Orbital ATK

The Partner You Can Count On™

Propulsion Products Catalog

May 2016

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Dear Customer:

Orbital ATK would like to take this opportunity to provide you with the latest version of our Propulsion Products Catalog to help you address your future propulsion requirements. This catalog describes flight-proven motors and development motors in our product line. These products provide a wide range of proven designs, existing manufacturing processes, and tooling which enable paths to lower risk and lower cost solutions to your requirements. Generally, flight-proven current production products can be delivered the soonest for the least risk and lowest non-recurring cost, providing some advantages over new designs.

If current production motors contained in this catalog do not address specific needs, we have the capability to modify designs to meet application motor performance requirements. The practicality of tailoring motor performance has been demonstrated many times in derivatives of earlier design configurations (many examples exist in the STAR™, Orion, and CASTOR® series, for instance). Orbital ATK would be happy to work with you to evaluate and optimize potential solutions to your requirements, so don't hesitate to contact us.

Orbital ATK continues to invest in the development of new products and capabilities. Ongoing activities include new stage propulsion as well as extensive work with controllable solid-propulsion systems, which use proportional valves to control performance, and liquid and electric propulsion for small spacecraft.

Orbital ATK is committed to being the propulsion provider of choice to multiple customers and markets. This demonstrated commitment has resulted in decades of reliable launch success. We look forward to and encourage future collaborations and partnerships with commercial and government customers that satisfy and service a broad range of propulsion needs and opportunities.

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ACRONYM LIST

ACS	Attitude control system — A thruster system used to maintain spacecraft/missile positioning and orientation. Also referred to as a reaction control system (RCS) in some applications
AKM	Apogee kick motor — A motor used to circularize the orbit of a spacecraft, often to geosynchronous earth orbit (GEO)
ASAS	Advanced Solid Axial Stage — ASAS is used as a designation for a family of enhanced performance motors that generally incorporates common technologies such as high-strength graphite composite cases, high performance propellants, advanced ordnance, and/or thrust vector control nozzles with electromechanical actuation. These motors are identified by primary diameter, case length, and TVC content. For example, ASAS 21-120V is a 21-inch-diameter motor with a 120-inch case and TVC nozzle
BIT	Built-in test — A feature of electronic devices that allows their operability to be confirmed via a signal provided in response to a test command or query
CSC	Conical shaped charge — An ordnance product typically used as part of upper stage destruct systems to satisfy range safety requirements
CTPB	Carboxyl-terminated polybutadiene — A type of polymer used as a propellant binder
EOSA	Electro-optical safe and arm — A class of safe-and-arm device based on isolation of the unit and primary initiation functions using laser systems and fiber optics to reduce weight and eliminate sensitivity to electrostatic energy that results from the use of long wiring runs for ordnance systems typically used in launch vehicles
EPDM	Ethylene propylene diene monomer — A class of elastomeric rubber insulation materials typically used to insulate motor cases
ESA	Electronic safe and arm — A class of safe-and-arm device based on the use of semiconductor bridge initiator technology. ESA designs provide capabilities for reporting health status of the ordnance system and incorporating specific safety and command and control protocols
ETA	Explosive transfer assembly — ETAs are used as part of a space motor ignition train, generally to transfer the initiation signal from a safe-and-arm device to another ordnance component such as a through-bulkhead initiator (TBI). These may be further identified as an FETA = flexible ETA, or RETA = rigid ETA
ETR	Eastern Test Range
GBI	Ground-based interceptor
GEM	Graphite epoxy motor — Orbital ATK developed GEM designs for the Delta II launch vehicle. Designed to take advantage of proven, off-the-

	shelf technologies, the GEM system provides increased performance and heavier lift capability
GEO	Geosynchronous earth orbit — 22,600 miles out from the earth is an orbital location where satellites remain over a fixed point on the earth
GMD	Ground-based Midcourse Defense
GPS	Global positioning system — A satellite constellation providing precise navigation and location data for military and commercial users
GSE	Ground support equipment — Equipment used to support motor integration with the spacecraft and/or launch vehicle and to provide associated final motor checks
HEW	Head end web — A type of grain design in which the propellant completely covers and is generally bonded to the motor head end
HTPB	Hydroxyl terminated polybutadiene — A type of polymer used as a propellant binder
IMP	Interplanetary monitoring platform
IRBM	Immediate-range ballistic missile
JPL	Jet Propulsion Laboratory, Pasadena, CA
LCS	Large class stage – A high-performance, high-reliability booster being developed by Orbital ATK with the support of the U.S. Air Force
LEO	Low earth orbit — A position reached by the Space Shuttle and many launch systems prior to orbital adjustments that are typically made using perigee kick motor (PKM) and apogee kick motor (AKM) propulsion
MDA	Missile Defense Agency
MER	Mars Exploration Rover — Designation for the 2003 to 2004 NASA missions to Mars that landed the Spirit and Opportunity rovers
NSI	NASA standard initiator
PBAN	Polybutadiene acrylic acid acrylonitrile polymer — A binder formulation widely used on large rocket boosters such as the Titan III and Space Shuttle
PKM	Perigee kick motor — A motor typically used to raise a satellite into elliptical orbit
RAD	Rocket-assisted deceleration — Designation for motors used to decelerate payloads such as the Mars RAD motors

RAVEN	RApid VEctoring Nozzle
RCS	Reaction control system
RPM	Revolutions per minute — Used to designate spin rates used to stabilize spacecraft. Note that the cited spin rates are the highest levels to which the design was tested or analyzed, not necessarily its maximum spin capability
RSRM	Reusable solid rocket motor — Designation used for the Space Shuttle boosters
S&A	Safe and arm — Used to designate an electronic or electromechanical device that inhibits ordnance functions to provide enhanced safety
SCB	Semiconductor bridge — The SCB chip is used in a line of initiators that provides fast and repeatable function times using low initiation energy
SLS	Space Launch System
SRM	Solid rocket motor
SRMU	Solid rocket motor upgrade — Originally developed for the U.S. Air Force and Lockheed Martin to increase the launch capability of the Titan IVB Space Launch Vehicle (retired)
SSB	Solid strap-on booster
STS	Space Transportation System — The Space Shuttle
TBI	Through bulkhead initiator — Part of a space motor ignition train
TLI	Trans-Lunar Injection — Designation for a motor system used to inject a satellite into a lunar orbit. This specific designation applies to the STAR 37FM-based TLI stage used for the Lunar Prospector spacecraft
TCR	Orbital ATK line of resins and pre-impregnated composite materials available in combination with a variety of fibers for industrial, commercial, and aerospace applications
TIRS	Transverse impulse rocket system — Designation for motors used to stabilize the lander during descent as part of the Mars Exploration Rover mission
TVA	Thrust vector actuation — Refers to the system used to actuate a TVC nozzle
TVC	Thrust vector control — Refers to a type of movable nozzle
UWARS	Universal water activated release system — A program that uses a qualified SCB initiator produced by Elkton
WTR	Western Test Range

INTRODUCTION

Orbital ATK space propulsion and ordnance products outlined in this catalog reflect more than 50 years of experience in providing high-performance and reliable propulsion for the aerospace industry. This catalog presents technical information on numerous product lines within the Orbital ATK Space Propulsion Product portfolio: Orion, CASTOR®, CASTOR 120®, LCS (large class stage), GEM (graphite epoxy motor), SRMU (solid rocket motor upgrade), the Space Shuttle RSRM (reusable solid rocket motor) and its derivative motors, the STAR™ series of space motors and integrated upper stages, ASAS™ (advanced solid axial stage), ordnance products, and space launch structures.

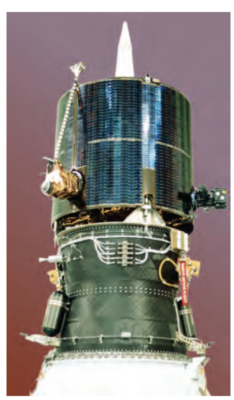
RSRM Boosters Lift the Space Shuttle

GEM and STAR Propulsion Power Delta II

CASTOR and Orion Motors Boost Taurus

Solid rocket motor technology provides excellent reliability, tailorable ballistic performance, and low costs for many space, upper-stage, and missile defense applications. Introduction of high-strength composite materials has further enhanced performance for many classes of motors. In addition, Orbital ATK motors with thrust vector control nozzles and attitude control systems provide significant upgrades in solid propulsion system capabilities.

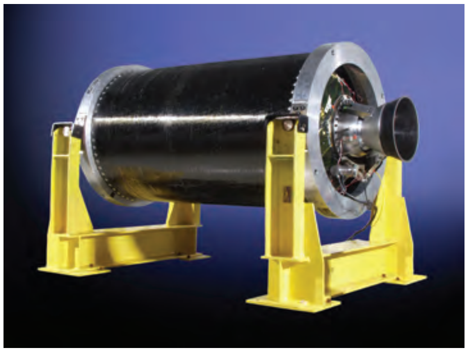
STAR 48 Motor and Magellan Satellite Begin Journey to Venus



Lunar Prospector (STAR 37 Integrated Stage)

LCS I Static Test

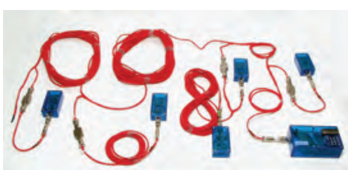
Sometimes existing designs must be modified, stretched, offloaded, or scaled up to achieve performance goals and/or to accommodate structural interfaces established for specific missions or applications. Orbital ATK routinely modifies our products to meet evolving customer needs through detailed design, analysis, and testing of new propulsion systems that maintain the heritage of prior, flight-proven designs when it saves time and cost.

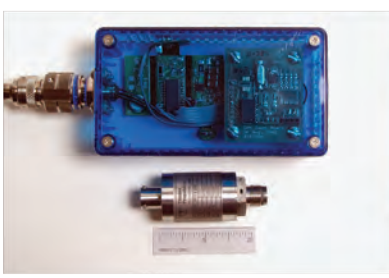


Rapid Vectoring Nozzle (RAVEN) Demonstration Motor

ASAS 21-120 Motor Test

Our ordnance products have also established excellent flight reliability records in both motor ignition and destruct system applications. Current electronic safe-and-arm technology can be applied by Orbital ATK to reduce ordnance weight and cost and to precisely control ordnance events for your propulsion systems.





ESA

Conical Shaped Charge (destruct ordnance)

We have also included an overview of Orbital ATK's integrated stage capabilities. Orbital ATK has a broad range of capabilities, including simple stage hardware and stage/vehicle integration support, to more complex three-axis stabilized, inertially-guided vehicle designs. Orbital ATK now offers fully autonomous single or multiple stage stacks and all of the required avionics hardware, flight software, and mission design and management services.

In addition to hardware, Orbital ATK routinely provides a variety of support services, including engineering design trades, launch and integration support, field handling training, aging and surveillance, demilitarization, testing, and analysis. These services support mission assurance goals leading to successful flight. We also routinely provide shipping containers and ground support equipment for use with the motors. To accommodate new environments or structural interfaces, we can define and support delta-qualification of components and/or complete motor assemblies. Orbital ATK can also design skirts and interstages and provide heaters, thermal blankets, and flight termination ordnance to adapt our products to your needs.

Shipping Container

Lunar Prospector Size With Lifting Beam Tooling for Stage/Motor Handling

This catalog contains data sheets that summarize the principal design and performance characteristics of each existing propulsion product. The information provided in the data sheets will permit initial evaluation of our current products in reference to your mission requirements. We encourage you to involve us in these evaluations and welcome the opportunity to provide optimal solutions for your mission needs.

Inquiries regarding specific product lines should be directed to our business development representatives as listed below. In addition to the products noted in this catalog, Orbital ATK can provide reliable space structures, aerospace tanks, and hypersonic propulsion technology. For information about these and other Orbital ATK products, please visit our website at www.Orbital ATK.com.

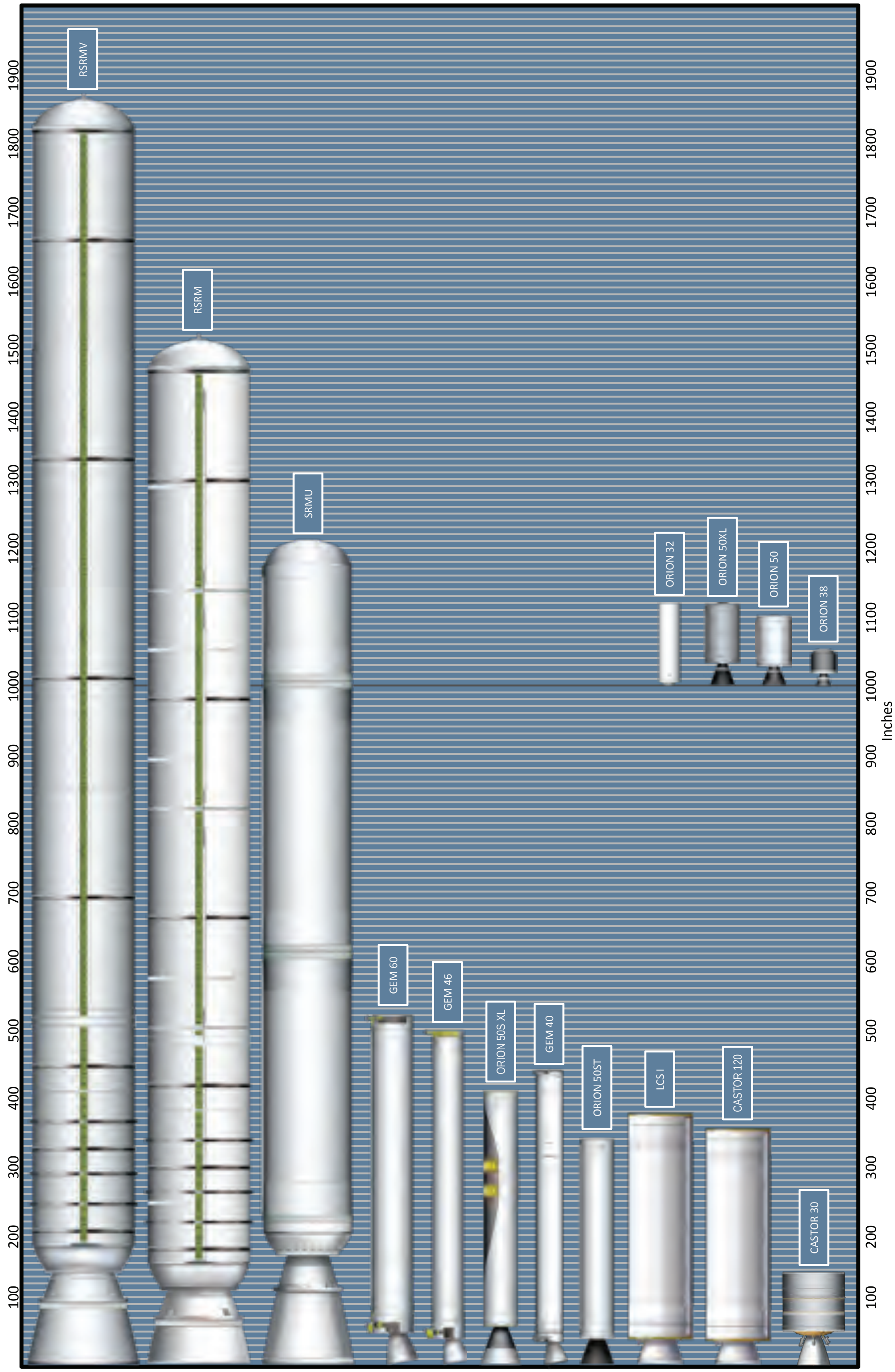
Products	Contact No.	Contact E-mail Address
STAR, ASAS, and CASTOR I and II Motors; STAR™ Stages; Ordnance	Phone: (410) 392-1430 Fax: (410) 392-1205	starmotors@Orbital ATK.com
Orion, CASTOR, LCS, GEM, SRMU, and RSRM Motors/derivatives	Phone: (801) 251-5373 Fax: (801) 251-5548	commercialmotors@Orbital ATK.com
Space Structures	Phone: (801) 775-1962 Fax: (801) 775-1207	Larry.Mortensen@Orbital ATK.com
Tanks	Phone: (323) 722-0222 Fax: (323) 721-6002	psi.tank@Orbital ATK.com
Hypersonic Propulsion Technology	Phone: (631) 737-6100 Fax: (631) 737-6121	GASL.Marketing@Orbital ATK.com

LARGE MOTOR SUMMARY INFORMATION

ORION, CASTOR, LCS, GEM, AND RSRM MOTOR SERIES CAPABILITIES

Orbital ATK's large motor series (Orion, CASTOR, LCS, GEM, and RSRM families) 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. (NOTE: Similar summary data is provided under the STAR motor section for the STAR motor series.)



Orbital ATK Motor Comparision

Table 1. Large Motor Summary

Motor	Nozzle	Diameter (inches)	Overall Length (inches)	Propel-lant Weight (lbm)	Total Weight (lbm)	Mass Fraction	Total Impulse (lbf-sec)	Burn Time (sec)	Status
Orion Motor Family									
Orion 32	Vectorable	32	121	4,280	4,721	0.91	1,186,000	41.0	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	372.4	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	30,570	0.92	8,239,110	149.8	Flight-proven
CASTOR 30B	Vectorable	92	169.7	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
***Large Class Stage (LCS)**									
*LCS I	Vectorable	92.1	378.3	114,194	123,665	0.92	31,774,000	77.9	Qualified
*LCS III	Vectorable	92.1	164.5	28,278	31,307	0.91	8,483,300	133.0	Qualified at simulated altitude
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	6,959,000	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

Motor	Nozzle	Diameter (inches)	Overall Length (inches)	Propel-lant Weight (lbm)	Total Weight (lbm)	Mass Fraction	Total Impulse (lbf-sec)	Burn Time (sec)	Status
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
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	789.3	*	*	*	*	*	In development
GEM-63XL	Fixed	63	862.0	*	*	*	*	*	In development
Solid Rocket Motor Upgrade (SRMU)									
SRMU	Vectorable	126	1,349	695,427	776,038	0.89	195,476,128	135.7	Flight-proven
Reusable Solid Rocket Motor (RSRM) and Derivatives									
RSRM	Vectorable	146.1	1,513.5	1,106,059	1,255,334	0.88	297,001,731	122.2	Flight-proven
1-Segment Commercial	Vectorable	146.1	499.6	336,231	404,601	0.83	92,978,688	115.8	Design
1.5-Segment Com-mercial	Vectorable	146.1	697	476,496	558,993	0.85	132,700,522	117	Design
2-Segment Commercial	Vectorable	146.1	860	619,003	715,659	0.86	170,800,000	114.1	Design
2.5-Segment Com-mercial	Vectorable	146.1	1,037	758,990	867,215	0.87	209,304,469	113.2	Design
3-Segment Commercial	Vectorable	146.1	1,156.2	843,286	981,686	0.86	223,000,000	133.7	Design
4-Segment Commercial	Vectorable	146.1	1,476.3	1,114,155	1,278,078	0.87	298,000,000	132.8	Design
RSRM V (5-Segment)	Vectorable	146.1	1,864.7	1,427,807	1,616,123	0.88	381,367,646	131.9	Completing qualification

*** In development, subject to refinement**

Table 2. Large Motor Test and Flight History as of 01 May 2016

Motor	Applications/Uses	Number of Static Fire Tests	Number of Motors Flown	TVC	Production Status
Orion 32	Technology Demonstration	2 (HCDM, MCRT)	0	Yes	Development
Orion 32-5	Technology Demonstration	1	0	Yes	Development
Orion 32-7	Technology Demonstration	1	0	Yes	Development
Orion 38	Pegasus/Taurus/Pegasus XL/ Taurus XL/Minotaur I/Minotaur IV/GMD OBV	3	76	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	1	56	Optional	Production
Orion 50 XLT	Taurus XL	0	5	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	32	No	Production
Orion 50S XLG	GMD OBV/ALV/IRBM Target	5	17	Optional	Production
Orion 50S XLT	Taurus XL	0	3	Optional	Production
CASTOR IVA	Delta II/Atlas 2AS	7	313	No	Out of Production
CASTOR IVB	Maxus/Targets	4	33	Yes	Out of 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	1	Yes	Production
CASTOR 120	Athena Ic/Athena IIc/ Taurus/Taurus XL	2	16	Yes	Out of production
CASTOR 120XL		0	0	Yes	Production
LCS I	Conventional Strike/Family of Motors	1	0	Yes	Demonstrated
LCS III	Conventional Strike/Family of Motors	1	0	Yes	Demonstrated

Motor	Applications/Uses	Number of Static Fire Tests	Number of Motors Flown	TVC	Production Status
GEM 40	Delta 2	13	990	No	Production
GEM 40VN	GMD BV+	3	3	Yes	Out of Production
GEM 46	Delta 2 Heavy/Delta 3	3	81	Fixed/TVC	Out of Production
GEM 60	Delta 4	14	48	Fixed/TVC	Production
SRMU	Titan IVB	6	34	Yes	Out of Production
RSRM	Space Shuttle	28 (+5-seg ETM-3)	220	Yes	Out of Production
1-Seg. RSRM		0	0	Yes	Concept
1.5-Seg. RSRM		0	0	Yes	Concept
2-Seg. RSRM		0	0	Yes	Concept
2.5-Seg. RSRM		0	0	Yes	Concept
3-Seg. RSRM		0	0	Yes	Design
4-Seg. RSRM		0	0	Yes	Design
RSRM V (5-Seg.)	Space Launch System (SLS) / formerly Ares I First Stage	4	0 (+Ares I-X, 4-seg)	Yes	Completing development and qualification

Reliability/Success Rate: Demonstrated success rate of 99.76% in flight and static tests. One static test faillure and four flight failures in 2,120 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

Orion Series

The Orion family of motors began with three stages originally designed for use in a joint venture with Orbital Sciences Corp. for 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 (GMD) ground-based interceptor (GBI). New applications continue to evolve, such as target vehicle configurations for Missile Defense Agency (MDA).

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. Orbital ATK 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 below. The motor identification key provides a further explanation for nomenclature designations in the Orion motor series.

