt/5 minutes), are electrostatic discharge-tolerant, can be tailored to meet MIL-STD-1385B HERO requirements, and are qualified to MIL-STD-1512 requirements. This device produces a 8,500°F plasma at the bridge allowing initiation of insensitive materials. In addition, SCBs are inherently mass producible at the chip and assembly level.



SCB Chip and Initiator



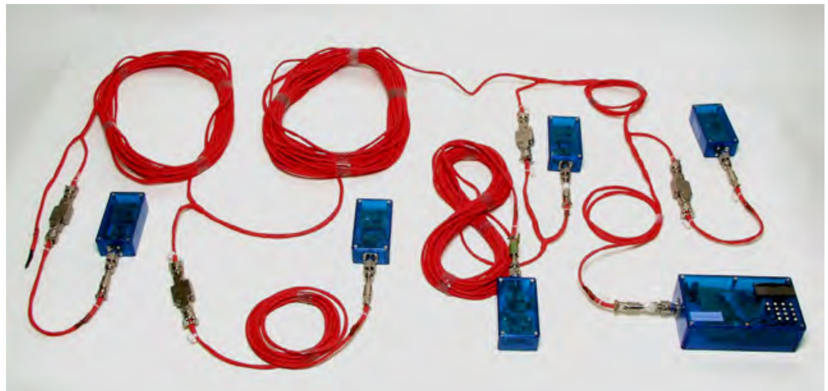
Universal Water Activated Release System (UWARS)

SCB initiators also provide excellent capability for health status monitoring and have proven compatible with high-acceleration environments in gun-launched applications (tank rounds), having survived forces in excess of 30,000 g. On-going SCB development and production efforts conducted at Northrop Grumman will further reduce unit costs and provide compatible electronic initiation systems that can reduce overall ordnance system weight.

Advanced Electronics-Based Ordnance. Traditional launch vehicle and spacecraft ordnance systems use dedicated, direct-wire systems. These systems employ bridgewire-type squibs, shielded twisted pair cable harnesses dedicated to each squib, and an electronic ordnance controller. Because the safety functions are performed in the ordnance controller (remote from the point of initiation), the firing energy must be transmitted along the entire length of the cable harness. The cabling must therefore be shielded from external electromagnetic interference. Safety-critical initiation events are typically supported by separate dedicated systems. This approach results in high system weight, larger cable bundles, very limited health monitoring capabilities, and higher system power requirements.

As a result, Northrop Grumman has developed ordnance products that can replace the conventional safe and arm, explosive transfer assemblies, and through-bulkhead initiators used for this type of application. These advanced ordnance systems combine modern electronics with SCB initiators to reduce weight and enhance reliability and safety for next-generation ordnance applications versus conventional electromechanical systems. These products are discussed below.

Electronic Safe and Arm (ESA). Among these products are the ESA, a device that contains a single SCB initiator that produces an output approximately the same as a NASA standard initiator. The ESA is designed to thread directly into a motor igniter. It has a bulkhead to contain motor pressure and a single electrical connector interface. The small envelope and weight of this safe and arm permits direct installation into the igniter and eliminates the need for explosive transfer assemblies and through bulkhead initiators. The electronic safety features of the ESA will be supplemented with a blocking rotor mechanism driven by a small DC micromotor. The design will mechanically and electrically isolate the electrical initiator from the rest of the ignition train.



Addressable Bus Ordnance System Breadboard Prototype

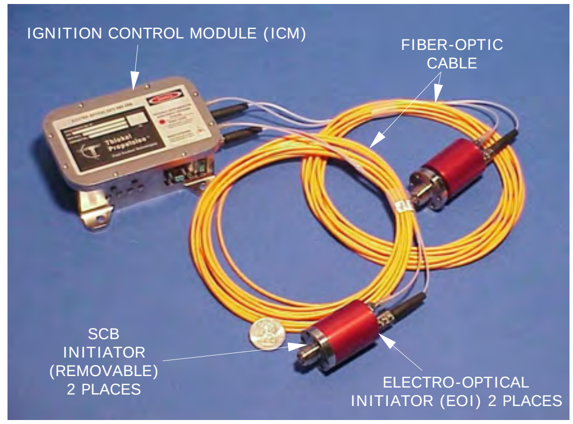
Northrop Grumman performed initial environmental and operational testing of prototype ESA units under the ASAS II contract (1999 to 2000). A prototype of the ESA was also used to initiate a Northrop Grumman technology demonstration rocket motor in November 2000 and Northrop Grumman's RApid VEctoring Nozzle (RAVEN) motor in 2003.