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 XL	50 XLT	38		Taurus XL/ Minotaur C
50S XLG	50 XL	38		Taurus Lite
		50 XL	38 38	Minotaur I Minotaur IV
50S				Hyper-X
50S XLG	50 XL	38		GMD GBI
50S XLG*	50 XLT			IRBM target

*** with lengthened nozzle**

Motor Identification Key

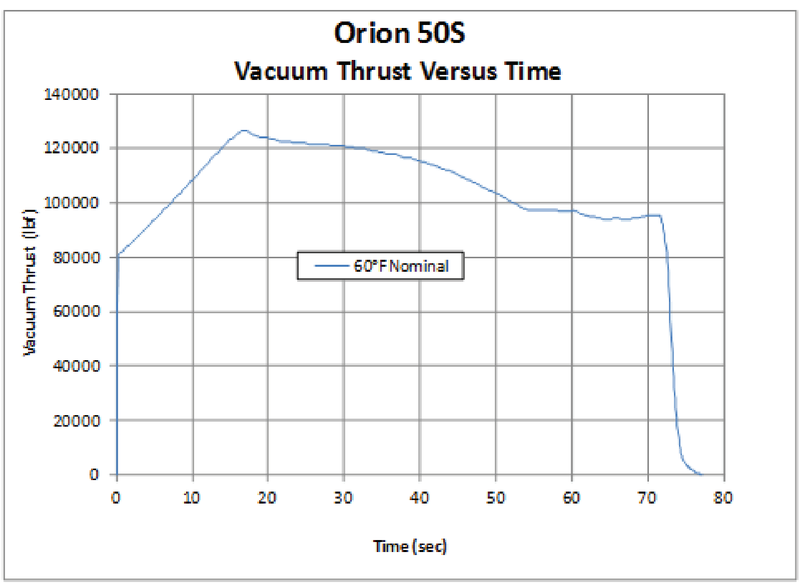
Example **Orion** **50** **S** **XL** **G** **T**

- 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 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

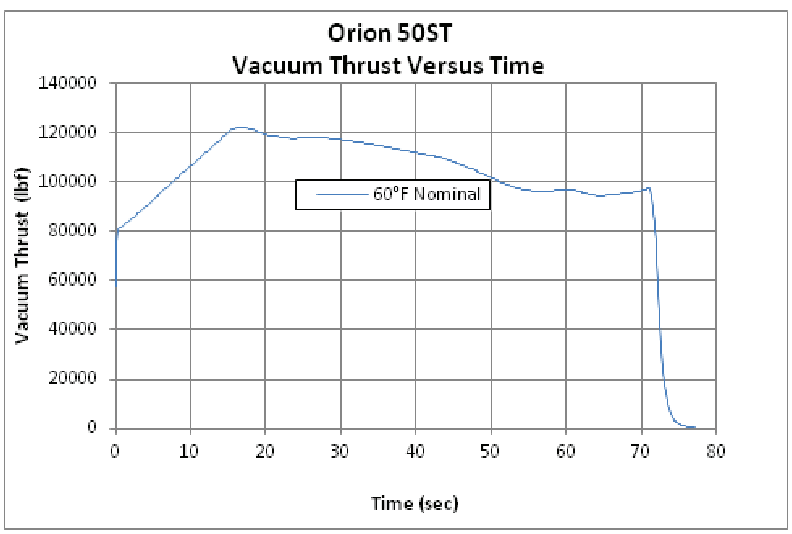
** Pegasus standard first stage

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

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 six 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

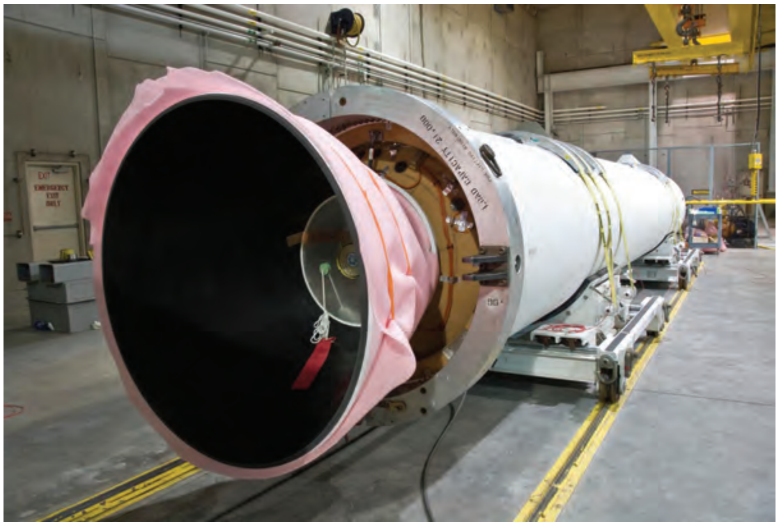
TEMPERATURE LIMITS

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

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

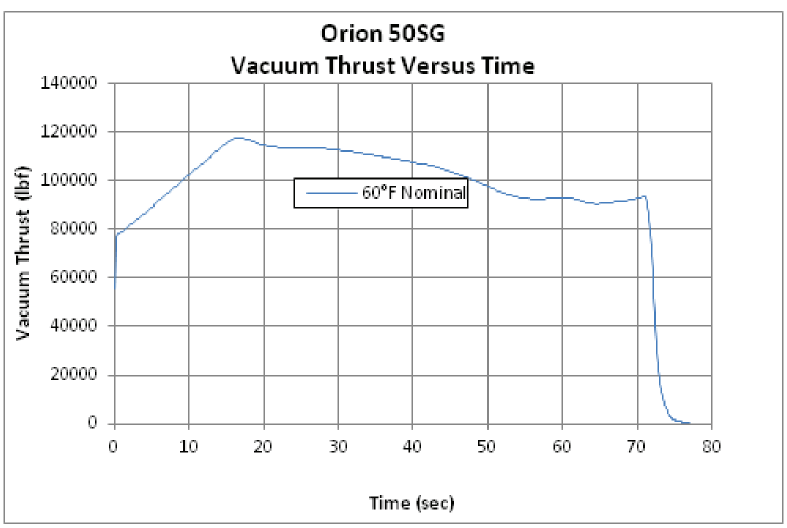
** Taurus standard first stage

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

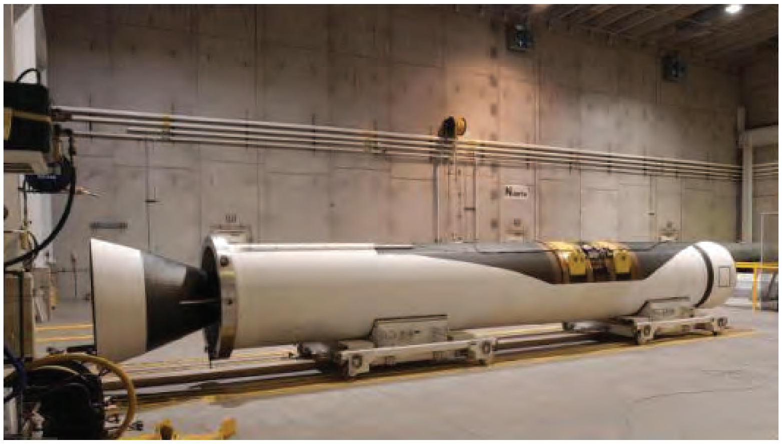
TEMPERATURE LIMITS

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

PRODUCTION STATUS
.... QUALIFIED, INACTIVE PRODUCTION

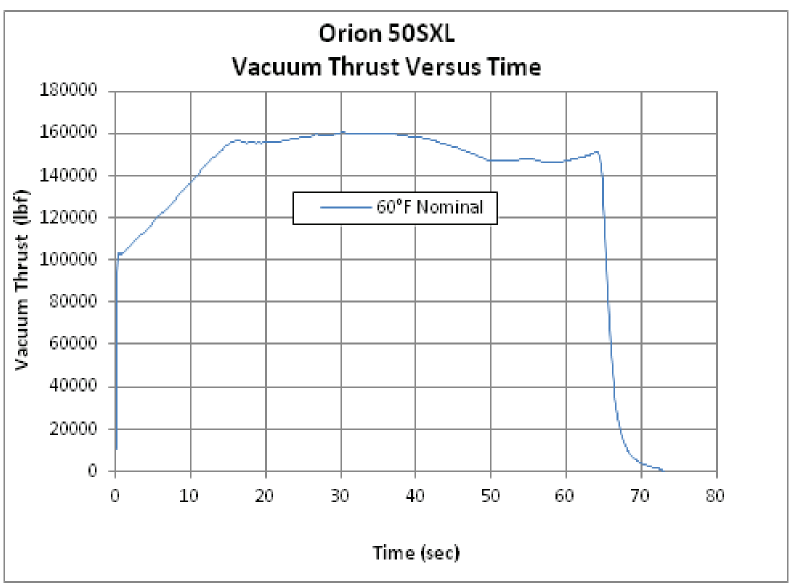
Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

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. To date, this fixed-nozzle XL version has performed successfully on 32 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

**Pegasus XL first stage

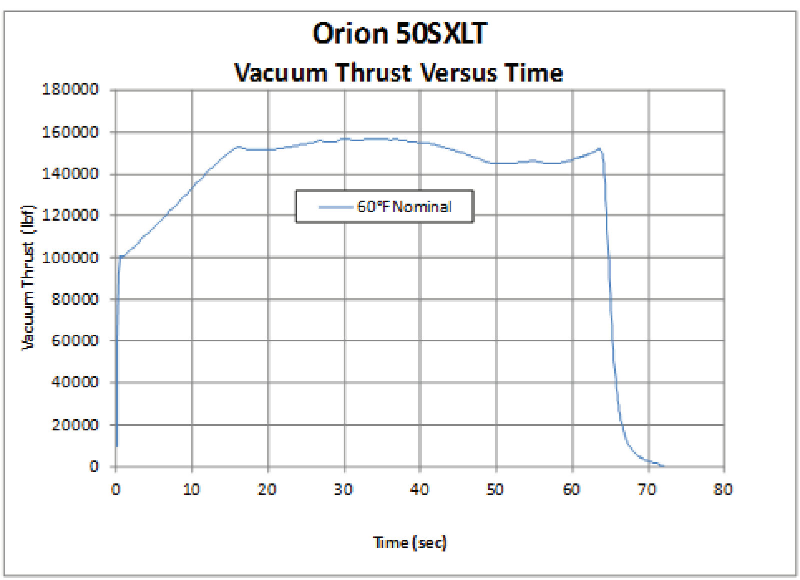
Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

Orbital ATK

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

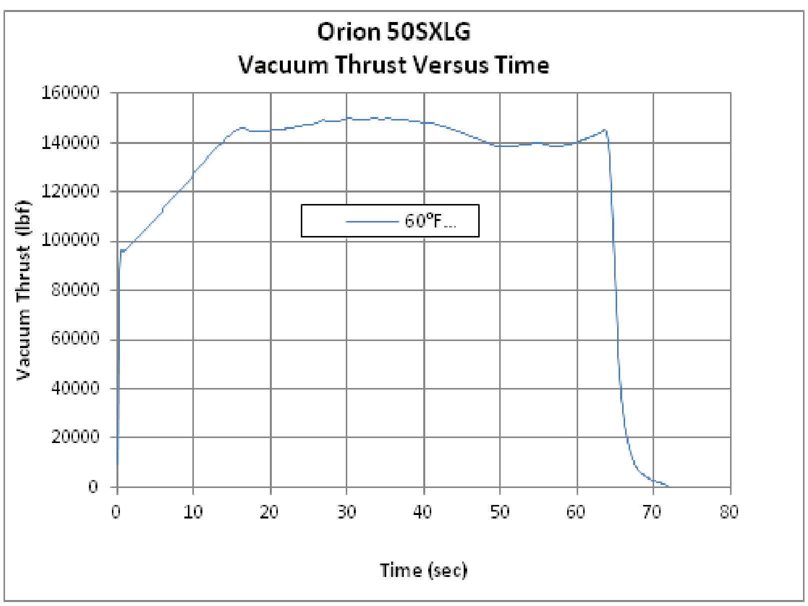
PRODUCTION STATUS
.... FLIGHT-PROVEN, PRODUCTION

**Taurus XL first stage

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.



MOTOR DIMENSIONS

Motor diameter, in. 50.2
Overall motor length (including nozzle), in. 372.4
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

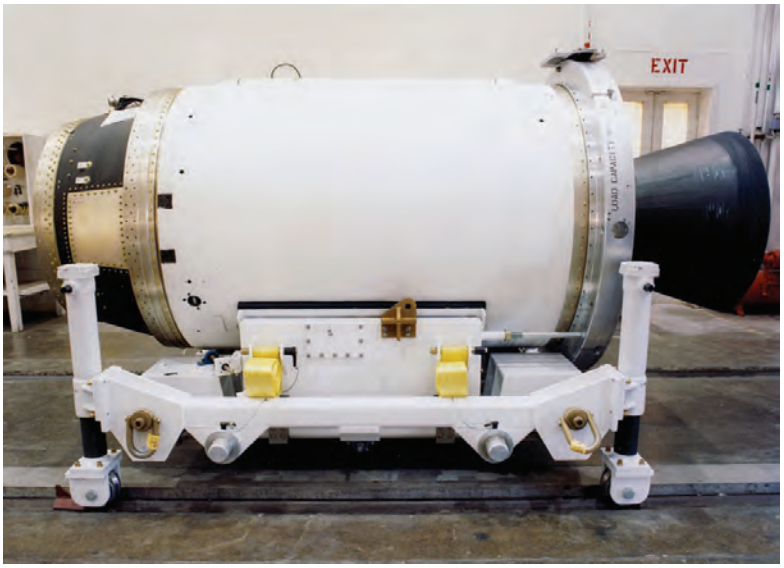
Operation ....+36°-100°F
Storage ....+30°-100°F

PRODUCTION STATUS

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

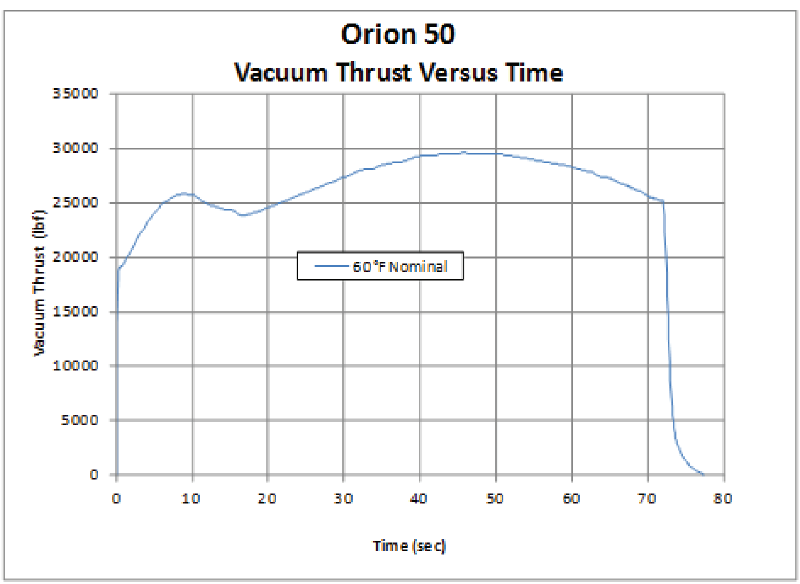
**Taurus Lite and GMD first stage

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 10 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 on six 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

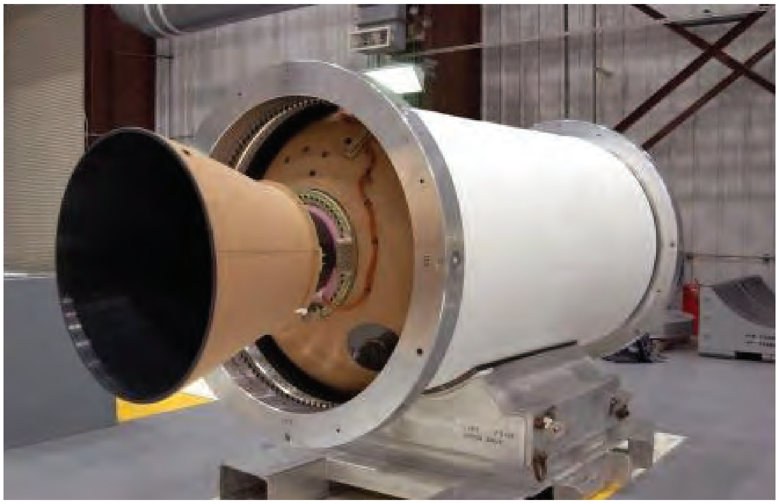
TEMPERATURE LIMITS
Operation .... +36°-100°F

STORAGE .... +30°-100°F

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

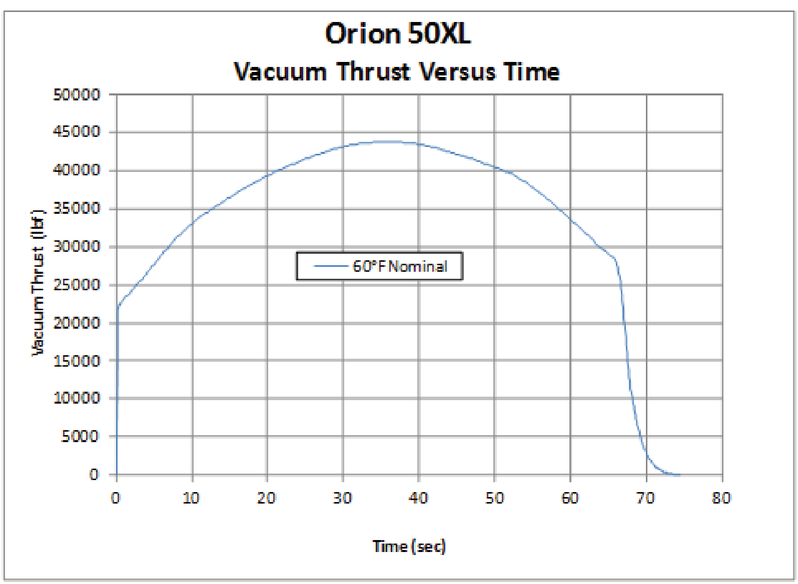
**Pegasus and Taurus standard second stage

ORION 50 XL (50 XLT)



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.



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

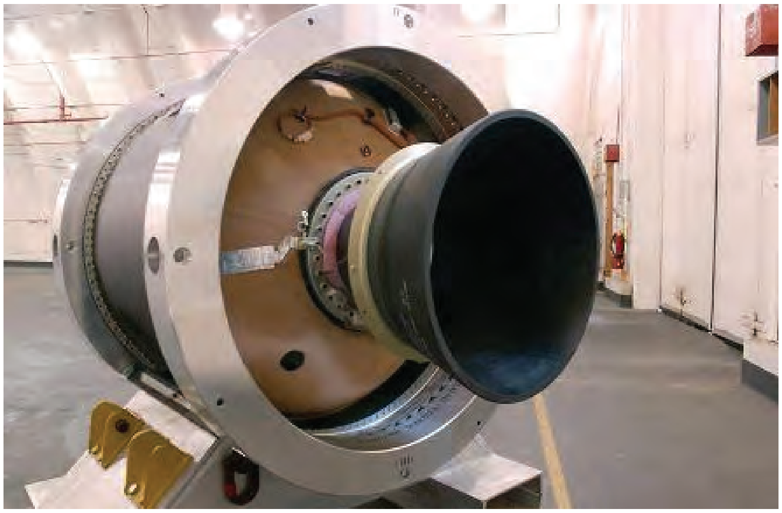
Operation .... +36°-100°F
Storage .... +30°-100°F

PRODUCTION STATUS

.... FLIGHT-PROVEN, PRODUCTION

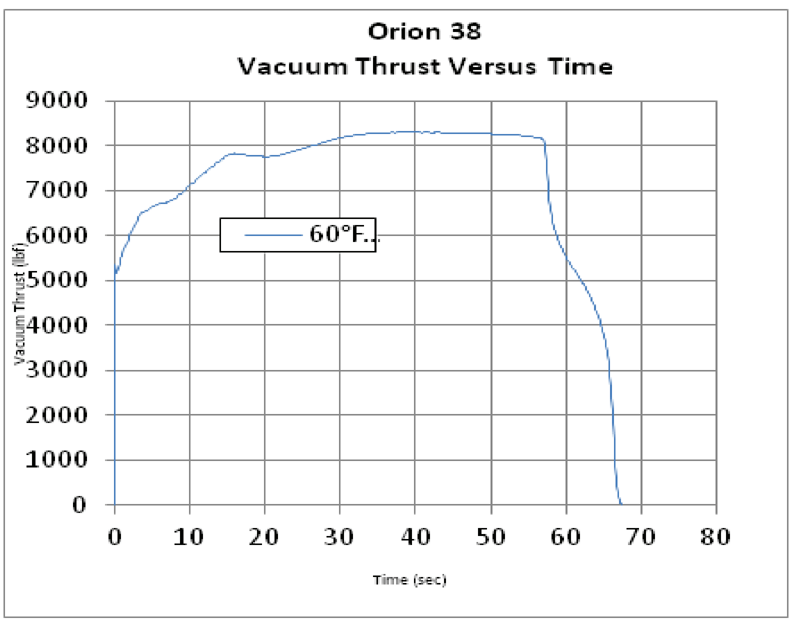
**Pegasus XL second stage, Minotaur I third stage

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, and Taurus Lite launch vehicles; and as the fourth stage of the Air Force's Minotaur vehicle. This motor has performed successfully in more than 75 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

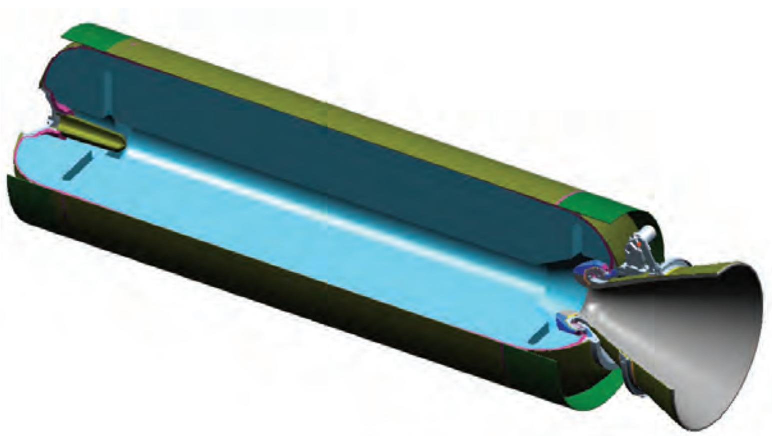
TEMPERATURE LIMITS

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

PRODUCTION STATUS
.... FLIGHT-PROVEN, PRODUCTION

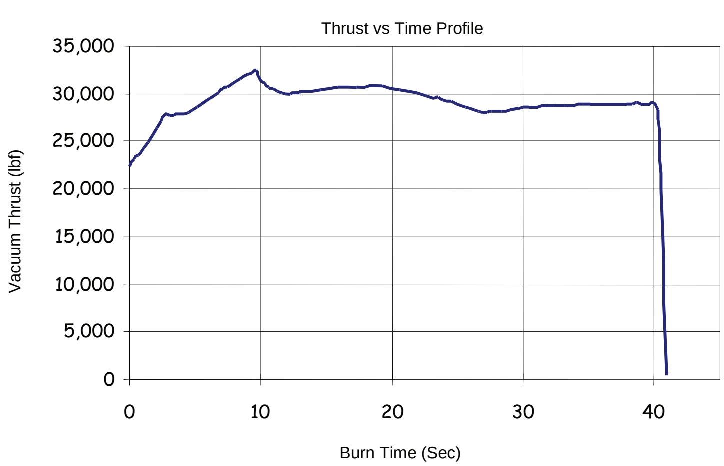
Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

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 121 inches long and nominally designed as a second-stage motor. A longer version (up to 255 inches) for potential first stage application and a reduced length version (down to 70 inches) are also in design evaluation. This motor configuration has not flown; however, all components, except skirts, are flight-proven.



MOTOR DIMENSIONS

Motor diameter, in. 32

Overall motor length (including nozzle), in. 121

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec. 41

Average chamber pressure, psia..........................660

Total impulse, lbf-sec.................................1,186,000

Burn time average thrust, lbf 28,800

NOZZLE

Housing material..Aluminum

Exit diameter, in. 24.9

Expansion ratio, average.......................................23

WEIGHTS, lbm

Total loaded 4,721

Propellant 4,280

Burnout 418

PROPELLANT DESIGNATION

..............QDL-2, HTPB POLYMER, 20% ALUMINUM

RACEWAY .... OPTIONAL

ORDNANCE .... OPTIONAL

TVA .... OPTIONAL

TEMPERATURE LIMITS

Operation...+20°-100°F

Storage ....+20°-100°F

PRODUCTION STATUS.................IN DESIGN

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, TVC version with first stage, second stage, or strap-on booster application

Orbital ATK 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. Orbital ATK 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.

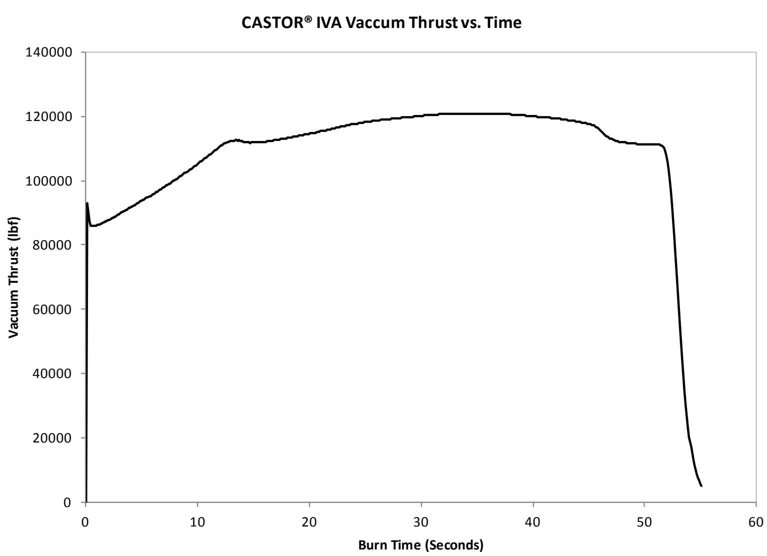
Development of the CASTOR 120 motor began in 1989. The CASTOR 120 was designed, using proven technology, to meet the need for a medium-sized, reliable, solid rocket booster. The primary goals of the program were to achieve a >0.999 reliability rating and a 50% cost reduction. CASTOR 120 motors have served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

More recently, an upper stage CASTOR 30/30B and CASTOR 30XL have been added to the series. CASTOR 30/30B/30XL have each flown successfully on Orbital ATK's Antares launch vehicle.