Addressable Bus Ordnance System. Under a 2001 and 2002 Advanced Ordnance Development program, Northrop Grumman designed, fabricated, and demonstrated a breadboard addressable bus ordnance system based on ESA designs. The program also demonstrated implementation of communication protocols allowing individual device control and the ability to merge ordnance and telemetry system features on a single bus.

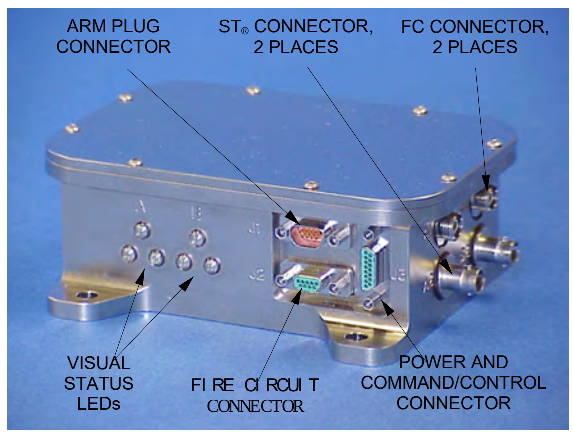
Northrop Grumman's addressable bus solution mitigates or eliminates many of the negative attributes associated with traditional ordnance systems. By substituting SCB-based squibs as an enabling technology, a digital bus network will support multiple, individually addressed devices (or nodes) that incorporate safety at the point of initiation and provide new, extensive ordnance and system health monitoring and telemetry gathering capabilities. The Northrop Grumman-developed ESA device forms the basis of the initiator nodes in the proposed system. Because firing energy is stored and switched at the individual system nodes, only low-voltage power and digital commands are transmitted over the system cables. Significant protection from external electromagnetic interference is therefore achieved without heavy shielding. Individual cables are no longer necessary because all of the ordnance events are controlled from a common bus that utilizes a digital communication protocol. As a result, reductions in cabling mass and improvements in installation and checkout can be realized.

Electro-Optical S&A (EOSA). Northrop Grumman has also demonstrated EOSA technology. This approach combines laser light energy and photovoltaic technology to control and power electro-explosive devices. An advantage of this approach is that it uses fiber optics and thereby isolates the electro-explosive device from typical electrical wires used to transfer energy and commands. Northrop Grumman worked with Sandia National Laboratories to perform development and demonstration efforts for all the critical components including the ignition control module, fiber-optic cabling, and electro-optical initiators.

Inquiries regarding Ordnance products should be directed to our business development representatives at starmotors@ngc.com.



EOSA



ESOA ICM

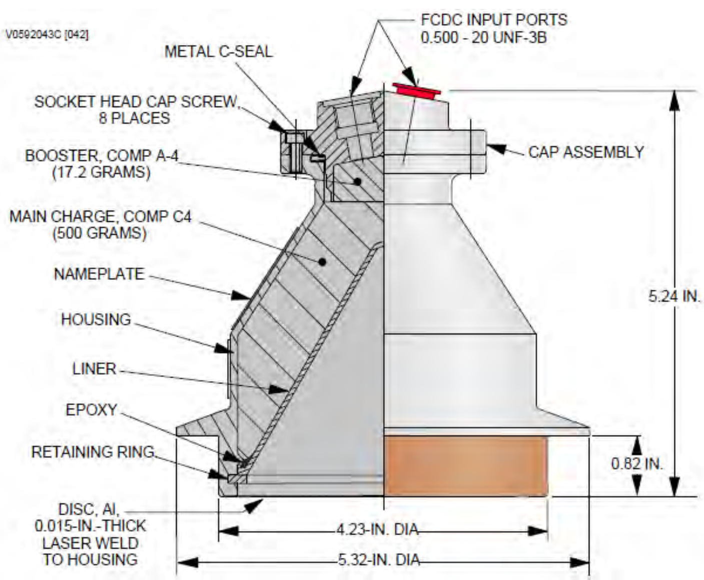
MODEL 2011
TE-0-958-1

DESTRUCT CONICAL SHAPED CHARGE (CSC)

Northrop Grumman's Model 2011 CSC is an upgraded version of the highly successful Model 2001 design developed in the 1960s for use on the Delta launch vehicle. The Model 2011 has the same envelope, mounting interfaces, and explosive weight as its predecessor, the Model 2001.