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 increase 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

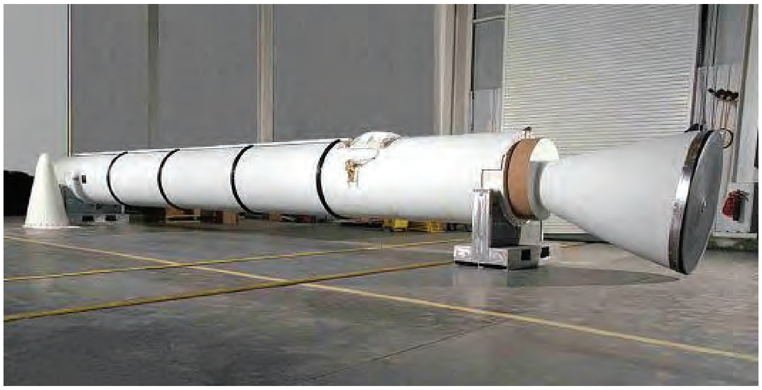
ORDNANCE .... YES

TVA .... NO

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

PRODUCTION STATUS
.... FLIGHT PROVEN, INACTIVE PRODUCTION

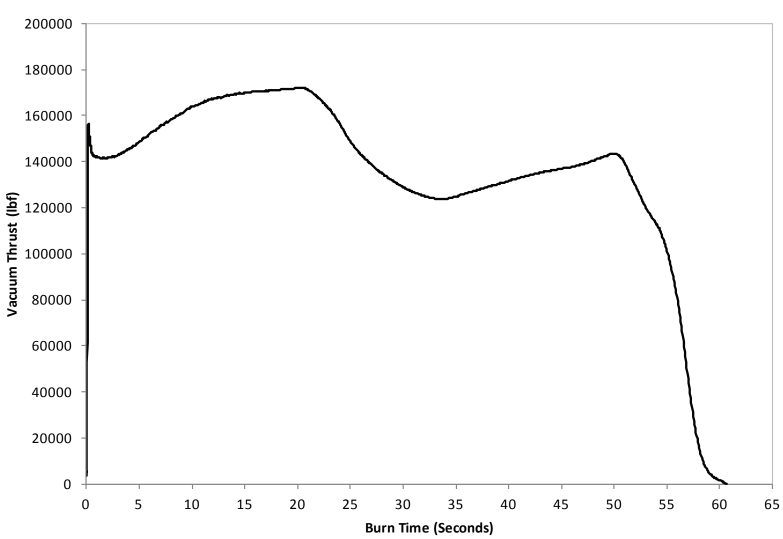
CASTOR IVA-XL



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 uses modified CASTOR IVA-XL motors with 6-degree canted nozzles as solid strap-on boosters (SSB). The H-IIA can use two or four SSBs depending on mission requirements and vehicle configuration. The first CASTOR IVA-XL SSB motors flew on the H-IIA vehicles in 2002.

CASTOR® IVA-XL Vaccum Thrust vs. Time



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

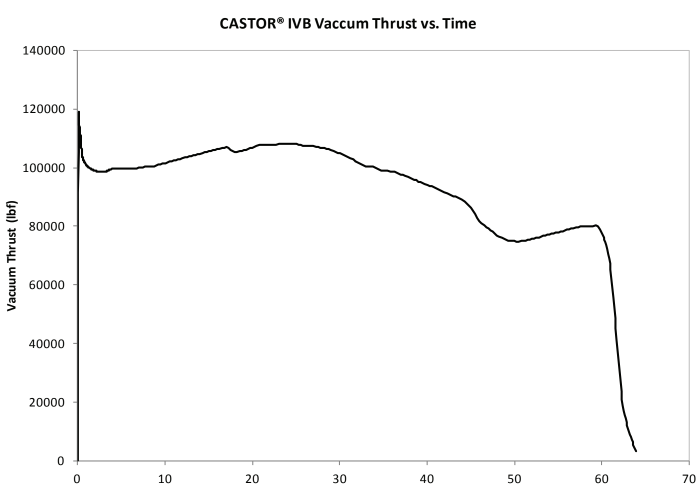
.... FLIGHT PROVEN, INACTIVE PRODUCTION

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

CASTOR IVB

VECTORABLE NOZZLE IN-LINE BOOSTER

The CASTOR IVB motor was the first in the series of CASTOR IVA motors to incorporate TVC 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, INACTIVE PRODUCTION

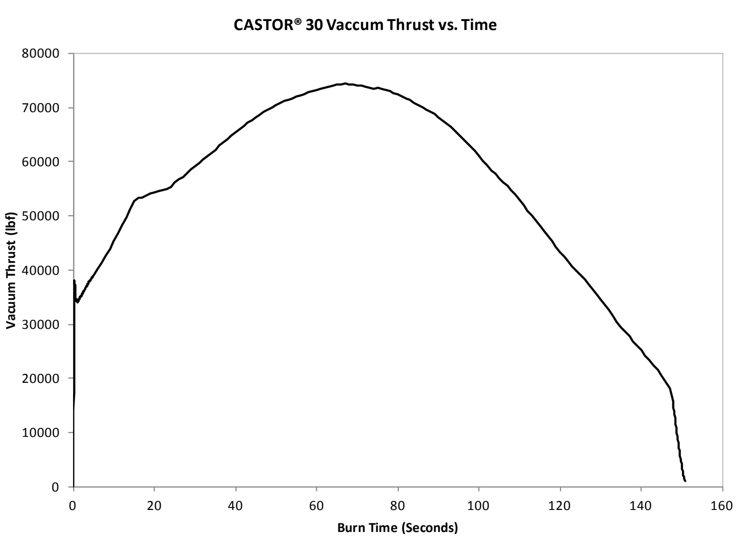
Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

Orbital ATK

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

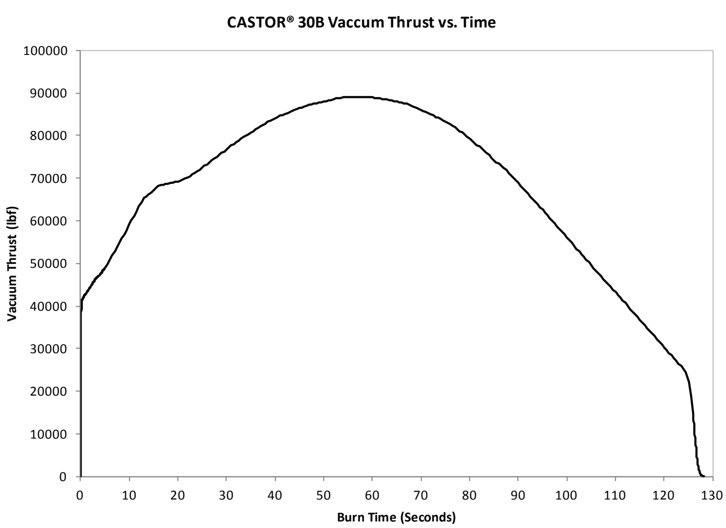
PRODUCTION STATUS ....FLIGHT-PROVEN

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

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

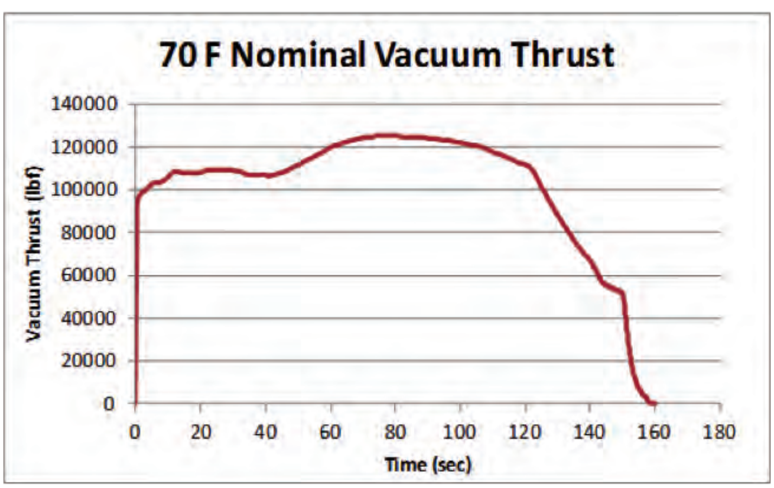
PRODUCTION STATUS.......... FLIGHT-PROVEN

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

CASTOR 30XL

VECTORABLE NOZZLE IN-LINE UPPER STAGE BOOSTER

The CASTOR 30XL is a new 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 on the Large Class Stage (LCS) I and LCS 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 TVA system with actuators, thermal battery and electronic controller. A simulated altitude qualification static test was sucessfully completed March 2013.



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

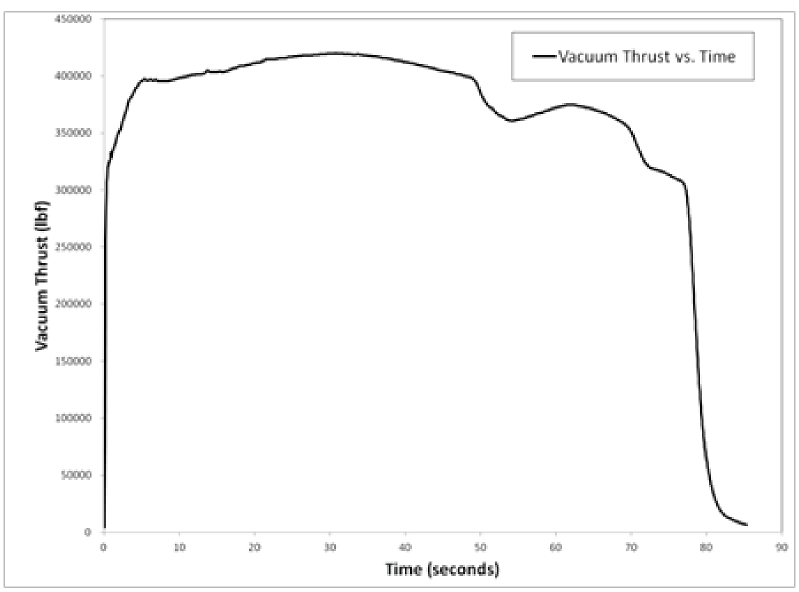
Operation...+55°-85°F
Storage… ....+30°-100°F
PRODUCTION STATUS..............FLIGHT-PROVEN,
....IN PRODUCTION

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

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 TVC. The TVC 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

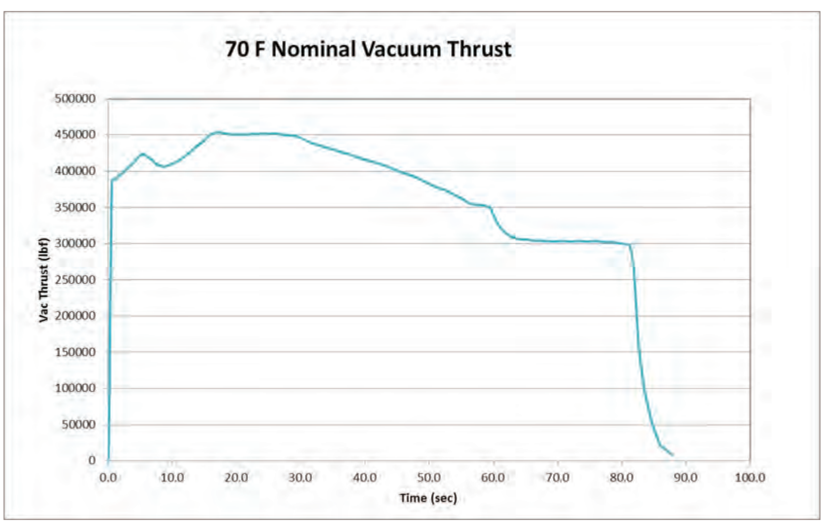
TEMPERATURE LIMITS
Operation ....+30°-100°F
Storage ....+30°-100°F

PRODUCTION STATUS
.... FLIGHT PROVEN, INACTIVE PRODUCTION

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 on the Large Class Stage (LCS) I and LCS III. The motor is 378.3 inches long and nominally designed as a medium-sized in-line booster. It features an electro-mechanical TVA 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 THROUGH STATIC TEST, IN PRODUCTION

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Dated 05 April 2016

LARGE CLASS STAGE (LCS)

HIGH-PERFORMANCE, HIGH-RELIABILITY BOOSTERS

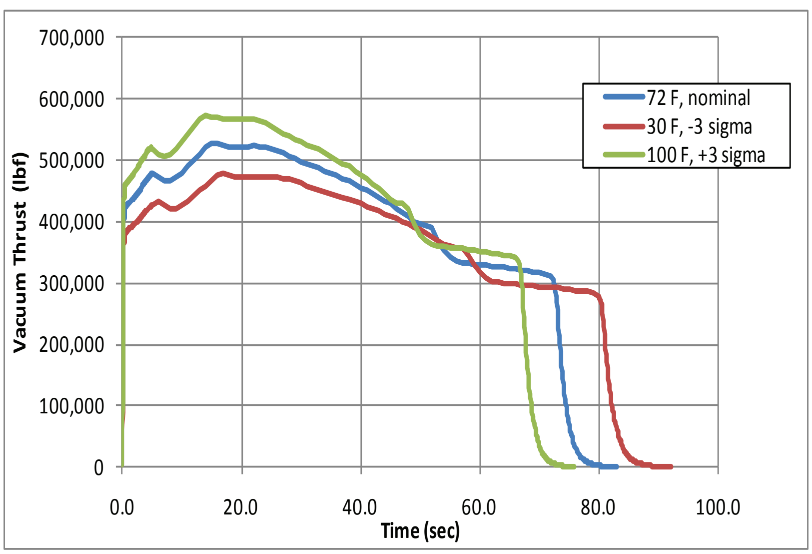
Orbital ATK developed and demonstrated, with the support of the U.S. Air Force, large class (92-inch-diameter) stages (LCS) that may be applicable to multiple future common strategic propulsion systems and potential application to a family of motors capability. The motors include the latest in emerging technologies to enhance performance and reliability while reducing cost. Motors have been successfully demonstrated in full-scale static test.

LCS I was developed as a first stage ground-launched booster and LCS III was developed as an upper stage motor.

LCS I

VECTORABLE NOZZLE IN-LINE BOOSTER

LCS I is a large booster stage motor designed for first stage use. The high-performance motor is being developed by Orbital ATK for the Large Class Stage I program and uses state-of-the-art emerging material and processing technologies for increased performance and reliability with reduced cost. Orbital ATK and the Air Force are developing the motor to meet a range of potential future strategic or launch vehicle applications. Key features of the motor include a domestic fiber case and an electromechanical TVC system providing ±5-degree vector capability. A successful ground static test was completed on May 23, 2015.



MOTOR DIMENSIONS

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

MOTOR PERFORMANCE (72°F NOMINAL, VACUUM)

Burn time to 150 psia, sec 77.9
Maximum thrust, lbf 511,100
Effective specific impulse, lbf-sec/lbm…. 279.0
Total impulse, lbf-sec 31,774,000
Burn time average thrust, lbf 408,400

WEIGHTS, LBM

Total motor...123,665
Propellant 114,194
Burnout (est)..8,884

PROPELLANT DESIGNATION

.... TP-H1246, 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 ....QUALIFIED

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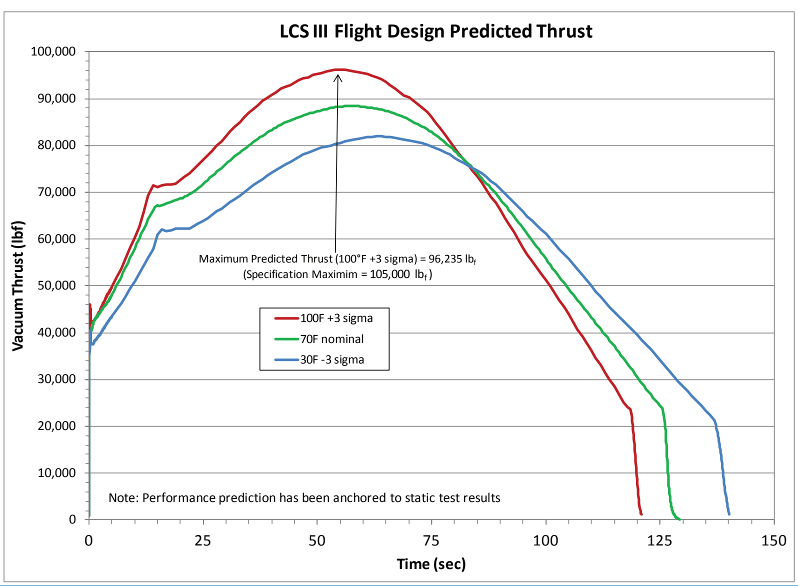
LCS III

VECTORABLE NOZZLE

LCS III is an upper stage motor designed to ignite at altitudes in excess of 85,000 feet. The high-performance motor was developed by Orbital ATK for the Large Class Stage III program and uses state-of-the-art emerging material and processing technologies for increased performance and reliability with reduced cost. Orbital ATK and the Air Force have developed the motor to meet a range of potential future applications. Key features of the motor include a domestic fiber case and an electromechanical TVC system providing ±3.5-degree vector capability. LSC III was successfully demonstrated in late 2011 in a full-scale static test at Arnold Engineering Development Center in Tennessee using a vacuum chamber designed to simulate upper atmospheric conditions.



MOTOR DIMENSIONS

Motor diameter, in. 92.1
Overall motor length (including nozzle), in. 164.5
Nozzle exit cone diameter, in. 60.00

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec 133.0
Maximum thrust, lbf 86,840
Effective specific impulse, lbf-sec/lbm… 300.3
Total impulse, lbf-sec 8,483,300
Burn time average thrust, lbf 63,730

WEIGHTS, LBM

Total motor 31,307
Propellant 28,278
Inert 3,029
Burnout (est) 2,845

PROPELLANT DESIGNATION

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

RACEWAY .... YES

ORDNANCE .... NO

TVA .... YES

TEMPERATURE LIMITS

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

PRODUCTION STATUS

.... QUALIFIED AT SIMULATED ALTITUDE

GEM MOTOR SERIES

RELIABLE, LOW-COST BOOSTERS

The Graphite Epoxy Motor (GEM) series originated with the GEM 40 motor. Orbital ATK 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. A new GEM 63 is in development for use on future launch vehicles.

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. Orbital ATK 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.

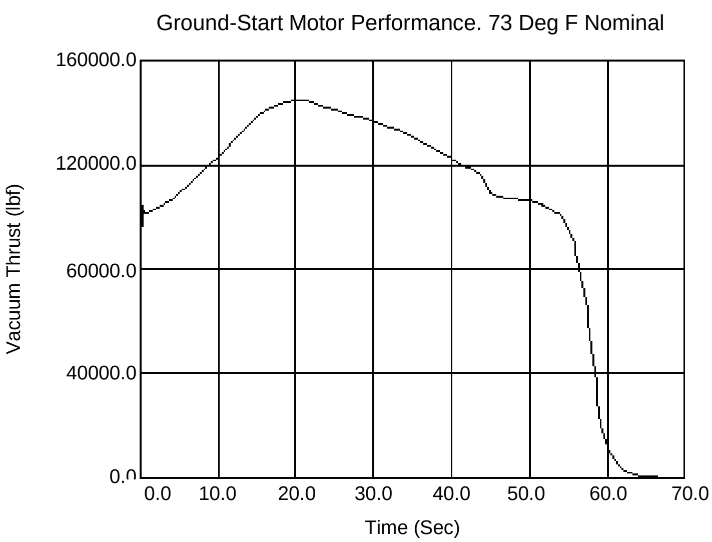
The GEM family of motors includes:

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

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. The GEM 40 has flown on Delta II vehicles since 1991.



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

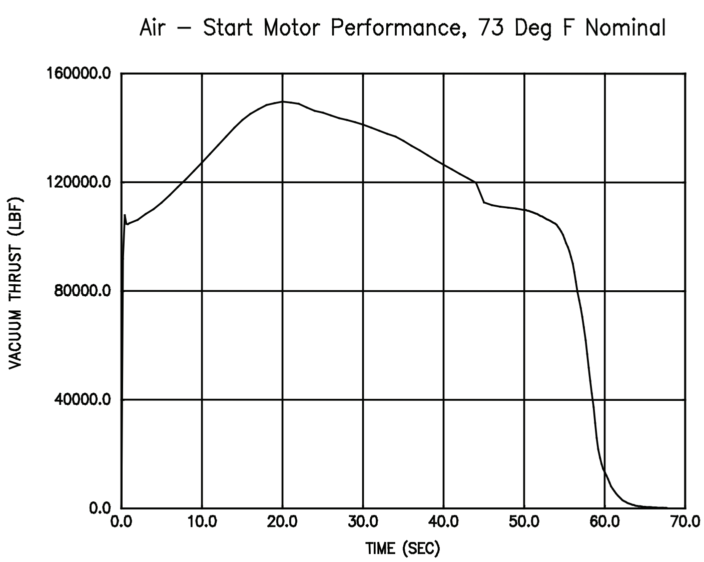
Operation .....+30°-100°F
Storage .....+30°-100°F

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

GEM 40 (AIR IGNITED)

FIXED NOZZLE, AIR-IGNITED

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



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

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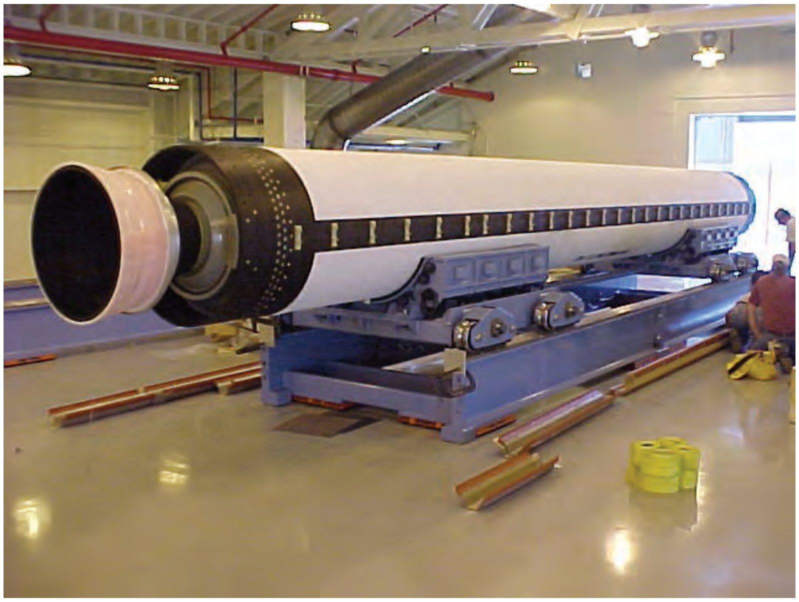
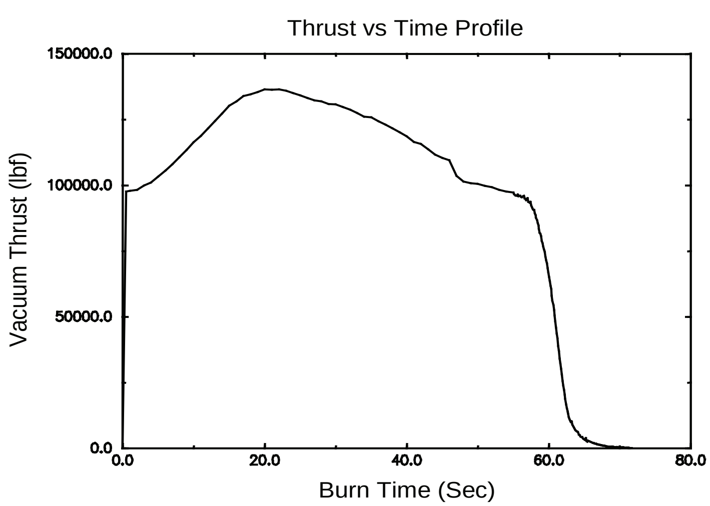
GEM 40VN



VECTORABLE NOZZLE, GROUND-IGNITED, IN-LINE MOTOR

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



MOTOR DIMENSIONS

Motor diameter, in. 40
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

Approved for Public Release
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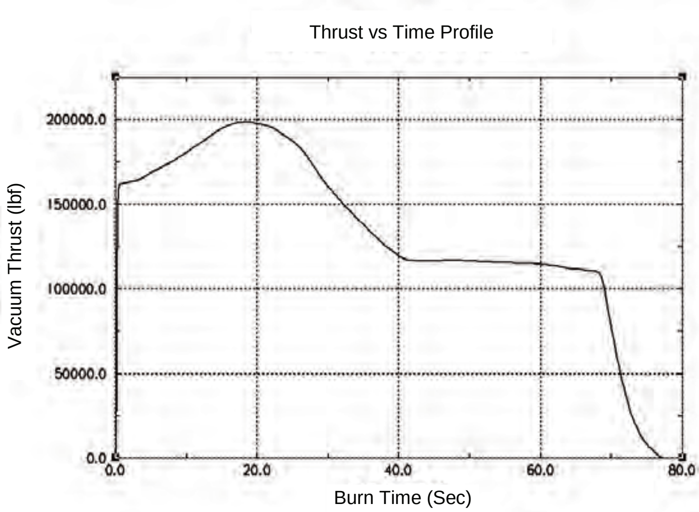
Dated 05 April 2016