The Model 2011 incorporates a 500-gram composition C-4 main charge, which provides excellent safety, performance, and long-term storage characteristics for a variety of flight termination applications. The Model 2011 is designed to provide several improvements over prior CSC designs. These include: 1) enhanced safety through the use of flexible confined detonating cord input, 2) hermetic sealing of each unit, and 3) incorporation of a liner manufactured to provide optimal target penetration and control of the jet angle.

Northrop Grumman has manufactured more than 1,000 CSCs for flight termination. The Model 2011 was qualified for use on the Atlas IIAS launch vehicle and was first flown in December 1993. Northrop Grumman's CSCs have flown in many other applications including the Delta, Japanese N, Titan/Centaur, and Atlas/Centaur launch vehicles. They have been reviewed and approved by Eastern and Western Range Safety for each application and meet the requirements of EWR 127-1.



CHARACTERISTICS

U.N. classification code	1.1D
Base charge	Composition C-4: 500 grams
Booster charge	Composition A-4: 17 grams
Cap material	Aluminum alloy
Housing material	Aluminum alloy
Liner material	Copper
Initiation input	Flexible confined detonating cord with Type III end tip (144 mg HNS) (detachable)
Attachment interface	Mounting flange using a Marman clamp
External finish	Clear anodic coating
Penetration at 6-inch stand-off	12-inch mild steel
Temperature environmental extremes	-65° to +160°F*
Qualification vibration	47.7 grms for 3 min/axis
Qualification shock	6,000 g at 700 to 3000 Hz, Q=10
Weight, gross	2.8 lb
Applications	Solid motor destruct, liquid tank destruct, payload destruct

*High-temperature exposure up to 30 days

For more information, contact:
starmotors@ngc.com.

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MODEL 2134B
TE-0-734

SAFE-AND-ARM (S&A) DEVICE

The Model 2134B was originally qualified for the McDonnell Douglas Delta II launch vehicle. Model 2134B has successfully flown on a number of launch vehicles including Delta, Space Shuttle, Ariane, Titan, Japanese N, and Long March. They have initiated upper-stage sequencing and booster destruct systems and ignited upper-stage motors. Model 2134B improves upon the safe and reliable design of its predecessors by: 1) upgrading detonators to meet the requirements of MIL-STD-1576 and NHB1700.7A and 2) the optional modification of the safety pin to comply with the safety requirements of MIL-STD-1576 and EWR 127-1.

The Model 2134B is a nonfragmenting, non-outgassing, electromechanical S&A initiation device that is remotely mounted and remotely actuated. Because of the nonfragmenting and non-outgassing feature, the device can be located on spacecraft without damage to nearby equipment. The motive power for the unit is furnished by a 28-volt reversible DC motor with an integral planetary gear speed reduction unit. The rotational power of the DC motor is transmitted to the output shaft through spur gears and a friction clutch.

The explosive rotor assembly, visual indicator, and rotary switches are located on the output shaft. These switches control the electrical circuitry, including motor control, remote indication, and firing signals. In the safe position, the explosive rotor assembly is out of phase with the explosive train. When the safety pin is removed and arming current is applied, the output shaft rotates 90 degrees to align the rotor with the explosive train. If arming current is applied with the safety pin installed, the motor operates through the slip clutch to preclude any damage to the unit. The safety pin physically prevents the rotor from rotating while being mechanically locked into place. The output area of the unit contains an adapter that provides interface of the explosive train with a receptor such as explosive transfer assemblies. The explosive transfer assemblies transfer the detonation output from the S&A device for purposes such as rocket motor ignition. The unit's redundant firing circuits and explosive trains assure a highly reliable initiation.

The Model 2134B has a separate firing connector for each firing circuit. A separate connector is also provided for the arm/disarm and monitor circuits.

CHARACTERISTICS

Unit weight:.......................... 3.4 lb (typical)

Motor operating voltage:.......................... 24-32 Vdc

Inrush:........................ 1.0-3.0 amps for 50 ms max

Running: .... 100-250 mA at 28 ±4 Vdc

Stalled rotor current: .... 360 mA max

Actuation time:.............. 0.15 to 0.3 sec at 28 ±4 Vdc

Operating temperature: .... –35° to 160°F

Firing circuit pin-to-pin resistance:
.... 0.87 to1.07 ohms (Version 1) or 0.90-1.10 (Version 2)

Detonator "no-fire" current/power:
.... 1 amp/1 watt for 5 minutes

Detonator "all-fire" current: .... 3.5 amps

Detonator (recommended) .... 5.0 to 22.0 amps

Firing time at 5.0 amps: .... 3 ms (typical)

Optional isolator mounts available for high shock/vibration environments

PERFORMANCE FEATURES

- Nonfragmenting and non-outgassing
- Safe if inadvertently fired in the safe position
- Remote electrical arming and safing
- The unit can be manually disarmed but cannot be manually armed
- Mechanical and electrical systems are inseparable whether the device is operated electrically or manually
- The firing circuit and explosive train are redundant
- Firing circuits and control/monitor circuits are located in separate connectors
- Remote monitoring of safe or armed status is integral within the circuitry
- A visual indicator window shows safe or armed status
- A safety pin prevents accidental arming of the unit during transportation, handling, and checkout
- The safety pin is nonremovable when arming power is applied
- In the safe position, the detonator lead wires are shunted and the shunt is grounded through 15,000-ohm resistors
- Firing circuits have 25-ohm resistors to provide for ordnance system checkout in safe position

For more information, contact:
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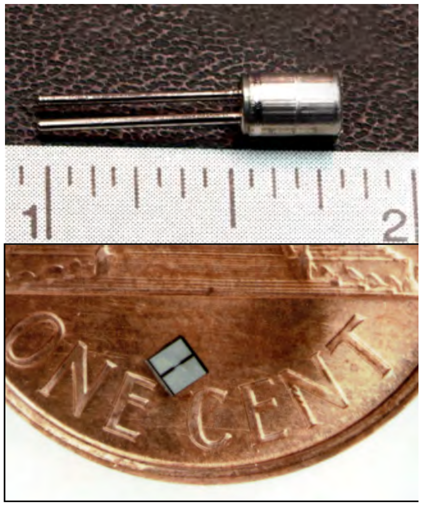
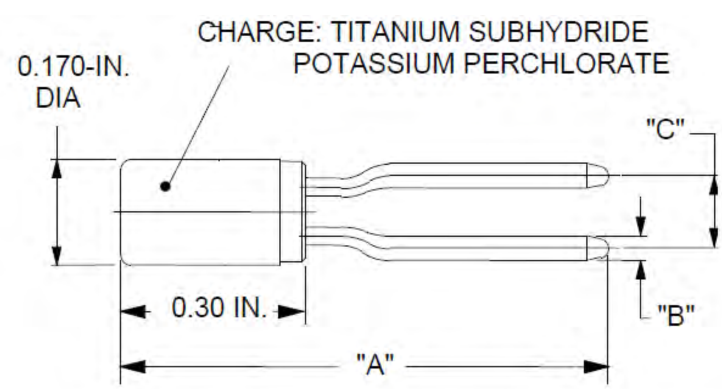
SCB INITIATOR
TEM-I-902



Northrop Grumman's Missile Products's unique squib design employs a patented semiconductor bridge (SCB) to provide advantages over traditional hot-wire devices. Operation of the SCB chip produces a plasma output that enhances safety by allowing the initiation of insensitive materials (rather than primary explosives) in the squib. It achieves highly repeatable and fast function times (as low as 50 msec). The SCB initiator has been qualified to MIL-STD-1512 and serves as part of the human-rated U.S. Air Force's universal water activated release system. The SCB takes only 10% of the energy required by a conventional bridgewire for initiation (requiring 1 to 3 millijoules versus 30 to 35 millijoules for conventional bridgewire devices), but can meet 1-watt/1-amp for 5 minutes minimum no-fire requirements. The SCB interface configuration and all-fire and no-fire levels can be tailored for individual mission requirements. The device currently meets both Department of Defense and Department of Energy military requirements for electrostatic discharge.

The output of the squib and its mechanical interface can be tailored for specific applications. Our baseline initiator design serves as the core component for all our new devices, including digitally and optically addressable units. Design modifications can be made as necessary to accommodate new requirements or optimize high-volume production needs.