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

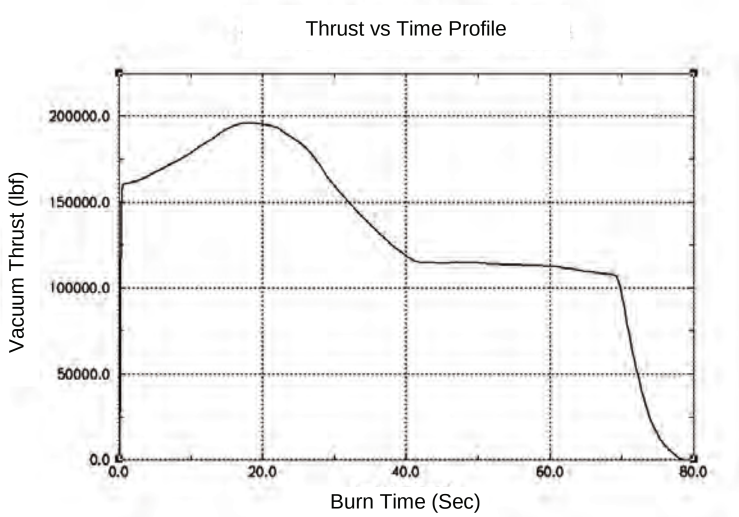
Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

Orbital ATK

GEM 46 (VECTORABLE, GROUND-IGNITED)

VECTORABLE NOZZLE, GROUND-IGNITED

The larger diameter, extended length graphite epoxy motor (GEM 46) is a strap-on booster system originally developed to increase the payload-to-orbit capability of the Delta III launch vehicle. The GEM 46 features an IM7/55A graphite composite motor case and an aramid-filled EPDM insulator. This configuration has a 5-degree canted, ±5-degree moveable nozzle assembly with a high performance 3-D carbon-carbon throat and carbon phenolic insulators. Ignition is accomplished with a forward mounted pyrogen igniter. This GEM 46 booster includes TVA, 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

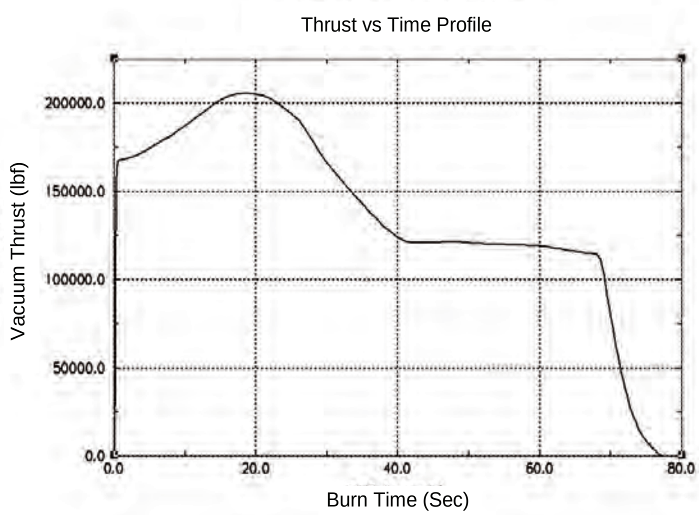
TEMPERATURE LIMITS
Operation .... +30°-100°F
Storage .... +30°-100°F

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

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

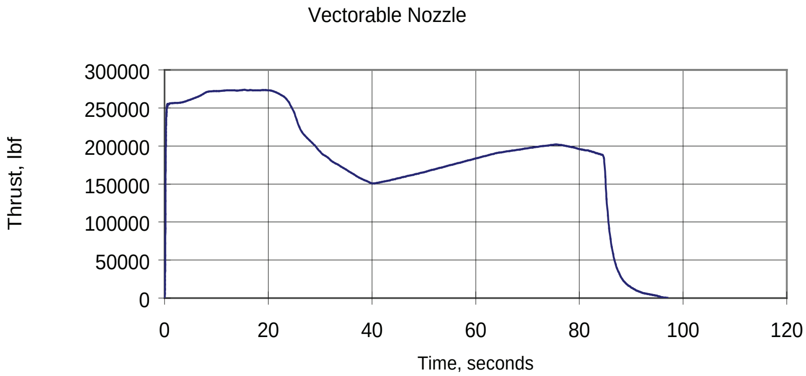
TEMPERATURE LIMITS
Operation .... +30°-100°F
Storage .... +30°-100°F

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

GEM 60 (VECTORABLE)

VECTORABLE NOZZLE

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



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, IN PRODUCTION

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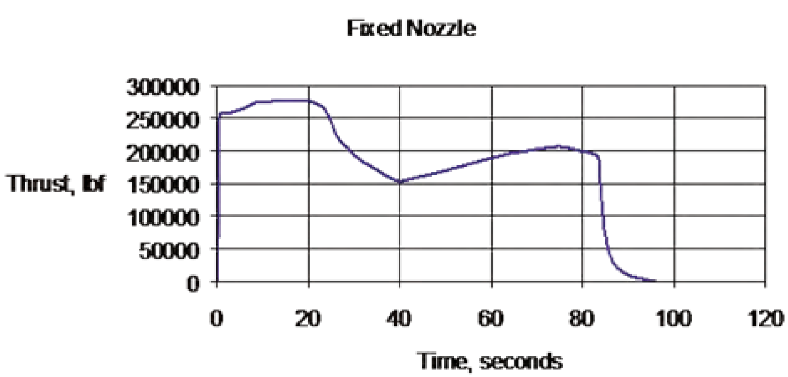
Dated 05 April 2016

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 (CFM) 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 (EELV) program.



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, IN PRODUCTION

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

Orbital ATK

GEM 63

FIXED NOZZLE BOOSTER

The GEM 63 is a new low cost, robust, state-of-the-art strap-on booster stage being designed for use on future launch vehicles. 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 motor is 789.3 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 currently in development and as such specifications may change. Full-scale static test and qualifiction are scheduled for mid-2018.

MOTOR DIMENSIONS

Motor diameter, in. 63
Overall motor length (incl. nozzle/fairing, etc) in.789.3
Nozzle exit cone diameter, in. 54.0

MOTOR PERFORMANCE (73°F VACUUM, VACUUM)

Burn time, sec. .... *
Maximum thrust,lbf .... *
Effective specific impulse, lbf-sec/lbm .... *
Total impulse, lbf-sec .... *
Burn time average thrust, lbf .... *

WEIGHTS, LBM

Total motor .... *
Propellant .... *
Burnout (est) .... *

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION.... .... 1.3

RACEWAY .... YES

ORDNANCE .... TBD

TEMPERATURE LIMITS

Operation ....+40°-90°F
Storage ....+30°-100°F

PRODUCTION STATUS

....IN DEVELOPMENT

* Please contact us for current information

GEM 63XL

FIXED NOZZLE BOOSTER

The GEM 63XL is a new low cost, robust, state-of-the-art strap-on booster stage being designed for use on future launch vehicles. 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 is being 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 862.0 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 currently in development and as such specifications may change. Full-scale static test and qualifiction are scheduled for mid-2018.

MOTOR DIMENSIONS

Motor diameter, in. 63
Overall motor length (incl. nozzle/fairing, etc) in. 862.0
Nozzle exit cone diameter, in. 55.0

MOTOR PERFORMANCE (73°F VACUUM, VACUUM)

Burn time, sec. .... *
Maximum thrust, lbf .... *
Effective specific impulse, lbf-sec/lbm .... *
Total impulse, lbf-sec .... *
Burn time average thrust, lbf .... *

WEIGHTS, LBM

Total motor .... *
Propellant .... *
Burnout (est) .... *

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION 1.3

RACEWAY .... YES

ORDNANCE .... TBD

TEMPERATURE LIMITS

Operation .... +40°-90°F
Storage .... +30°-100°F

PRODUCTION STATUS

.... IN DEVELOPMENT

* Please contact us for current information

SOLID ROCKET MOTOR UPGRADE (SRMU)

The SRMU was developed for the U.S. Air Force and Lockheed Martin to increase the launch capability of the Titan IVB Space Launch Vehicle (retired). This vehicle supplies access to space for critical national security as well as for civil payloads and can be launched from the East and West Coasts. SRMU motor segments are manufactured using state-of-the-art automation, robotics, and process controls for a consistent, reliable, high-quality product.

The SRMU increased the launch capability of the Titan IVB Space Launch Vehicle. Designed to take advantage of proven, off-the-shelf technologies, the SRMU system provides 25% increased performance and heavier lift capability than the boosters used on earlier configurations.

The SRMU is a three-segment, 10.5-ft-diameter solid rocket motor. A flight set consists of two SRMUs. When fully assembled, each SRMU is approximately 112 ft. tall and weighs over 770,000 lb. With the SRMU, the Titan IVB low earth orbit payload exceeds 47,000 lb and its geosynchronous orbit payload capability ranges up to 12,700 lb.

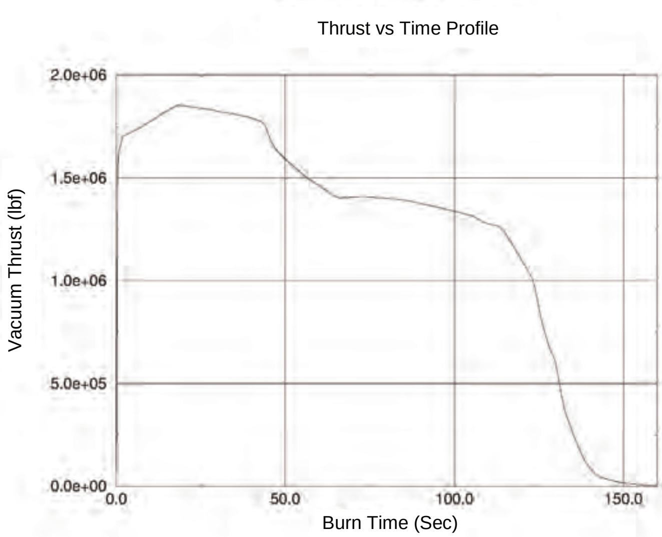
SRMU motor segments are manufactured using state-of-the-art automation, robotics, and process controls. Cases are filament wound with computer-controlled winding machines using a composite of high-strength fiber and durable epoxy resin. SRMUs are then cast and finished using an extensive network of computers and robotics, which enables highly accurate control of critical manufacturing processes for a consistent, reliable, high-quality product.

In 1997, Titan IVB launched the Cassini spacecraft and the Huygens Probe on an international mission to study Saturn. Weighing roughly 13,000 lb, the Cassini spacecraft is one of the largest ever launched. The spacecraft entered Saturn’s orbit on July 1, 2004.

SRMU


STRAP-ON BOOSTER/SEGMENT

With the solid rocket motor upgrade (SRMU), the Titan IVB low earth orbit payload exceeds 47,800 lb and its geosynchronous orbit payload capability ranges up to 12,700 lb (East Coast launch) and the low earth polar orbit capability ranges up to 38,000 lb (West Coast launch). The SRMU successfully flew its first mission in 1997 with subsequent missions flown for the Air Force's Milstar and Defense Support Program satellites, the National Reconnaissance Organization's military intelligence satellites, and NASA's Cassini satellite. The SRMU is a three-segment solid rocket motor, manufactured in segments, shipped to the launch site, and stacked at the site.



MOTOR DIMENSIONS
Motor diameter, in. 126
Motor length, in. 1,349

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)
Burn time, sec 135.7
Average chamber pressure, psia 859.5
Total impulse, lbf-sec 195,476,128
Burn time average thrust, lbf 1,440,502

NOZZLE
Housing material
.... 4340 steel with graphite epoxy overwrap
Exit diameter, in. 128.6
Expansion ratio, average 15.7

WEIGHTS, LBM
Total loaded 776, 038
Propellant 695,427
Case 35,075
Nozzle 14,706
Other 30,830
Burnout 80,611

PROPELLANT DESIGNATION
....QDT, 88% SOLIDS HTPB

HAZARDS CLASSIFICATION 1.3

RACEWAY .... YES

ORDNANCE .... YES

TVA .... YES

TEMPERATURE LIMITS
Operation ....25°-100°F

PRODUCTION STATUS ....
.... FLIGHT PROVEN, OUT OF PRODUCTION

Approved for Public Release
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Dated 05 April 2016

REUSABLE SOLID ROCKET MOTOR (RSRM)

In 1974, NASA chose Thiokol (now part of Orbital ATK) 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 is 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, TVC, 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.

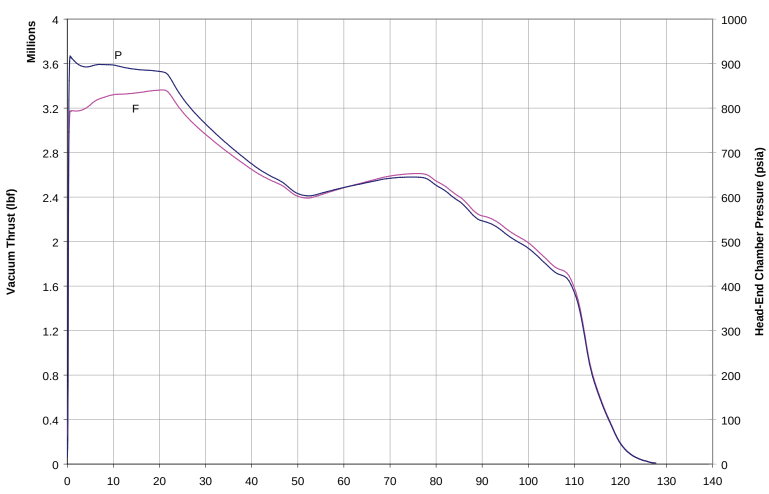
RSRM

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 generates an average thrust of 2,600,000 lb and burns for approximately 123.6 seconds. By the time the twin RSRMs have completed their task, the Space Shuttle orbiter has reached an altitude of 24 nautical miles and is traveling at a speed in excess of 3,000 miles per hour.

Engineers direct approximately 110,000 quality control inspections on each RSRM flight set. RSRMs are 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

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RSRM DERIVATIVES

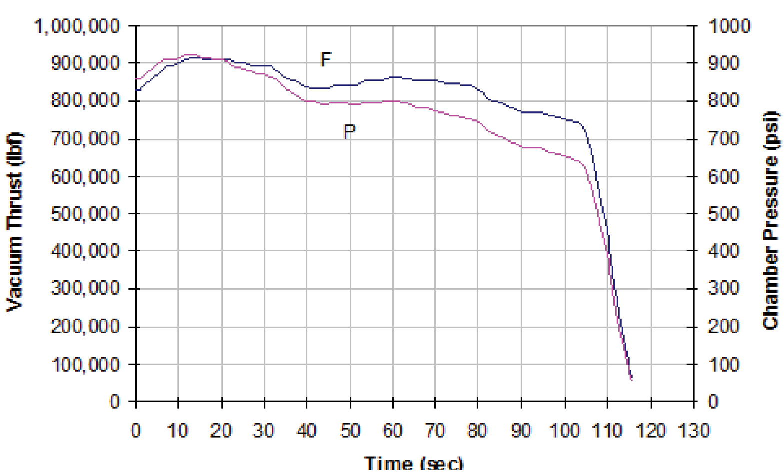
VECTORABLE NOZZLE HEAVY-LIFT BOOSTERS

Reusable solid rocket motor (RSRM) derivative boosters have the demonstrated reliability of the human-rated Space Shuttle system and the experience provided by a long heritage of successful flight. Examining recovered RSRM hardware and using RSRM program history has allowed for continuous reliability assessments and improvement to RSRM production hardware. Additional enhancements have been developed and matured through the Ares/Space Launch System (SLS) five-segment reusable solid rocket motor (RSRMV) programs. While RSRM production has ended, sustained RSRMV production for the SLS provides synergistic cost savings and reliable, qualified material sources to also support derivative boosters. Finally, a complete family of booster stacks in increments as small as a half segment allows customized and efficient payload matching. These derivative motors can be used as a first stage motor or a strap-on booster.

The existing NASA-heritage designs and processes may also be combined with commercial elements to provide high-thrust, safe, efficient, and capable first stage propulsion.

1-SEGMENT RSRM

FIXED/VECTORABLE NOZZLE



MOTOR DIMENSIONS

Motor diameter, in. 146.1
Motor length, in. 499.6

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec. 115.8
Average chamber pressure, psia......................750.8
Total impulse, lbf-sec 92,978,688
Burn time average thrust, lbf 802,989

NOZZLE

Housing material.....................................D6AC steel
Exit diameter, in. 93.8
Expansion ratio, average..................................10.75

WEIGHTS, LBM

Total loaded 404,601
Propellant 336,231
Case 30,867
Nozzle 16,000
Other..21,503
Burnout..66,072

TEMPERATURE LIMITS

Operation...+40º-90ºF

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION…. 1.3

TEMPERATURE LIMITS

Operation...+40º-90ºF

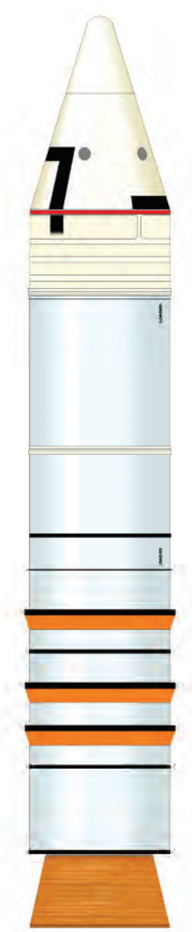
PRODUCTION STATUS

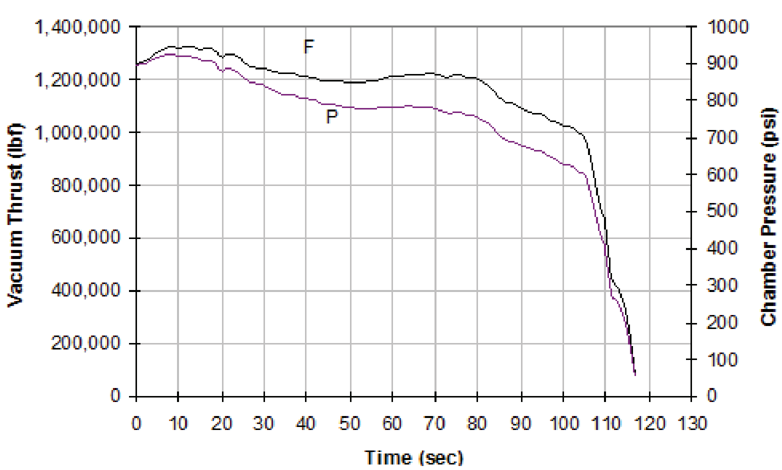
.... CONCEPT BASED ON A PRODUCTION MOTOR

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

1.5-SEGMENT RSRM

FIXED/VECTORABLE NOZZLE





MOTOR DIMENSIONS

Motor diameter, in. 146.1
Motor length, in. 697.0

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec. 117.0
Average chamber pressure, psia 741.6
Total impulse, lbf-sec 132,700,522
Burn time average thrust, lbf 1,134,183

NOZZLE

Housing material .... D6AC steel
Exit diameter, in. 113.3
Expansion ratio, average 11.8

WEIGHTS, LBM

Total loaded 558,993
Propellant 476,496
Case 41,666
Nozzle 16,000
Other 24,831
Burnout 79,286

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION… 1.3

TEMPERATURE LIMITS

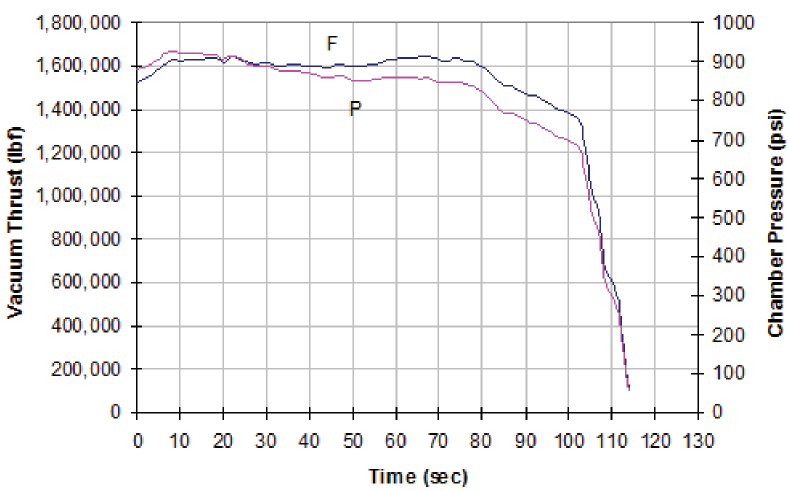
Operation .... +40º-90ºF

PRODUCTION STATUS

.... CONCEPT BASED ON A PRODUCTION MOTOR

2-SEGMENT RRSM

FIXED/VECTORABLE NOZZLE



MOTOR DIMENSIONS

Motor diameter, in. 146.1
Motor length, in. 860.0

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec. 114.1
Average chamber pressure, psia 798.7
Total impulse, lbf-sec 170,800,701
Burn time average thrust, lbf 1,497,451

NOZZLE

Housing material .... D6AC steel
Exit diameter, in. 118.7
Expansion ratio, average 10.4

WEIGHTS, LBM

Total loaded 715,659
Propellant 619,003
Case 52,465
Nozzle 16,000
Other 28,191
Burnout 93,075

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION.... .... 1.3

TEMPERATURE LIMITS

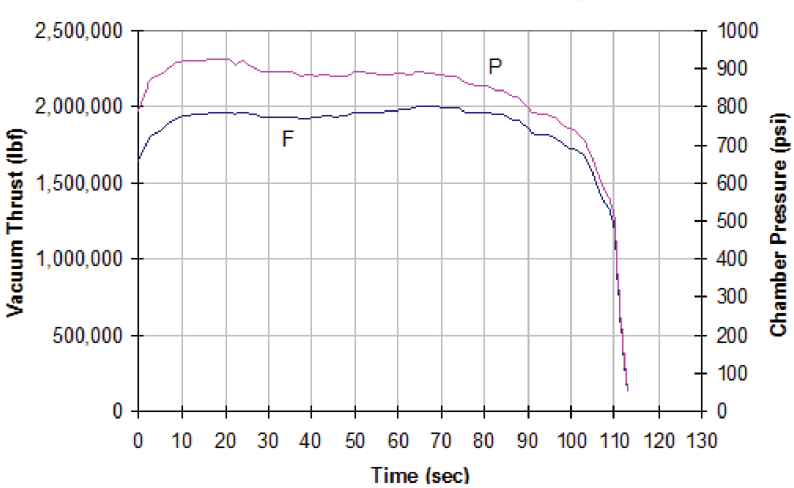
Operation .... +40º-90ºF

PRODUCTION STATUS

.... CONCEPT BASED ON A PRODUCTION MOTOR

2.5-SEGMENT RSRM

FIXED/VECTORABLE NOZZLE



MOTOR DIMENSIONS

Motor diameter, in. 146.1

Motor length, in. 697.0

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec. 117.0

Average chamber pressure, psia 741.6

Total impulse, lbf-sec 132,700,522

Burn time average thrust, lbf 1,134,183

NOZZLE

Housing material .... D6AC steel

Exit diameter, in. 113.3

Expansion ratio, average 11.8

WEIGHTS, LBM

Total loaded 558,993

Propellant 476,496

Case 41,666

Nozzle 16,000

Other 24,831

Burnout 79,286

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION… 1.3

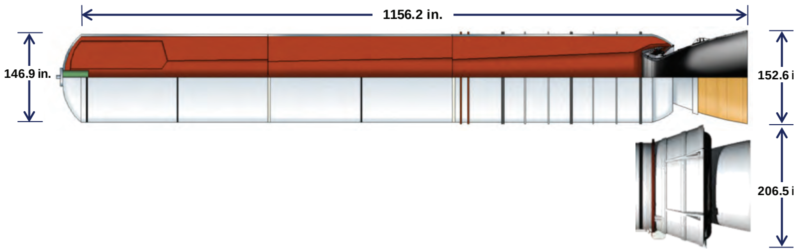
TEMPERATURE LIMITS

Operation .... +40º-90ºF

PRODUCTION STATUS

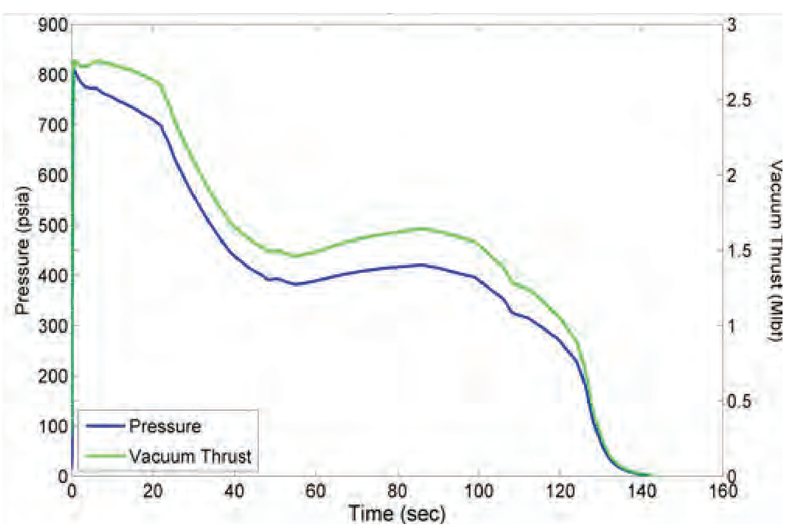
.... CONCEPT BASED ON A PRODUCTION MOTOR

3-SEGMENT RSRM



VECTORABLE NOZZLE, GROUND LAUNCH

This design combines existing NASA-heritage designs and processes with commercial elements to meet market-driven demands for competitive, capable, and reliable propulsion. The stage configuration consists of motor segments based on Ares and Space Launch System (SLS) upgrades to the Shuttle RSRM, an RSRM-design nozzle, and new, lower cost, aft skirt and TVC system. The benefits to using the Ares/SLS RSRMV motor segments include non-asbestos insulation, common materials and processes in the factory, and improved performance. The new non-asbestos insulation performs better, which allows thinner insulation and hence more propellant loading. The new TVC system provides ±5-degree capability and is based on a prototype electro-hydrostatic system designed for the Titan booster and leverages recent commercial TVC component development and qualification supporting CASTOR 30 motors.



MOTOR DIMENSIONS

Motor diameter, in. 146.1

Motor length, in. 860.0

MOTOR PERFORMANCE (70°F NOMINAL, VACUUM)

Burn time, sec. 114.1

Average chamber pressure, psia......................798.7

Total impulse, lbf-sec 170,800,701

Burn time average thrust, lbf 1,497,451

NOZZLE

Housing material.....................................D6AC steel

Exit diameter, in. 118.7

Expansion ratio, average....................................10.4

WEIGHTS, lbm

Total loaded 715,659

Propellant 619,003

Case 52,465

Nozzle 16,000

Other...28,191

Burnout...93,075

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION…. 1.3

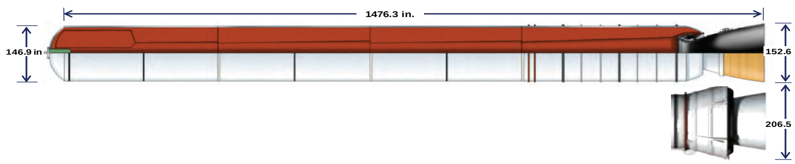
TEMPERATURE LIMITS

Operation..+40º-90ºF

PRODUCTION STATUS

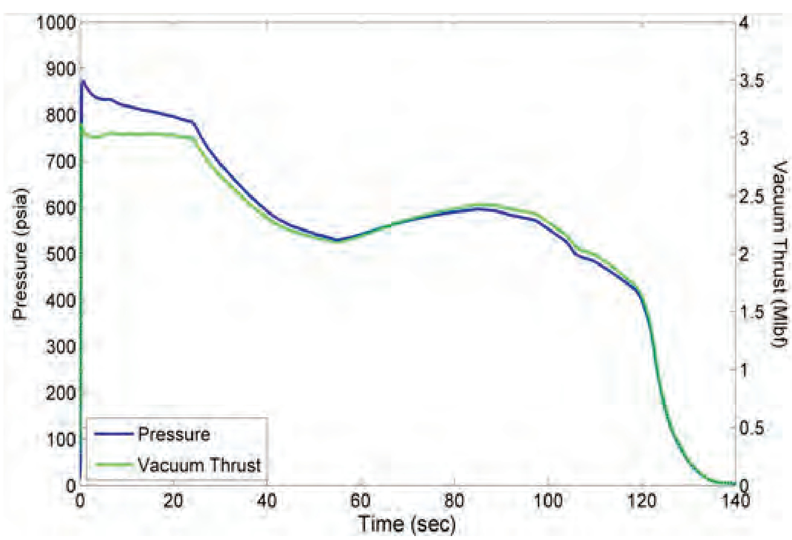
.... CONCEPT BASED ON A PRODUCTION MOTOR

4-SEGMENT RSRM



VECTORABLE NOZZLE GROUND LAUNCH

This design combines existing NASA-heritage designs and processes with commercial elements to meet market-driven demands for competitive, capable, and reliable propulsion. The stage configuration consists of motor segments based on Ares and SLS upgrades to the Shuttle RSRM, an RSRM-design nozzle, and new, lower cost aft skirt and TVC system. The benefits to using the Ares/SLS RSRMV motor segments include non-asbestos insulation, common materials and processes in the factory, and improved performance. The new non-asbestos insulation performs better, which allows thinner insulation and hence more propellant loading. The new TVC system provides ±5-degree capability and is based on a prototype electro-hydrostatic system designed for the Titan booster and leverages recent commercial TVC component development and qualification supporting CASTOR 30 motors.



MOTOR DIMENSIONS

Motor diameter, in. 146.9

Motor length, in. 1,476.3

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 1,278,078

Propellant 1,114,155

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

.... CONCEPT BASED ON A PRODUCTION MOTOR

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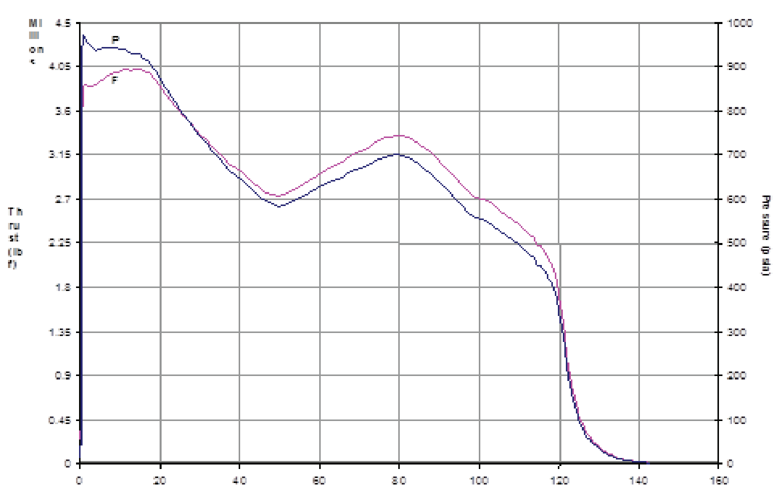
Dated 05 April 2016

5-SEGMENT RSRM

VECTORABLE NOZZLE GROUND LAUNCH

Orbital ATK and NASA are developing a five-segment RSRMV booster derivative that will generate a maximum thrust of approximately 3.6 million pounds. The five-segment RSRMV is also upgraded to incorporate newer technologies and materials such as non-asbestos insulation that provides cost and weight savings.

Originally baselined for Ares I/V under the Constellation program, the RSRMV is currently slated to be utilized as the baseline design for the initial flights under NASA's Space Launch System (SLS) architecture. Orbital ATK has conducted three successful development and one qualification static tests. A second qualification test is in preparation for mid-2016.



MOTOR DIMENSIONS

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

MOTOR PERFORMANCE (60°F NOMINAL, VACUUM)

Burn time, sec. 131.9
Average chamber pressure, psia 625.8
Total impulse, lbf-sec 381,367,646
Burn time average thrust, lbf 2,890,923

NOZZLE

Throat housing material .... D6AC steel
Exit diameter, in. 152.55
Expansion ratio, average 6.55

WEIGHTS, LBM

Total loaded 1,616,123
Propellant 1,427,807
Case 127,843
Nozzle 24,029
Other 36,444
Burnout 181,480

PROPELLANT DESIGNATION

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

HAZARDS CLASSIFICATION.... .... 1.3

TEMPERATURE LIMITS

Operation .... +40º-90ºF

PRODUCTION STATUS

........DEVELOPMENT TESTED, IN QUALIFICATION

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

STAR™ MOTOR SERIES

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

Orbital ATK'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 Orbital ATK 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. Orbital ATK 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:

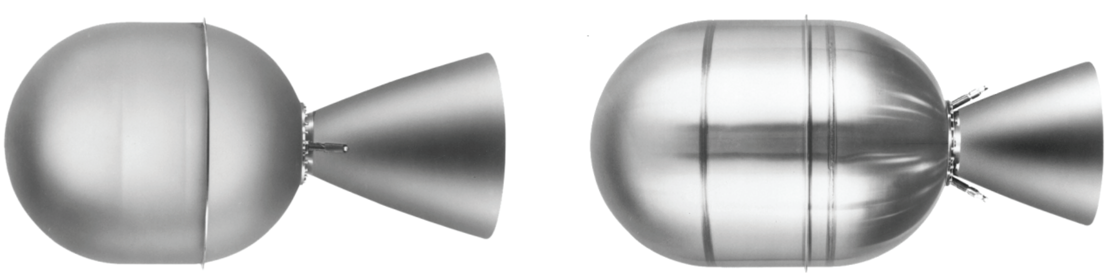
- Use of alternative case materials (steel, aluminum, titanium, composite)
- Qualification to new environments
- Use of proven materials to ensure space storability

- Exit cone length truncation or shortening to fit within a restricted envelope
- Provision of active thrust vector control (TVC) for vehicle steering
- Incorporation of a reaction control system (RCS) 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. Orbital ATK 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 (GSE) for the motor (e.g., turnover stands, handling stands, and leak test equipment)

Orbital ATK 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. Orbital ATK has prepared and provided to various customers documentation and field support for launches from Cape Canaveral Air Force Station (CCAFS) Kennedy Space Center (KSC), 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, Orbital ATK 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. Orbital ATK can also be enlisted to review and assess customer-prepared procedures for the safe handling of our rocket motors.

Field Support. Orbital ATK 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 Orbital ATK 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 (GSE). In addition to shipping containers, we can provide a variety of GSE for use in handling, inspection, and assembly of the rocket motor and ordnance devices. Orbital ATK also designs mission-specific equipment for installation of the motor into the spacecraft or stage. Typical GSE 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, Orbital ATK personnel have monitored all activities during development, qualification, and lot acceptance testing of Orbital ATK 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 RCS, allowing for potential of enhanced spacecraft usable weight on subsequent launches.

Typical postflight analysis that Orbital ATK 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.

STAR Motor Performance and Experience Summary

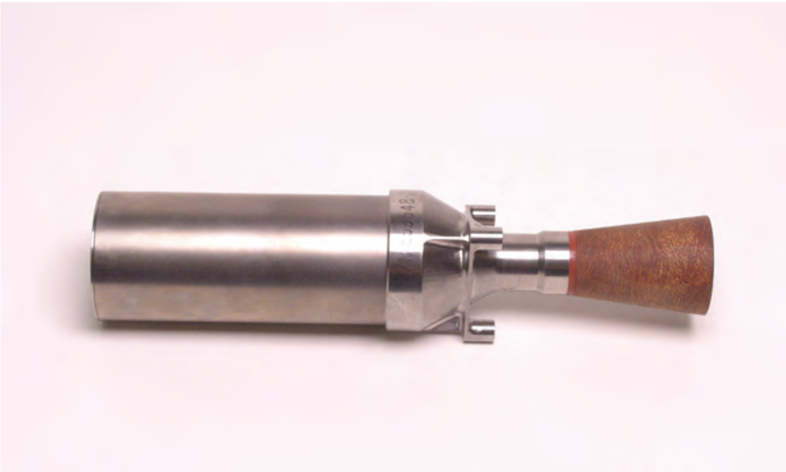
STAR Designation	Model Number	Nominal Diameter		Total Impulse, lb_f-sec	Effective **Specific** Impulse, lb_f-sec/lb_m	Propellant Weight		Propellant Mass Fraction	Tests	Flights
		in.	cm			lb_m	kg			
3	TE-M-1082-1	3.18	8.08	281.4	266.0	1.06	0.48	0.42	26	3
3A	TE-M-1089	3.18	8.08	64.4	241.2	0.27	0.12	0.14	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
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

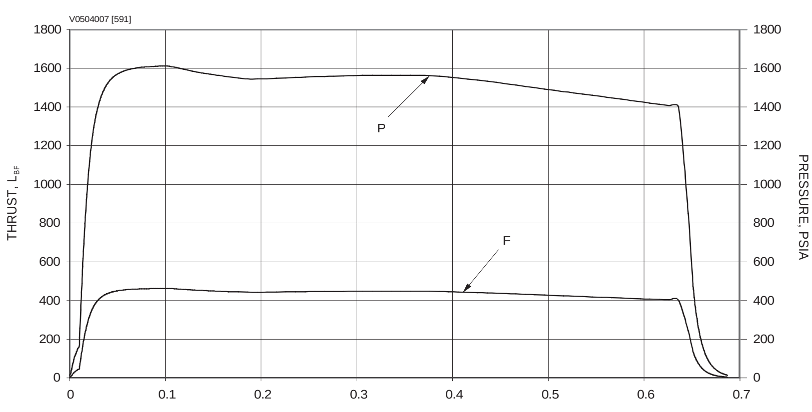
***STAR motors that have been replaced by other motor configurations**

STAR 3

TE-M-1082-1



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

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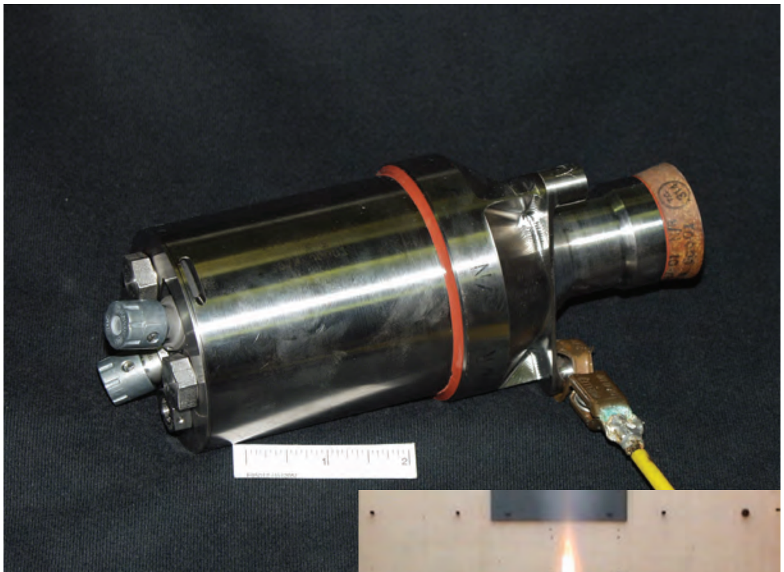
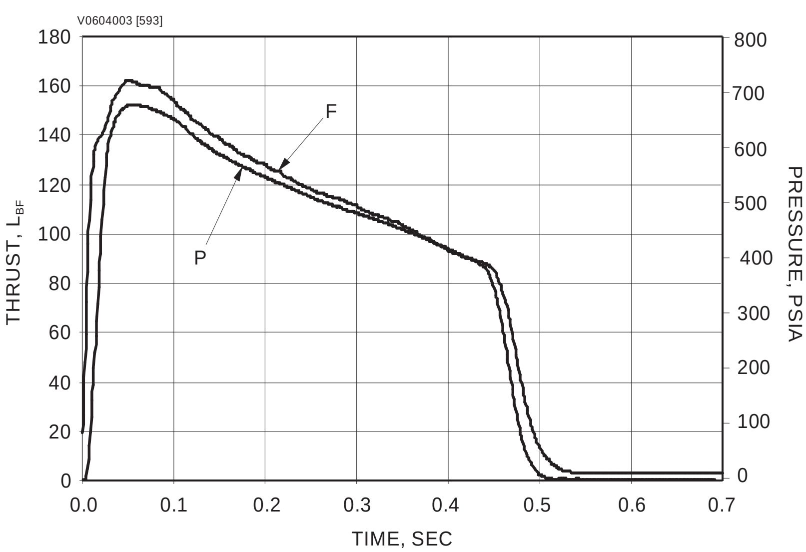
Dated 05 April 2016

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

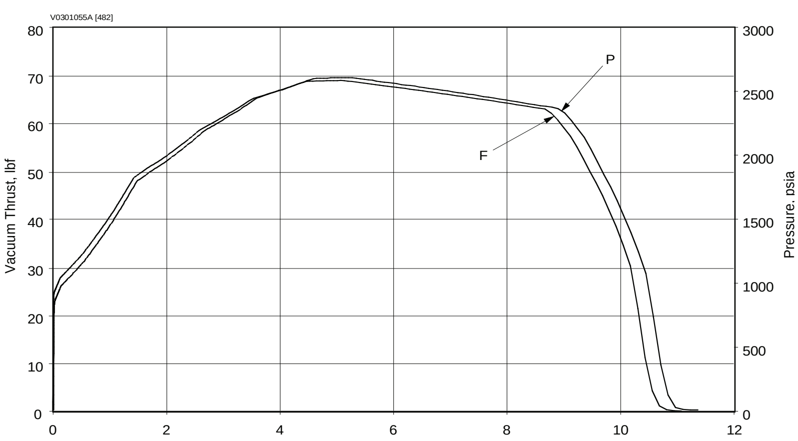
PRODUCTION STATUS

.... FLIGHT-PROVEN

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

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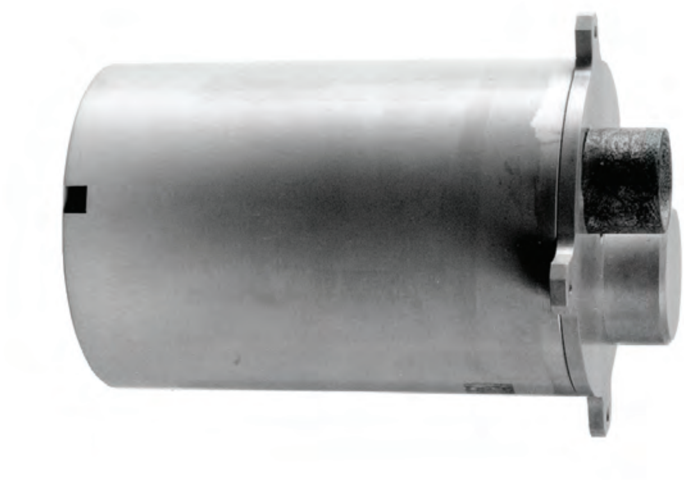
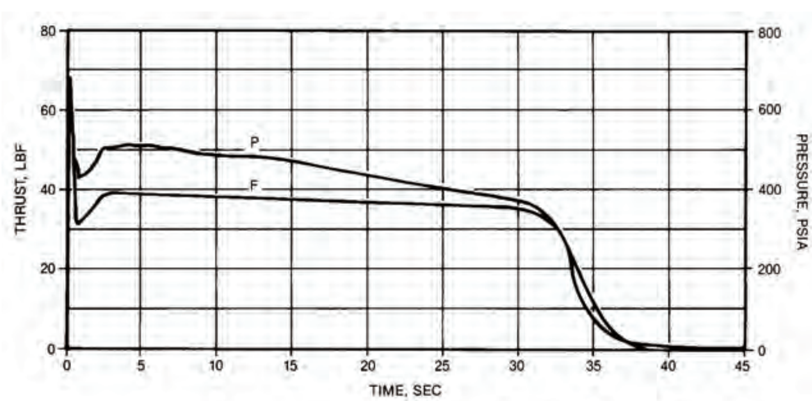
STAR 5A

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

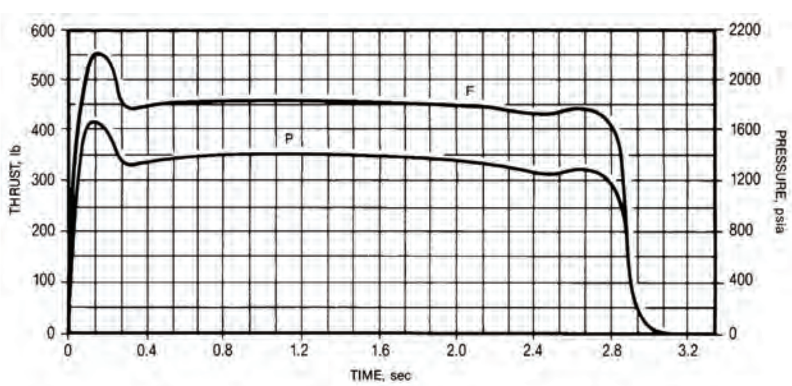
PRODUCTION STATUS
.... FLIGHT-PROVEN

Orbital ATK

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 is 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

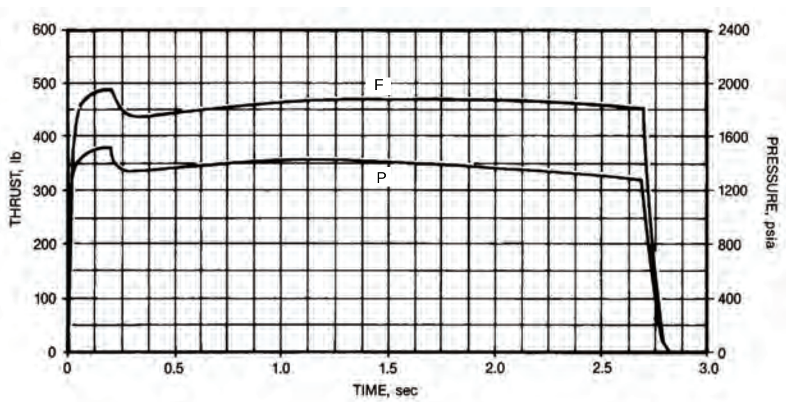
Orbital ATK

STAR 5CB

TE-M-344-16

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

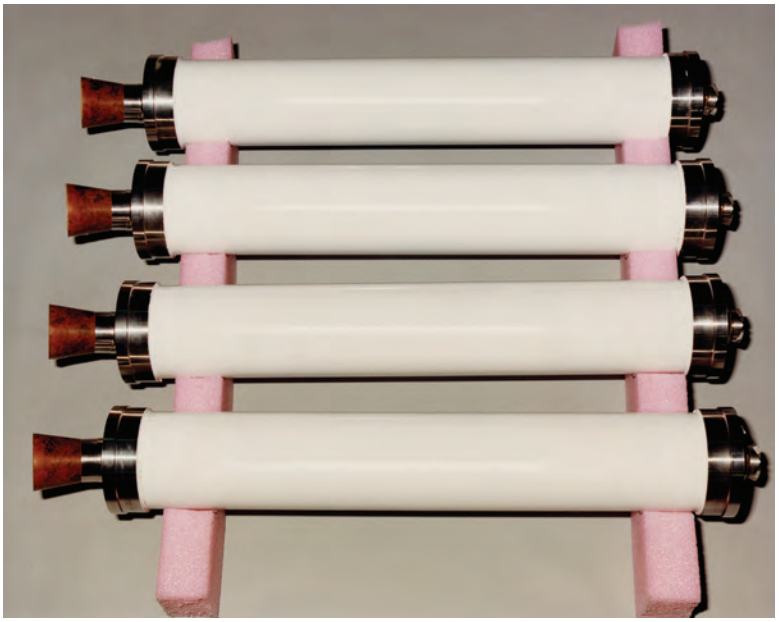
CASE MATERIAL .... 4130 STEEL

PRODUCTION STATUS .... FLIGHT-PROVEN

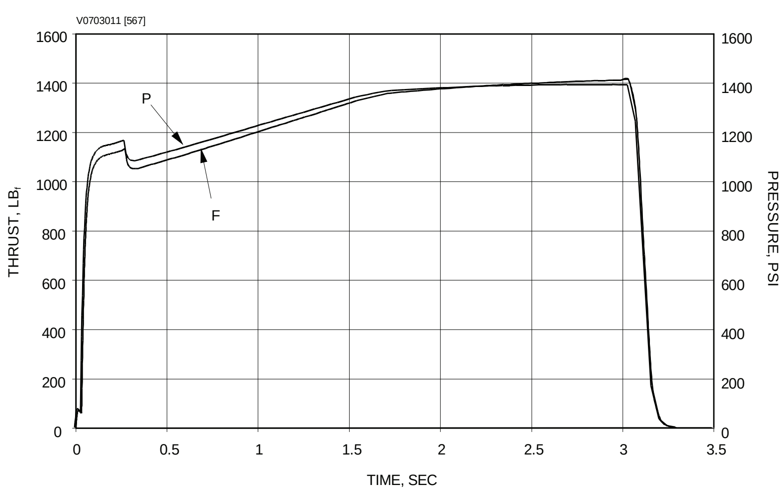
Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