PIN CONFIGURATION - BENT OR STRAIGHT
(A, B, C customer defined)

SAFETY/FEATURES/BENEFITS

- Contains no primary explosive material
- Pyrotechnic material test data compatible to MIL-STD-1316 approved material
- Qualified to MIL-STD-1512; human-rated
- Passed electrostatic discharge: 25 kV, 500 pF, through a 5,000-ohm resistor, over 100 pulses
- Passes 1-watt/1-amp, 5-minute no-fire requirement
- Passed 420°F performance testing
- Passed simulated 10-year aging
- Passed >50,000 g performance testing
- Passed 28-day temperature shock, humidity, and altitude environments per MIL-I-23659
- Radiated radio frequency sensitivity: MIL-STD-1385B (HERO), design-dependent
- Pressure shock: 15,000 psi
- Monitor current: 100ma, 1,008 hours, -40° to 194°F, 42 cycles
- Low, consistent energy requirements (1 to 3 mJ)
- Highly repeatable, fast function time (as low as 50 µs);
- Highly reliable (0.9992 at 95% confidence)
- Requires 10% of the energy of a bridgewire initiator
- Ability to customize interface configuration and all-fire and no-fire levels
- Autoignition: 350°F for 6 hours; 257°F for 12 hours
- Digital and optical addressable units available
- Excellent heritage: over 40,000 units fabricated and over 5,000 successfully tested
- Handling shock: 6-foot drop, -65° and 215°F, 75 drops
- Department of Energy-approved for use in actuators of weapon systems
- Thermal shock: 200 cycles, -40° to 194°F, 1 hour per cycle; 120 cycles, -65° to 215°F, 1-hour dwell

WARNING: THIS DEVICE MAY HAVE A PIN-TO-CASE RESISTANCE AS LOW AS 30 OHMS. SUFFICIENT ENERGY APPLIED FROM PIN TO CASE CAN CAUSE INITIATION. THE USER SHOULD TAKE ALL NECESSARY PRECAUTIONS TO HANDLE AND USE THIS DEVICE SAFELY IN A MANNER CONSISTENT WITH THE DESIGN

For more information, contact:
starmotors@ngc.com.

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ESA
TEM-0-1068-1

The electronic safe-and-arm (ESA) is a low-power, stand-alone S&A device for ordnance initiation. Designed as a drop-in replacement for traditional electromechanical devices, it provides fail-safe, no single-point failure, arm and fire interrupts, and physical blocking of pyrotechnic output in a smaller and lighter weight package. Based on Northrop Grumman's semiconductor bridge (SCB) squib technology, the ESA provides advanced electromagnetic interference immunity with safety at the point of initiation. By incorporating the SCB squib with a hermetic seal tested to >20,000 psi in the ESA, the traditional pyrotechnic transfer train components can be eliminated to allow for reduced hardware and lot acceptance test costs as well as reducing the burden of tracking items with limited shelf life. Added benefits of the ESA not available in electromechanical S&As are automatic built-in test capability plus the availability of serial status telemetry including safe/arm status and bridge resistance verification.

UNIQUE DESIGN

Dimensions.................. 1-inch diameter, 3.2-inch long
ESA assembly weight................................~125 grams
Installed protrusion length ....2.2 inch
Material construction .... 304L stainless steel

- Operates on typical 28 Vdc bus
- Threaded interface
- Harvard architecture microprocessor
- No primary explosives

FEATURES

- BIT capability
- Safe/arm monitor output (serial data)
- Initiator bridge verification
- LED visual status indicator
- Meets 1-amp/1-watt, 5-minute, no fire requirement
- Hermetic and maintains reliable pressure seal (proofed to 20,000 psi)
- Low-energy SCB initiator

DEMONSTRATED

- Tested in STAR motor ignition systems
- Tested in 21- and 24-inch-diameter tactical motor ignition systems (ASAS boosters)
- Tested in test motor
- Baseline for new design STAR motor ignition system

SAFETY

- Independent arm and fire inhibits
- Arm and fire sequence requirements
- Dual safing methods; quick safe feature and dual-bleed resistors for fail-safe discharge
- High- and low-side switch protection to isolate SCB from stray energy
- Range safety reviews successfully completed

Eastern/Western Range Review .... Spring 2000
Range Commanders Council Review........ Spring 2000
U.S. Army Safety Review Board....................Fall 1999