STAR 5D

TE-M-989-2



The STAR 5D rocket motor was designed and qualified (1996) to serve as the rocket-assisted deceleration (RAD) 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

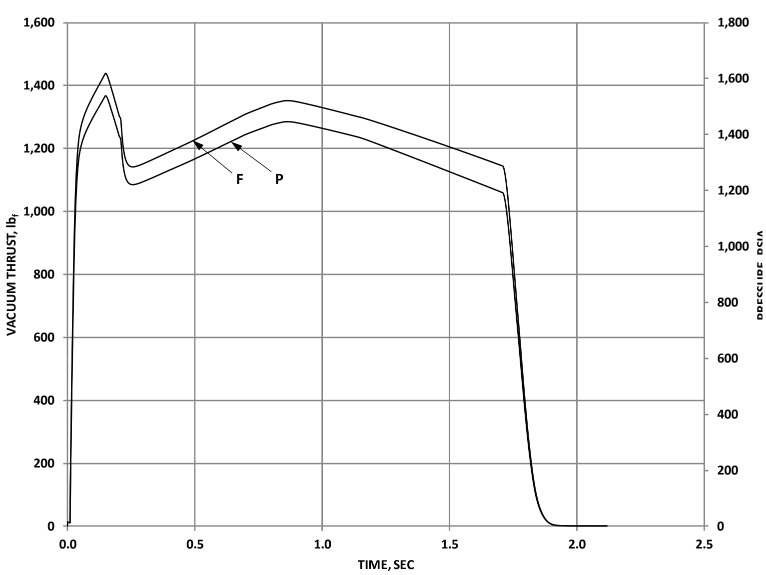
.... FLIGHT-PROVEN

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

STAR 5F

TE-M-1198

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

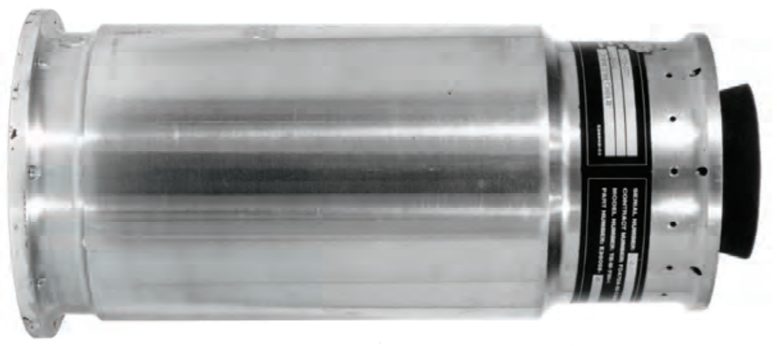
PROPELLANT DESIGNATION TP-H-3237B

CASE MATERIAL ....STAINLESS STEEL

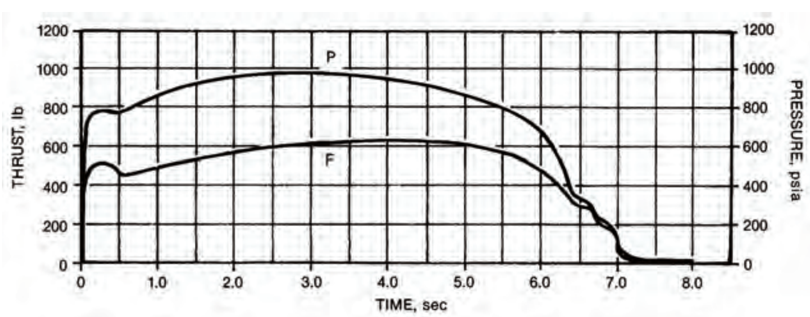
PRODUCTION STATUS
.... FLIGHT-PROVEN

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

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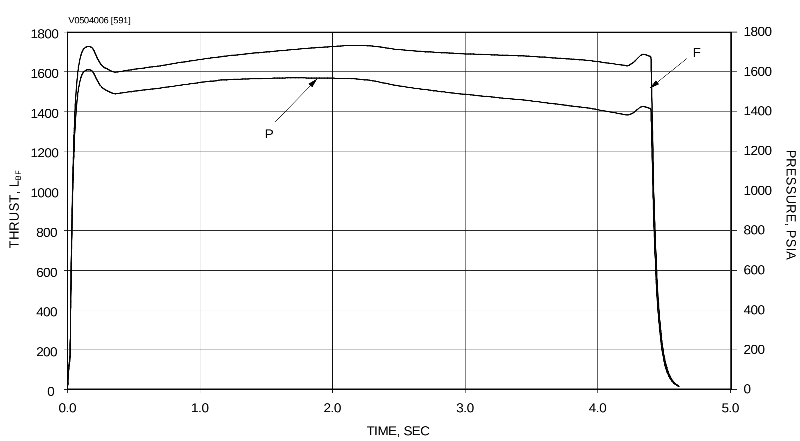
Dated 05 April 2016

Orbital ATK

STAR 8

TE-M-1076-1

The STAR 8 was developed and qualified (2002) as the rocket assisted deceleration (RAD) 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 .... -40°-104°F
Storage .... -65°-140°F

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL .... TITANIUM

PRODUCTION STATUS

.... FLIGHT-PROVEN

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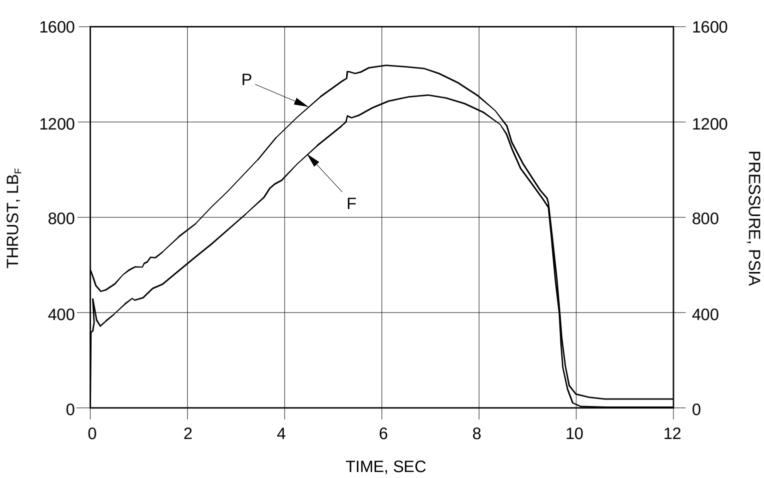
Dated 05 April 2016

Orbital ATK

STAR 9

TE-M-956-2

The STAR 9 rocket motor was developed in 1993 on independent research and development (IR&D) 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

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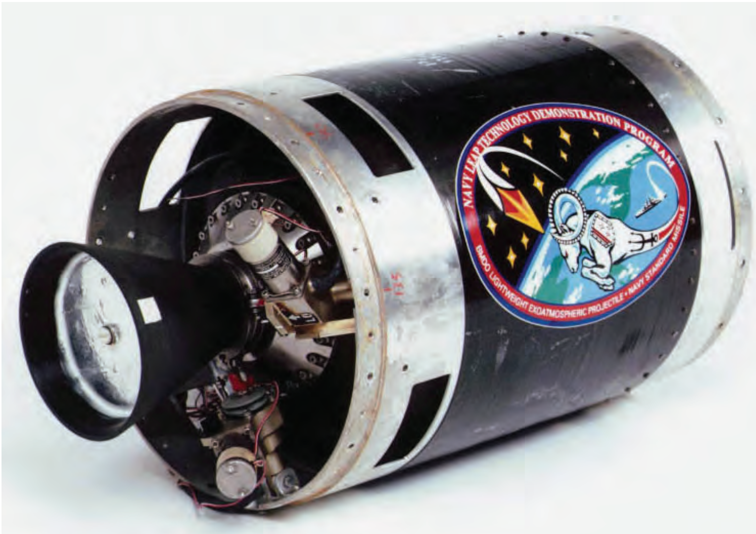
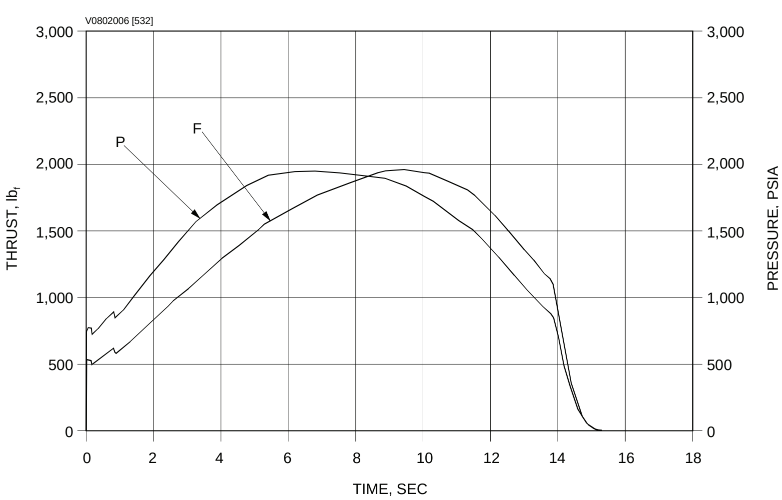
OSR No. 16-S-1432;
Dated 05 April 2016

STAR 12GV

TE-M-951



The STAR 12GV rocket motor served as the third stage of the U.S. Navy/MDA Terrier Lightweight Exoatmospheric Projectile (LEAP) experiments. The motor first flew in March 1995. The stage has TVC capability, head-end flight destruct ordnance, and utilizes a graphite-epoxy composite case. It is compatible with an aft-end attitude control system (ACS) module. Orbital ATK 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

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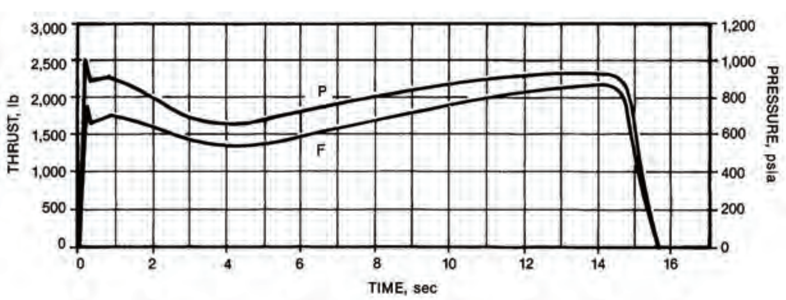
Dated 05 April 2016

Orbital ATK

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

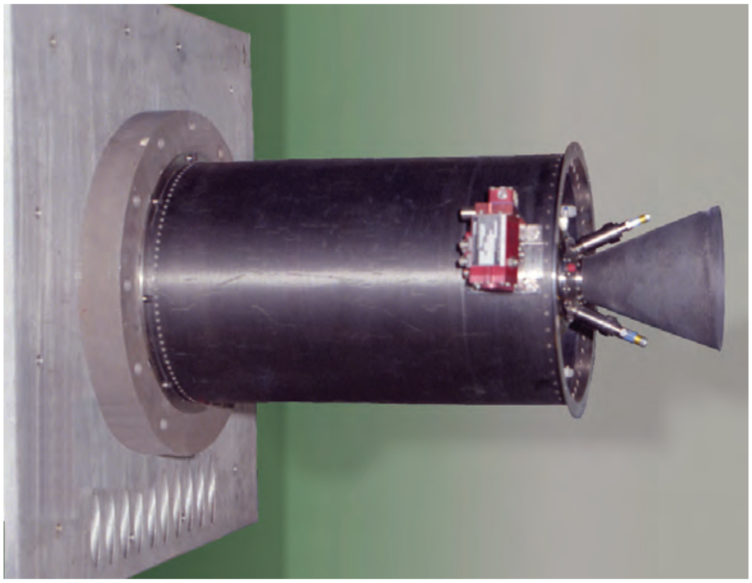
PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL .... TITANIUM

PRODUCTION STATUS
.... FLIGHT-PROVEN

STAR 15G

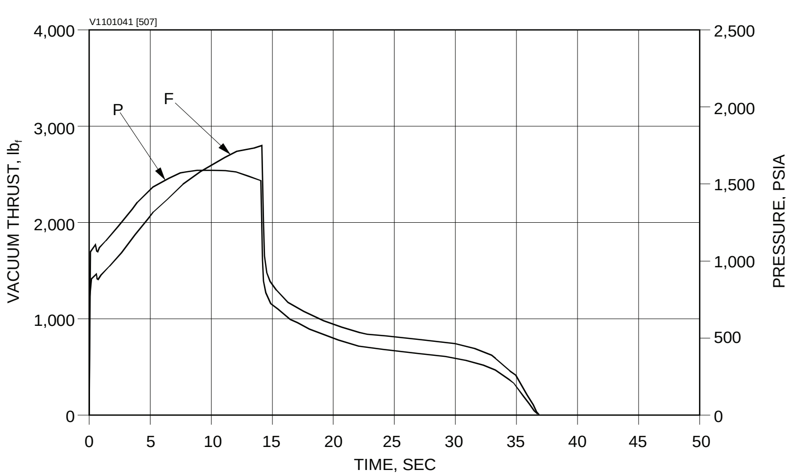
TE-M-1030-1



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 (DM) that was used to evaluate design features and component and material technology in seven tests between December 1988 and June 1991. Orbital ATK employed its Thiokol Composite Resin (TCR) 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 .... 40°-110°F
Storage .... 40°-110°F

SPIN EXPERIENCE, RPM 125

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL

.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS

.... FLIGHT-PROVEN

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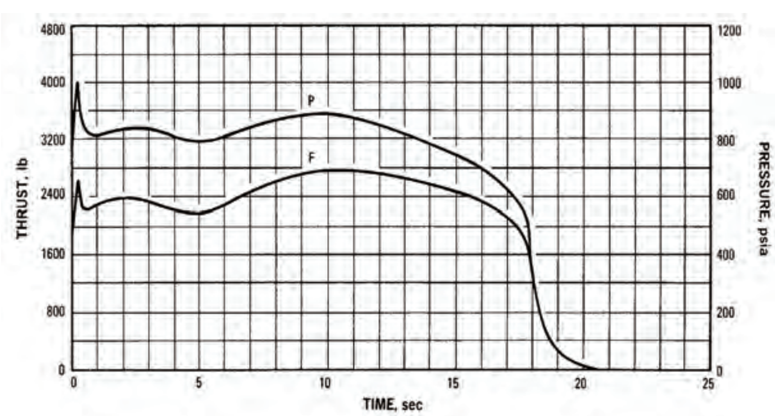
Dated 05 April 2016

STAR 17

TE-M-479

The STAR 17 motor has served as the apogee kick motor (AKM) 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 Orbital ATK and Arnold Engineering Development Center (AEDC) through March 1967. The initial STAR 17 flight was on Delta 57 in July 1968 from the Western Test Range (WTR). Subsequent launches have been conducted from Eastern Test Range (ETR) on Delta and the Atlas vehicle from WTR.



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

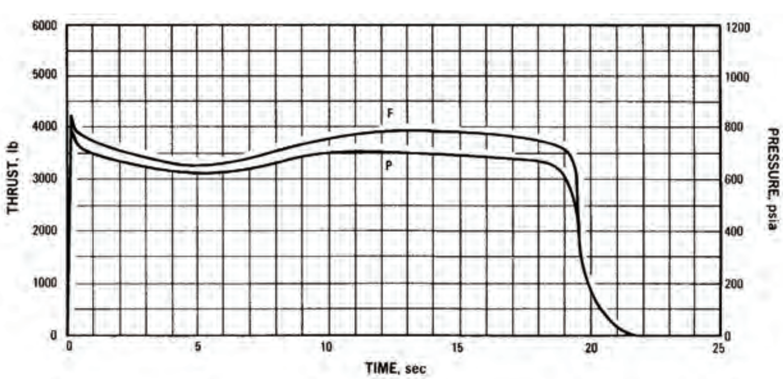
CASE MATERIAL .... TITANIUM

PRODUCTION STATUS
.... FLIGHT-PROVEN

STAR 17A

TE-M-521-5

The STAR 17A motor is an apogee kick motor (AKM) used for the interplanetary monitoring platform (IMP) 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 IMP 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 .... 0°-110°F
Storage .... 0°-110°F

SPIN EXPERIENCE, RPM 100

PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL .... TITANIUM

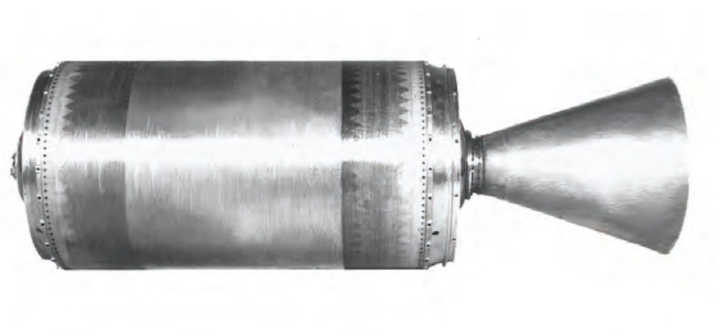
PRODUCTION STATUS
.... FLIGHT-PROVEN

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

Orbital ATK

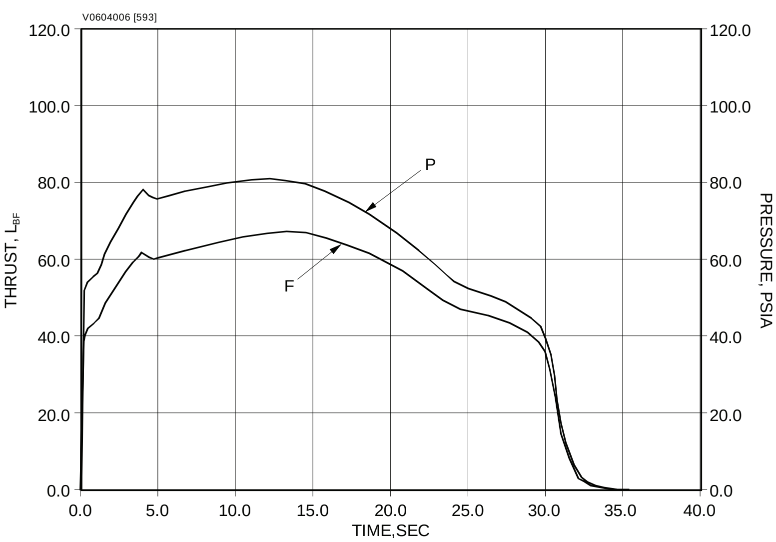
STAR 20

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 (WTR), San Marcos, and Wallops Flight Facility beginning with Scout 189 in August 1974.

Orbital ATK 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

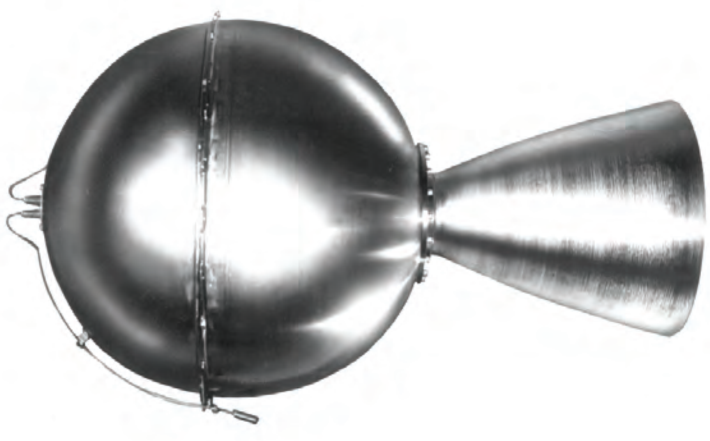
PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL .... FIBER GLASS-EPOXY COMPOSITE

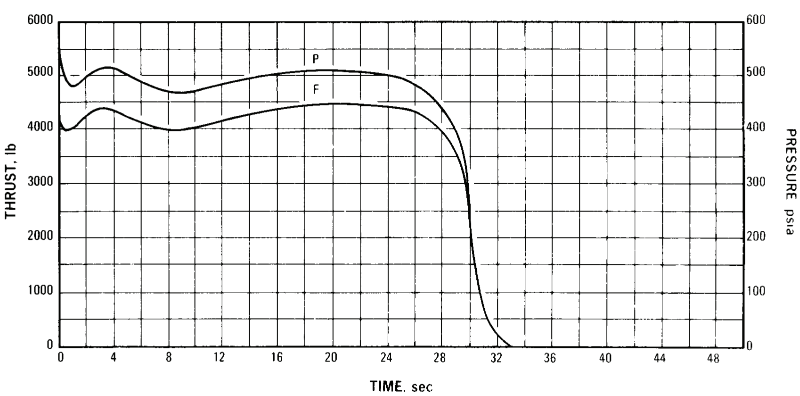
PRODUCTION STATUS .... FLIGHT-PROVEN

STAR 24

TE-M-640



The STAR 24 rocket motor was qualified in 1973 and flown as the apogee kick motor (AKM) 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 (ETR) and Western Test Range (WTR).



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

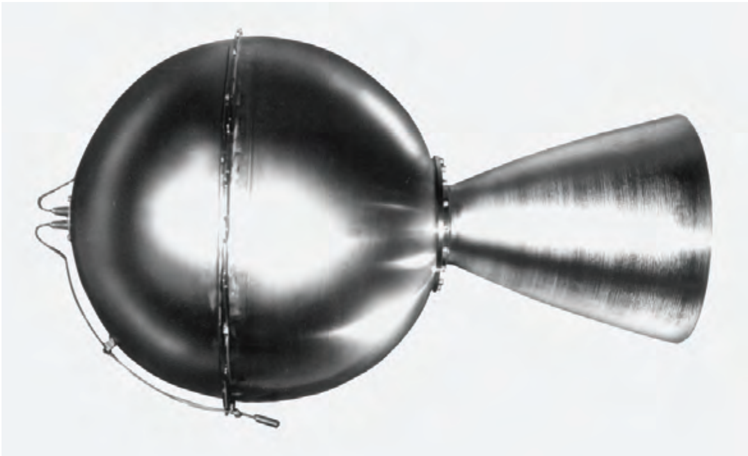
PROPELLANT DESIGNATION TP-H-3062

CASE MATERIAL .... TITANIUM

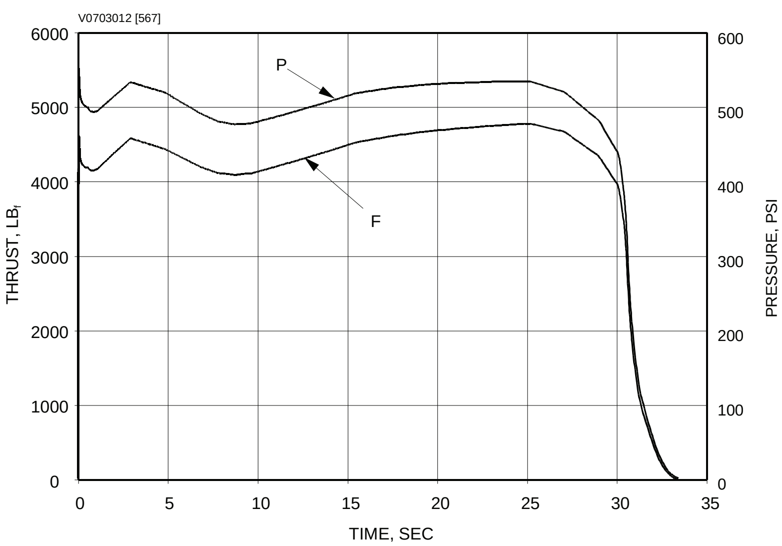
PRODUCTION STATUS .... FLIGHT-PROVEN

STAR 24C

TE-M-640-4



The STAR 24C was designed and qualified (in 1976) for launch of NASA's International Ultraviolet Experiment (IUE) satellite in January 1978 from the Eastern Test Range (ETR) 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

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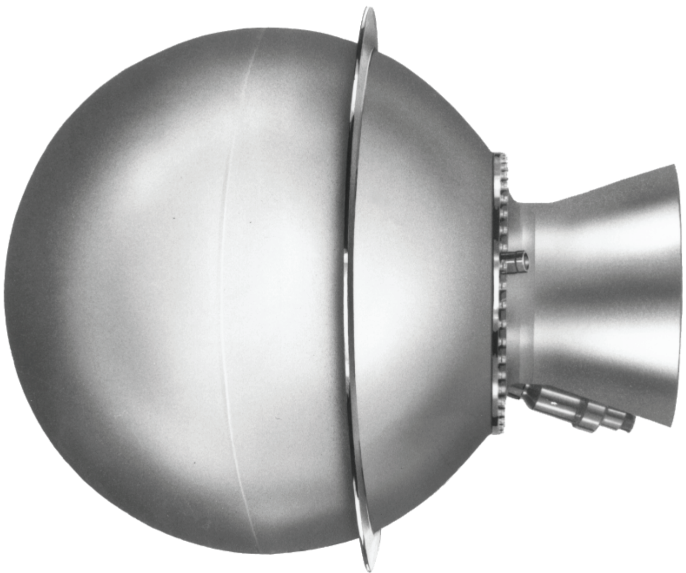
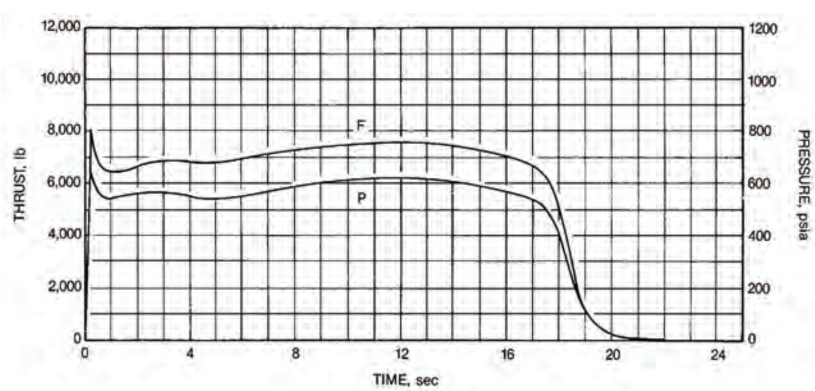
Dated 05 April 2016

STAR 26

TE-M-442



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

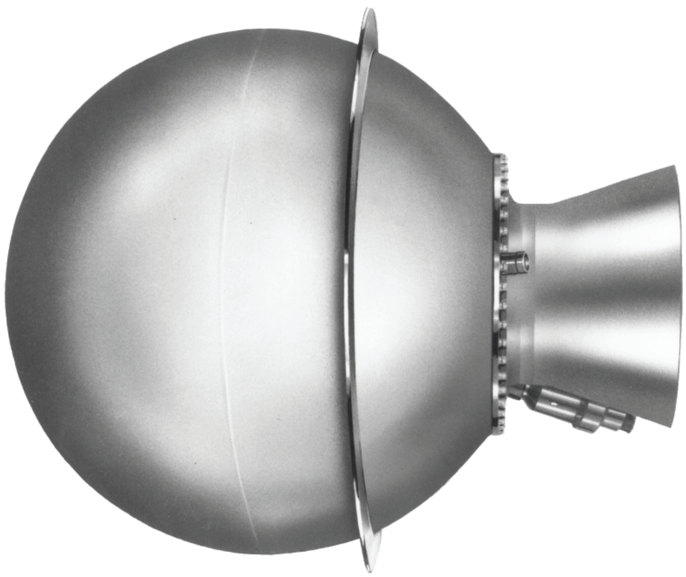
PROPELLANT DESIGNATION TP-H-3114

CASE MATERIAL .... D6AC STEEL

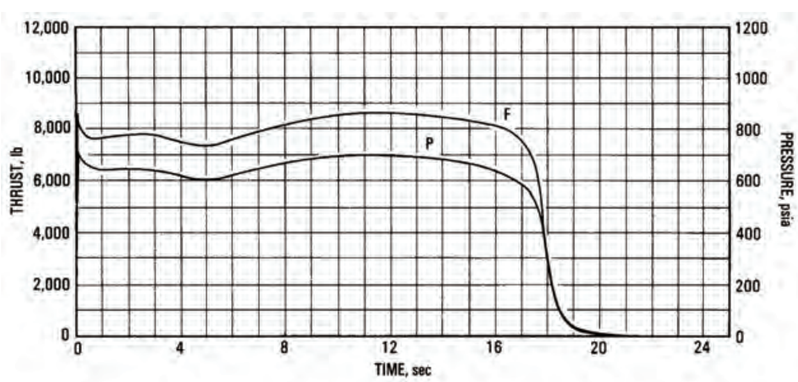
PRODUCTION STATUS
.... FLIGHT-PROVEN

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

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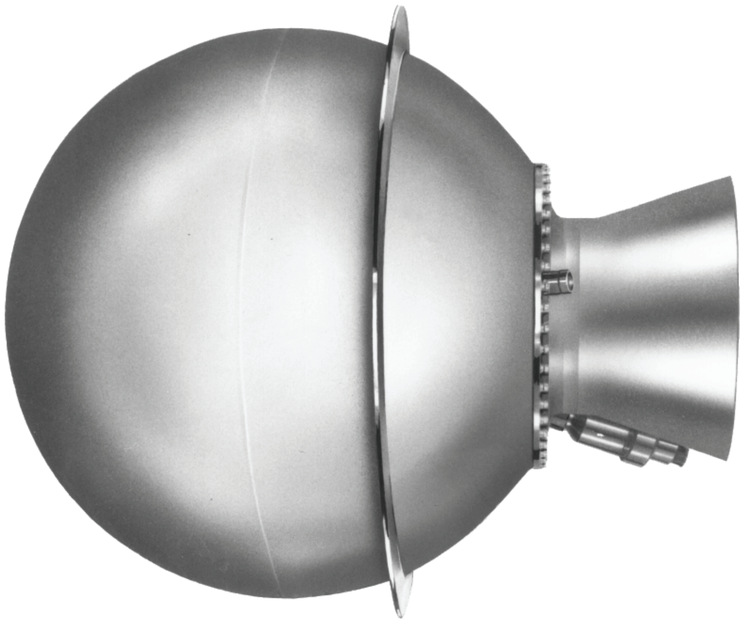
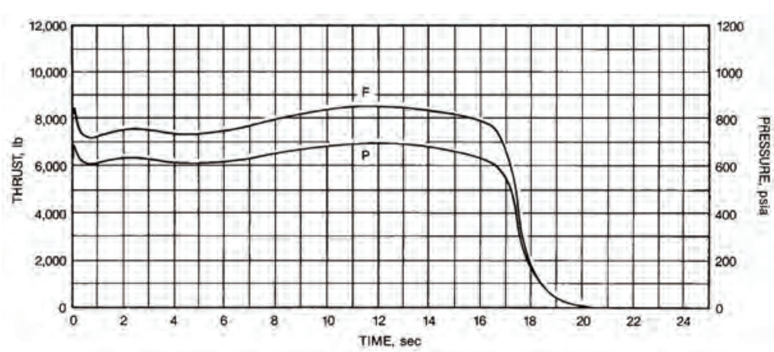
Dated 05 April 2016

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.... 50°-90°F

Storage.... 40°-100°F

SPIN CAPABILITY, RPM 250

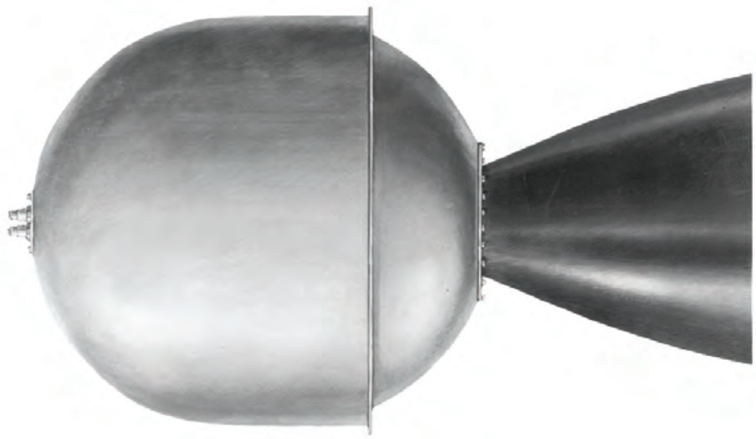
PROPELLANT DESIGNATION TP-H-3114

CASE MATERIAL ....TITANIUM

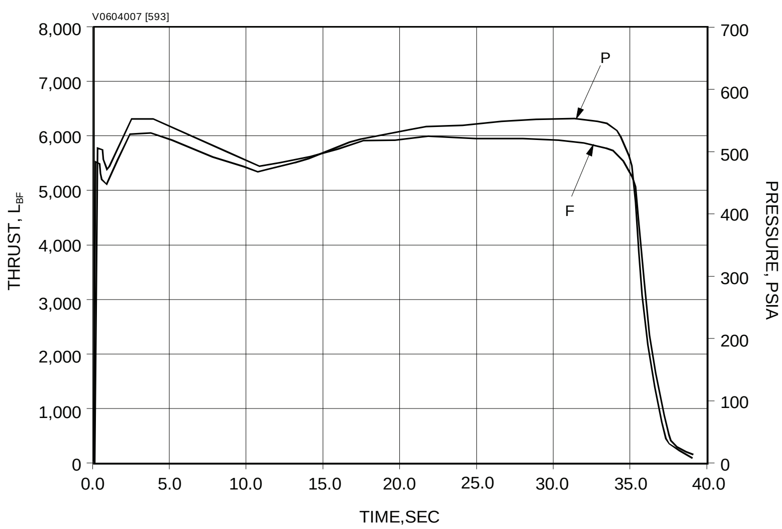
PRODUCTION STATUS.... FLIGHT-PROVEN

STAR 27

TE-M-616



The STAR 27 rocket motor was developed and qualified in 1975 for use as the apogee kick motor (AKM) 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 AKM 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 (WTR), 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

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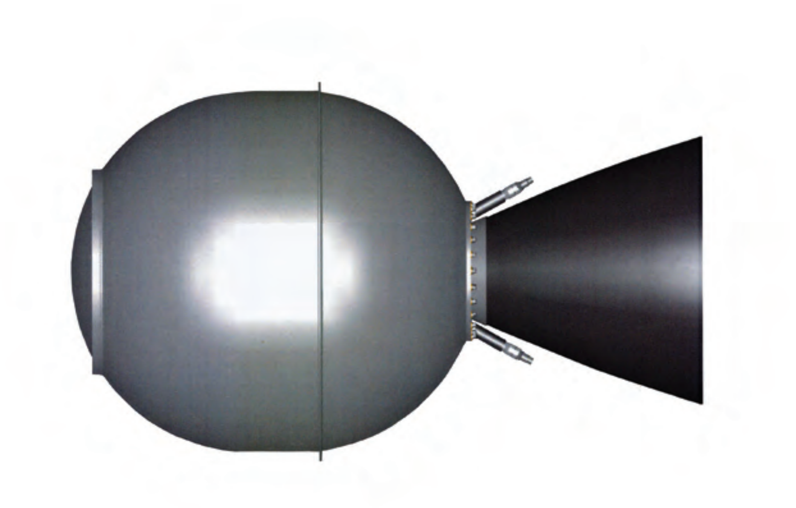
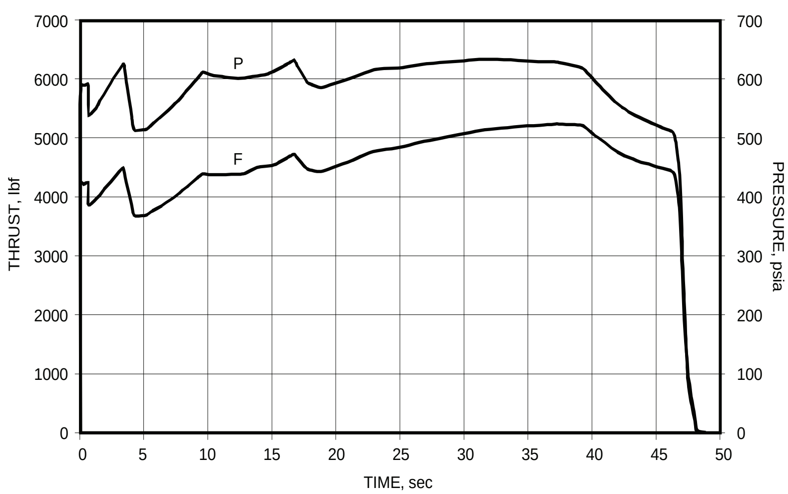
STAR 27H

TE-M-1157



The STAR 27H was developed as the apogee kick motor (AKM) 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 Orbital ATK'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

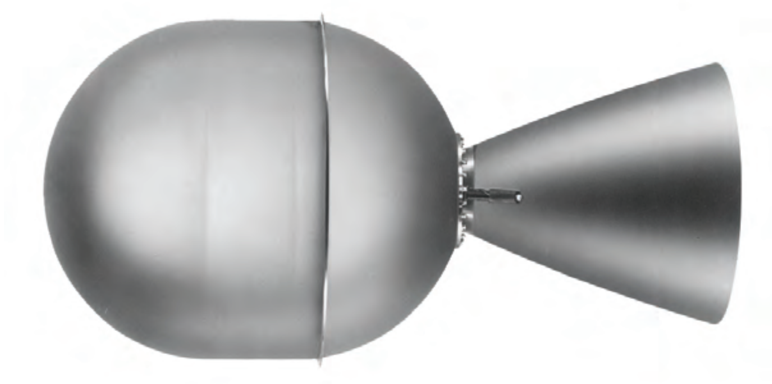
CASE MATERIAL .... TITANIUM

PRODUCTION STATUS .... FLIGHT-PROVEN

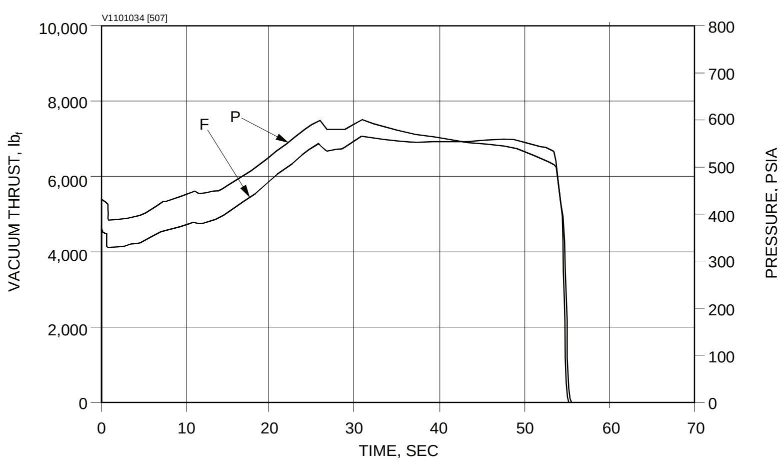
STAR 30 SERIES

STAR 30BP

TE-M-700-20



The STAR 30BP rocket motor serves as the apogee kick motor (AKM) for several different satellite manufacturers such as RCA/GE/Lockheed Martin, Hughes/Boeing, and Orbital. 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

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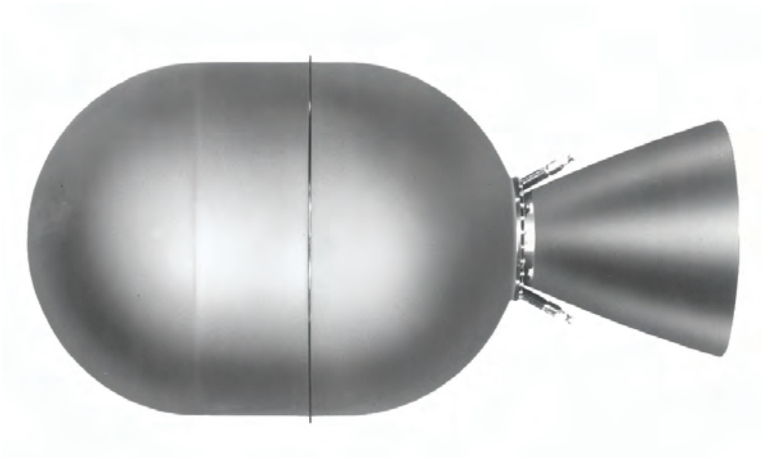
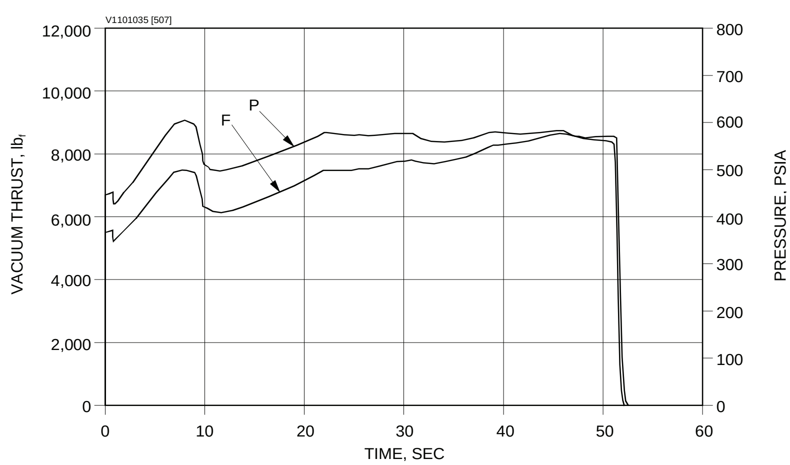
Orbital ATK

STAR 30C

TE-M-700-18



The STAR 30C was qualified in 1985 as an apogee kick motor (AKM) 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

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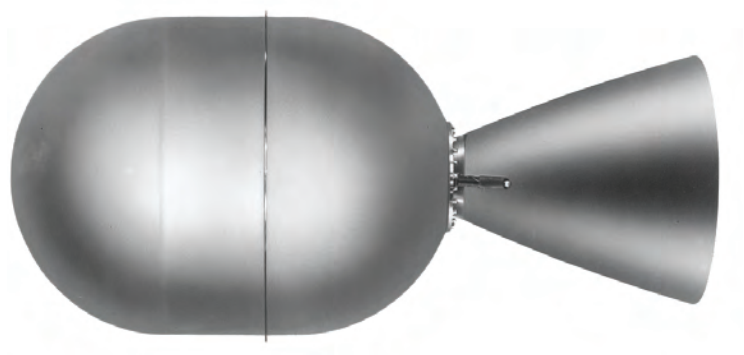
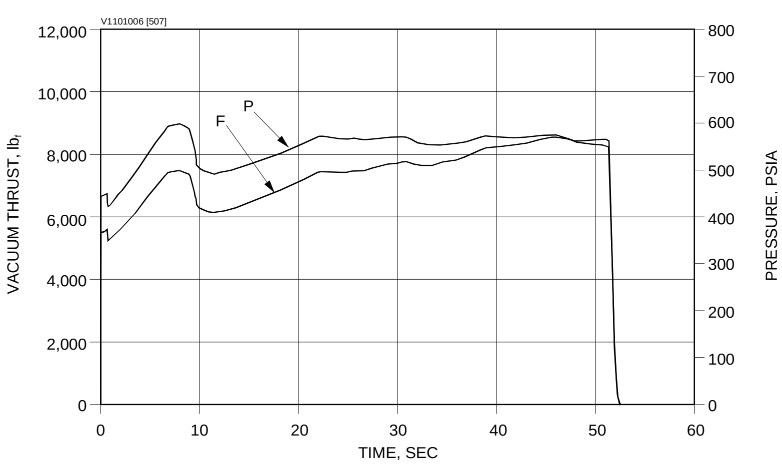
STAR 30C/BP

TE-M-700-25



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 Isp. 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

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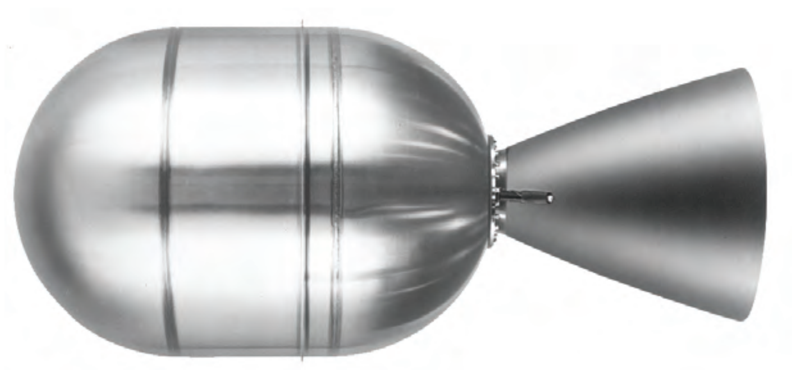
OSR No. 16-S-1432;
Dated 05 April 2016

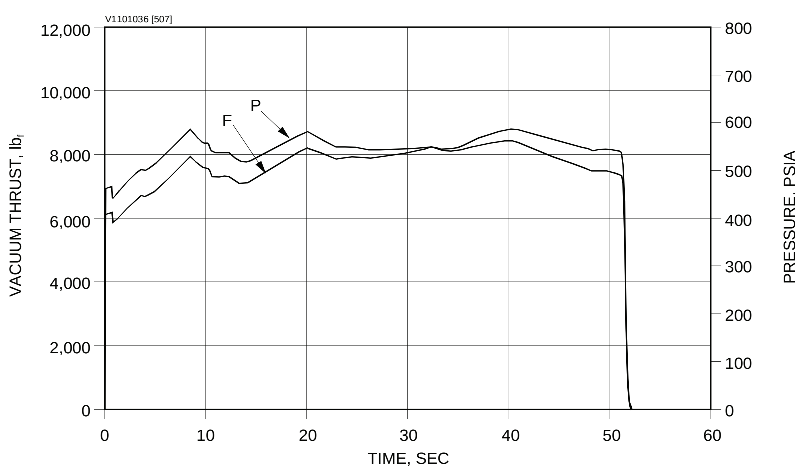
Orbital ATK

STAR 30E

TE-M-700-19



The STAR 30E serves as an apogee kick motor (AKM). 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 AKM 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.. 40°-90°F

Storage.. 40°-100°F

SPIN EXPERIENCE, RPM 100

PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL ....TITANIUM

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

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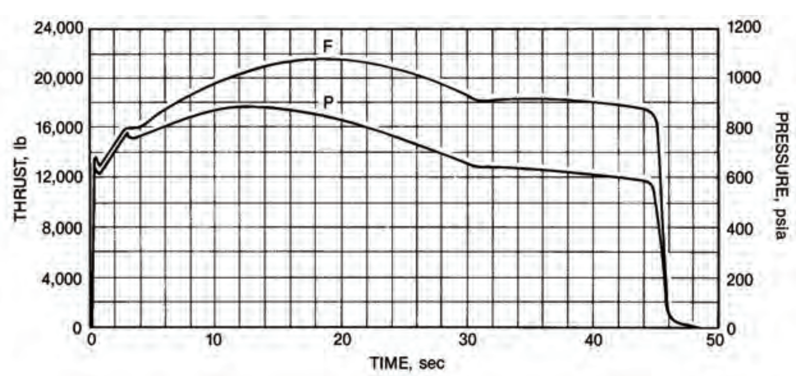
STAR 31 AND 37 SERIES

STAR 31

TE-M-762

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 (WTR) 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

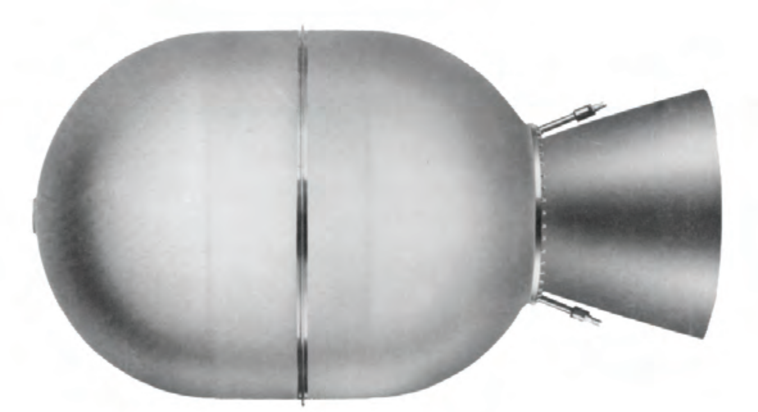
CASE MATERIAL
.... KEVLAR-EPOXY COMPOSITE

PRODUCTION STATUS
.... FLIGHT-PROVEN

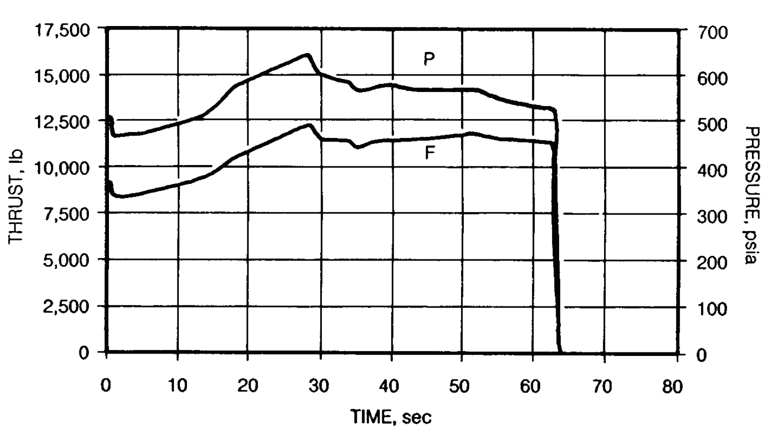
Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