SYSTEM PERFORMANCE

Arm signal voltage output......................... 22 – 36 Vdc
Peak power..................................... 7 W for 150 msec
Average power .... 1.4 W
Transient current ....<250 mA for 150 msec
Steady-state current....................................... □ 50 mA
Arm time ....<100 msec
Fire signal voltage input........................... 18 – 36 Vdc
Steady-state and transient current .... <10 mA
Fire output time...<10 msec
Quick safe..<1 msec
Bleed safe..<7 sec
SCB firing time.. <50 µsec

- Operates over long distances (several hundred feet)
- Extensive diagnostic and system status monitoring
- Capable of autonomous timing of events

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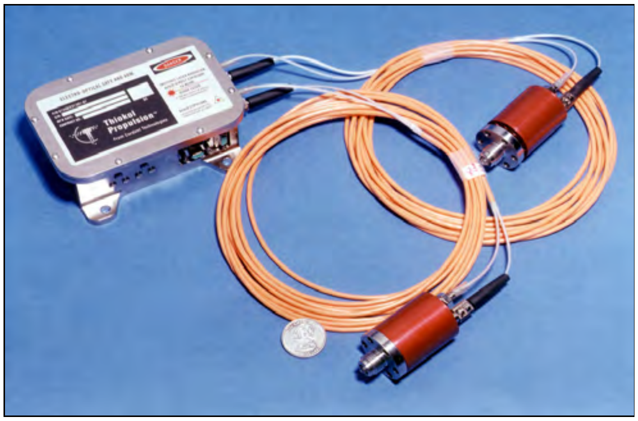
EOSA
TE-O-1054-1

NORTHROP GRUMMAN



Northrop Grumman is developing an electro-optical safe-and-arm (EOSA) device that combines laser light energy and photovoltaic technology to safely and reliably initiate electro-explosive devices.

The EOSA consists of an ignition control module (ICM), dual fiber-optic transmission cables (FOTC), and electro-optical initiators (EOI). This system provides complete isolation of the electrical initiator from sources of energy that could cause inadvertent initiation. All power, command, and data signals are transmitted optically between the ICM and the EOI by laser diodes via fiber optic cables. The optical signals are then converted to electrical signals by photovoltaic converters for decoding and action.

This relieves the system from transmission loss effects over long cable lengths that are detrimental to direct laser ordnance initiation systems and from the shielding and noise penalties associated with electrical transmissions.

System input/output, self-diagnostic functions, arming plug, and visual safe/arm indicators are contained in the ICM. Safe-and-arm functions and the initiator squib are contained in the EOI and are activated by coded optical signals from the ICM. System arming causes the EOI to charge a capacitor locally storing the firing energy at the point of initiation. The FIRE command from the ICM causes the EOI to discharge the capacitor to the initiator squib causing it to fire. Either the SAFE command or the loss of signal from the ICM will cause the EOI to rapidly discharge the capacitor through bleed resistors rendering the system SAFE.

A built-in-test capability provides a real-time system check and feedback of the safe/arm status to the user both visually and through vehicle telemetry. The design uses Sandia National Laboratories' patented electro-optical initiation technology and Northrop Grumman's patented MIL-STD-1512 qualified semiconductor bridge initiator.

SAFETY FEATURES

- Three independent and unique inhibits
- Dedicated connector for FIRE commands
- Dual safing methods:
- SAFE command for rapid capacitor discharge
- Dual bleed resistors for capacitor discharge for fail-to-safe loss of signal
- Visual LED status indicators for POWER, ARM, and SAFE
- Isolation from stray electrical and electromagnetic interference energy at the point of initiation
- Coded optical commands for immunity to stray optical energy
- Arming plug removal to interrupt all electrical power to the control module
- Does not utilize direct initiation of ordnance by laser light

PHYSICAL CHARACTERISTICS

EOSA assembly weight ....1.50 lb
ICM .... 1.63-in. high x 3.50-in. wide x 4.44-in. long
EOI ....1.20-in. dia. X 2.34-in. long
Fiber size ....100-micron silicon core fiber

SYSTEM PERFORMANCE

Operating voltage ....28 Vdc
Peak power (per channel) .... 5W for 1 sec
Average power (per channel) 3W
Arming/safing time...........................1 sec maximum
Firing time.. 100 msec

- Dual channels for complete redundancy
- Automatic BIT with extensive diagnostic and system health monitoring
- Ability to operate over hundreds of feet of cable
- Autonomous timing and sequencing of events

For more information, contact:
starmotors@ngc.com.

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