STAR 37FM

TE-M-783



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 serves 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

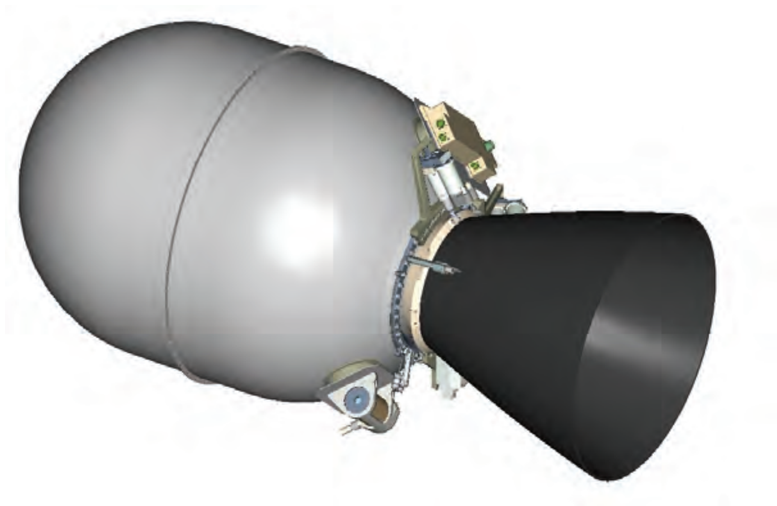
CASE MATERIAL ....TITANIUM

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

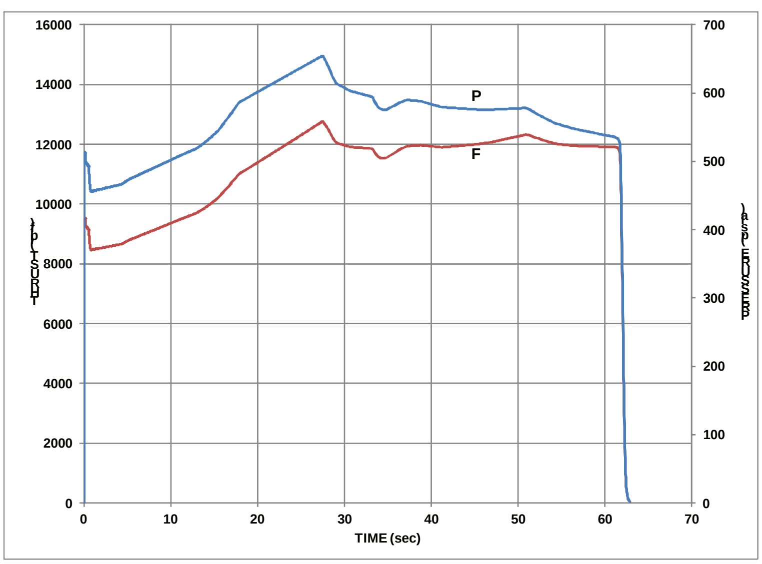
Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

STAR 37FMV

TE-M-1139



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 TVC 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

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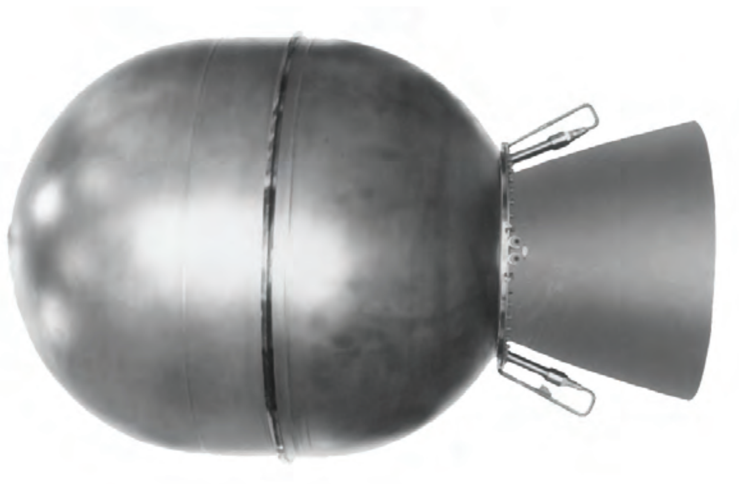
Dated 05 April 2016

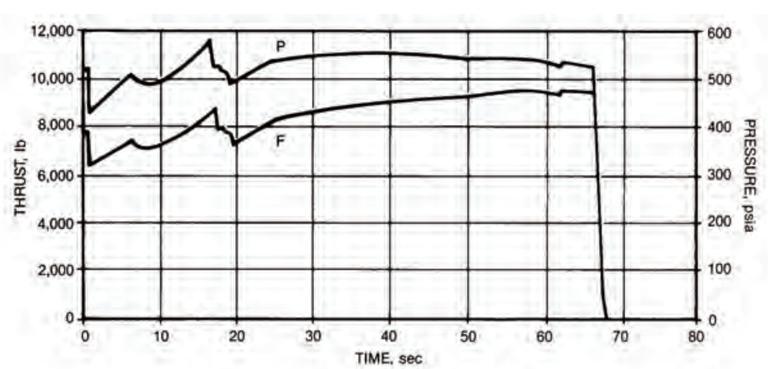
Orbital ATK

STAR 37XFP

TE-M-714-16/-17



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 (LEO) 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 (AKM) 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

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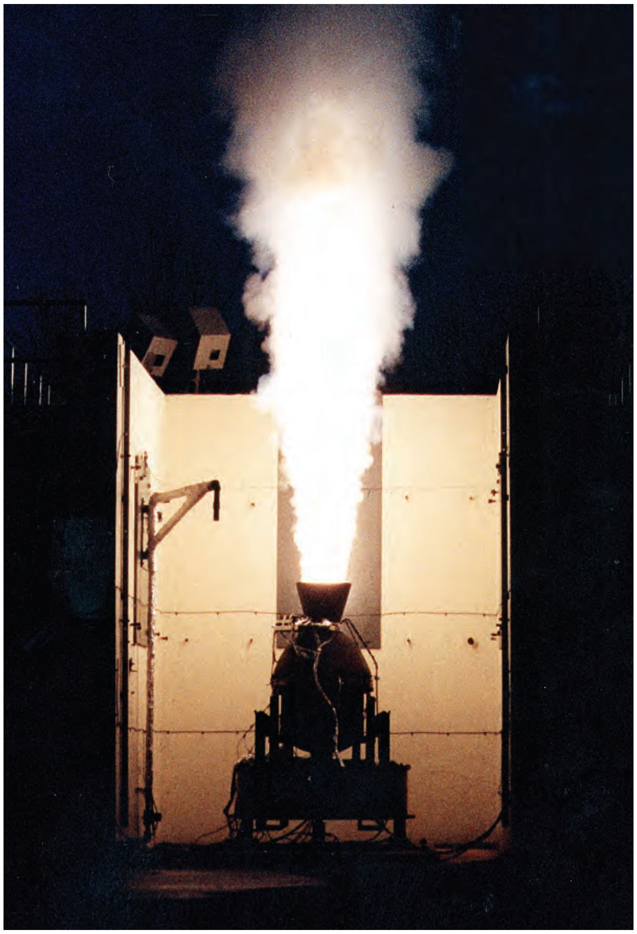
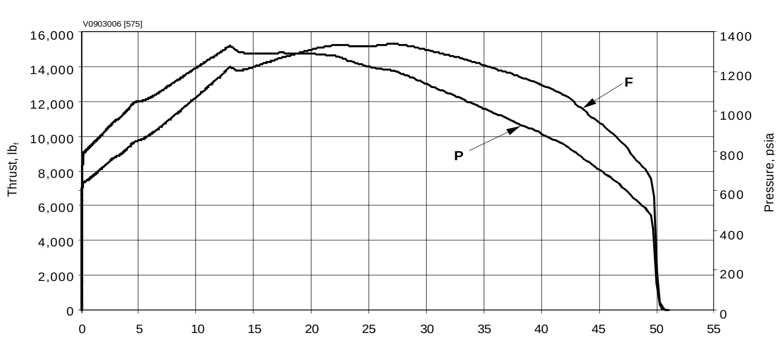
Dated 05 April 2016

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 (TVC) 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

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Orbital ATK

STAR 48 SERIES

STAR 48A

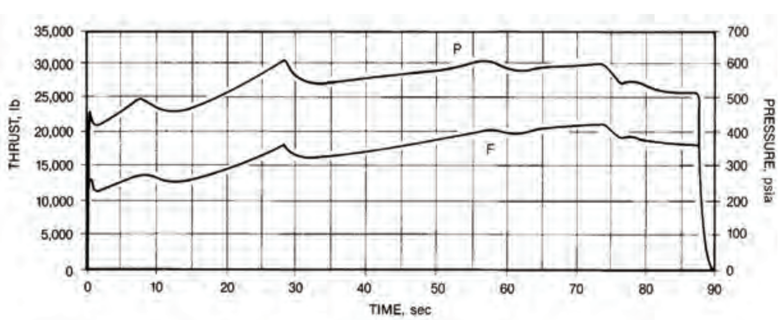
TE-M-799-1

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

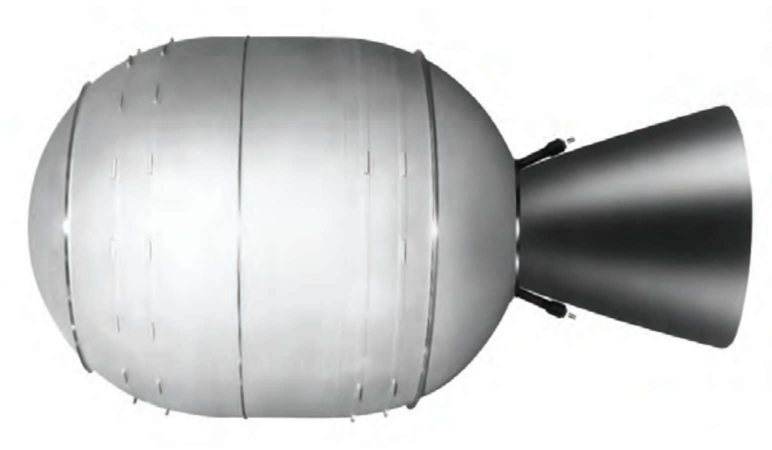
PROPELLANT DESIGNATION TP-H-3340

CASE MATERIAL ....TITANIUM

**Calculated thrust and impulse based on static test data

STAR 48A

TE-M-799

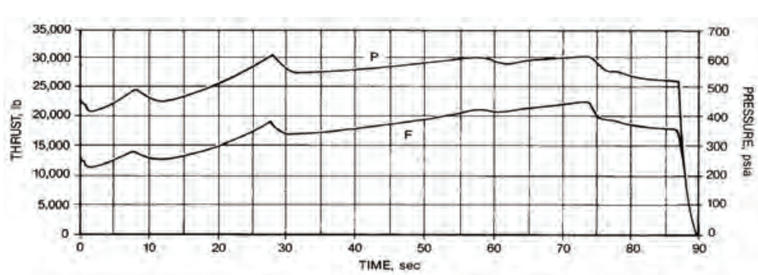


LONG NOZZLE

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

Approved for Public Release
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Dated 05 April 2016

Orbital ATK

STAR 48B

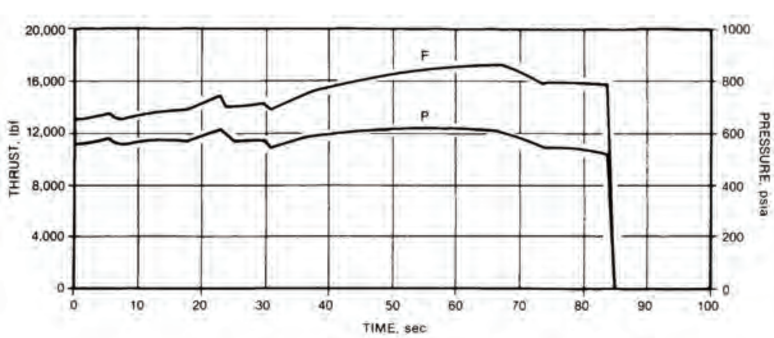
TE-M-711-17

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

STAR 48B

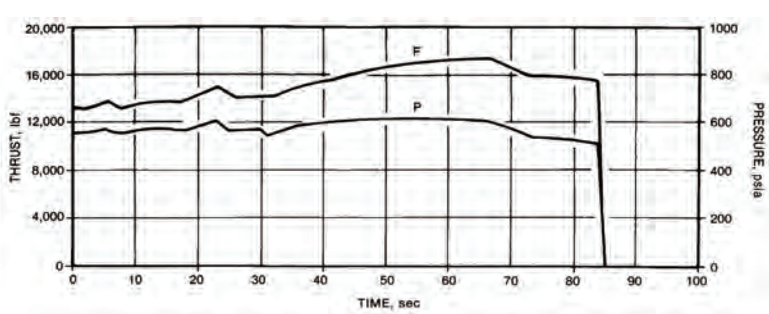
TE-M-711-18

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

Approved for Public Release
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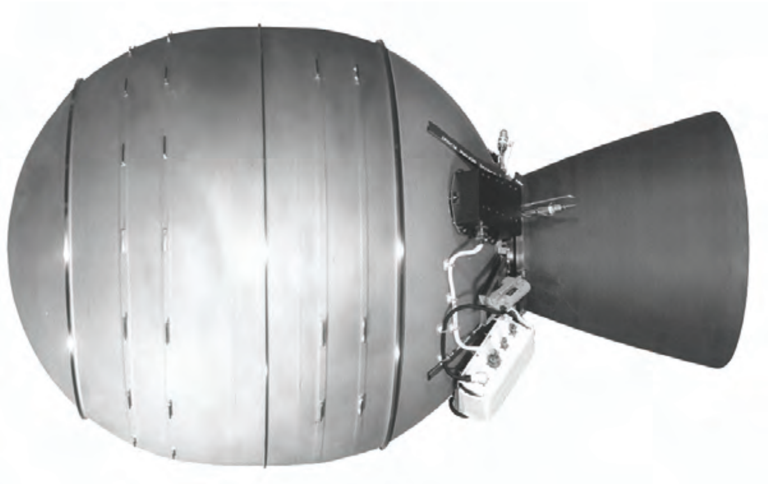
Dated 05 April 2016

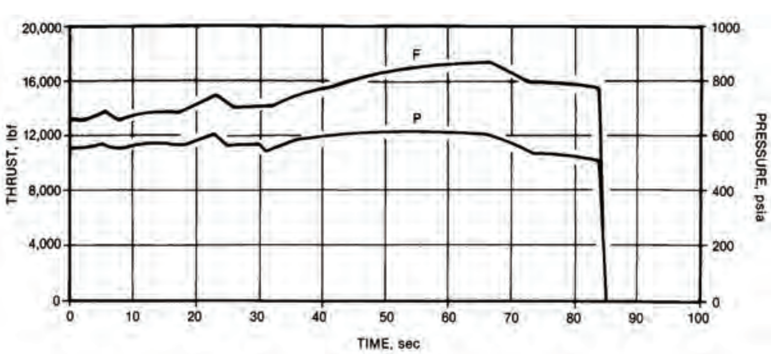
Orbital ATK

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

STAR 63 SERIES

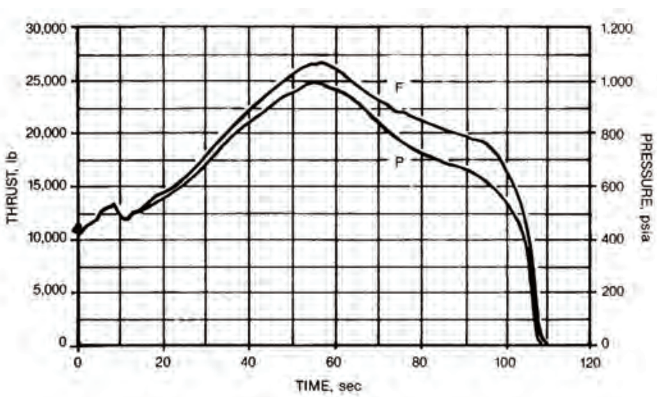
STAR 63D

TE-M-936

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 Isp 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 TVC nozzle and electromechanical actuation system.



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

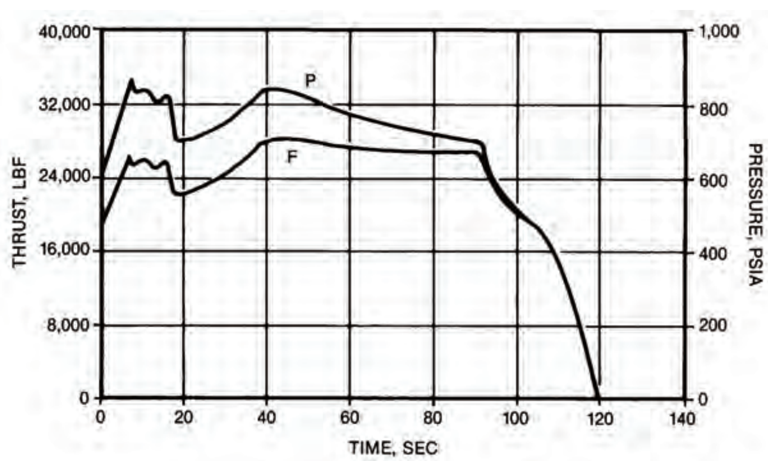
....................GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS .... DEVELOPMENT

STAR 63F

TE-M-963-2

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. 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

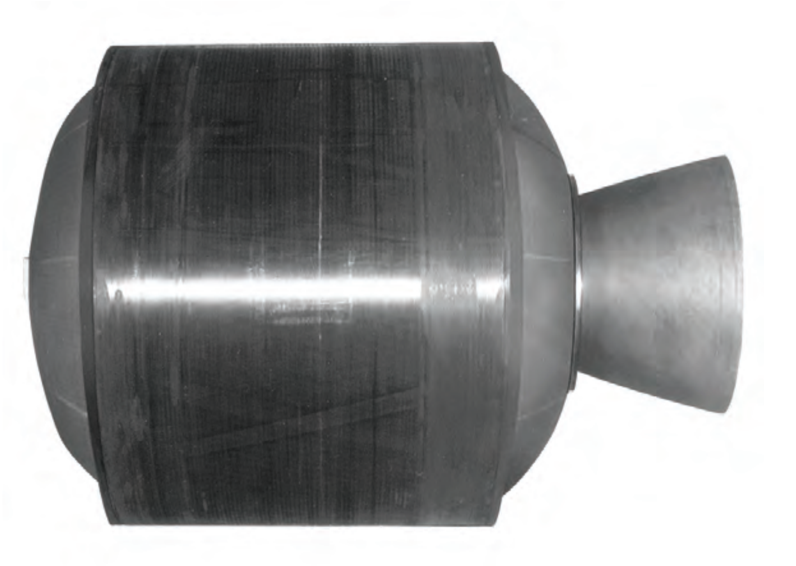
PRODUCTION STATUS .... DEVELOPMENT

Orbital ATK

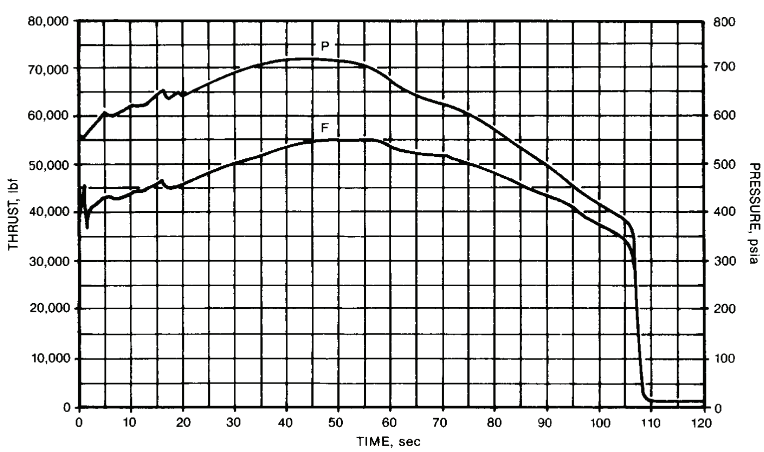
STAR 75 SERIES

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 Orbital ATK 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. 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

TEMPERATURE LIMITS

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

PROPELLANT DESIGNATION TP-H-3340

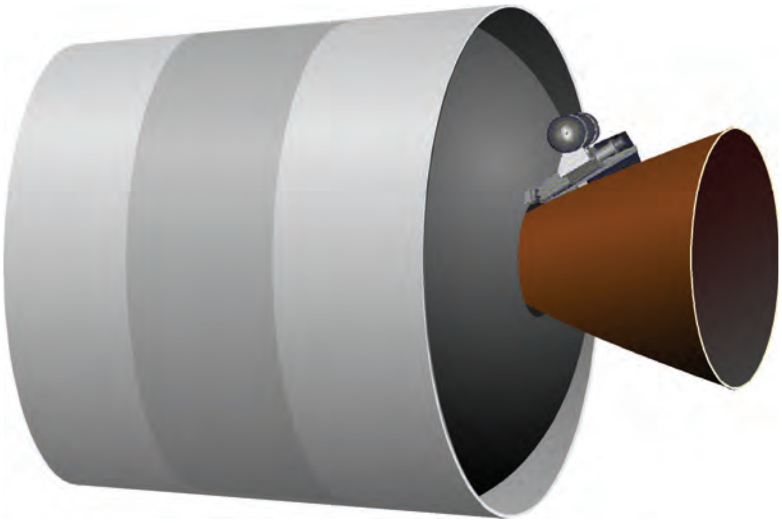
CASE MATERIAL .... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS .... DEVELOPMENT

*Development motor values. Flight design mass fraction is 0.89 with total impulse improvement of approx

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 (PDR) 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)

STAR STAGES

Orbital ATK 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, Orbital ATK 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.

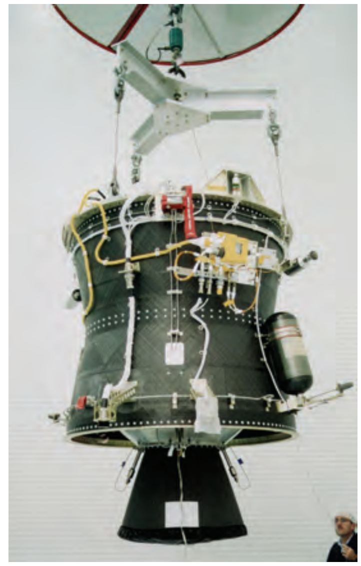
Orbital ATK uses avionics and pneumatic components, as well as flight software, that are common with our launch vehicle programs to provide the STAR stage with the following onboard capabilities:

- Guidance, navigation, and control (GN&C)
- 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. Orbital ATK 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. Orbital ATK 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.

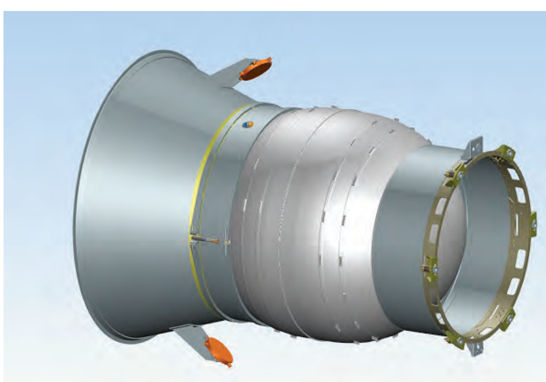
Orbital ATK has successfully incorporated STAR motor-based stages onto existing Orbital ATK launch platforms including Pegasus and Minotaur, and configured stages for mating directly with the spacecraft as shown for the Lunar Prospector trans-luner injection stage.

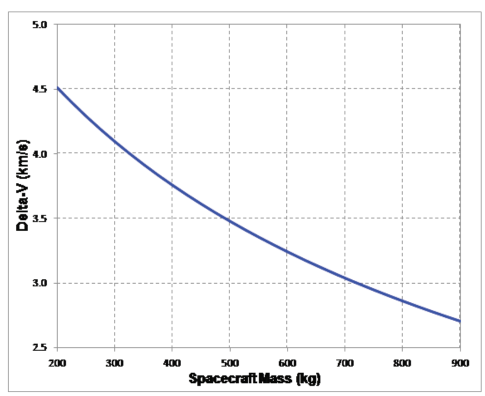
Orbital ATK is currently developing a STAR stage based on the STAR 48BV motor for a 2018 mission. This mass efficient, three-axis stabilized stage and its capability are shown below. The STAR 48BV stage provides guidance, control, sequencing, and electrical support throughout stage operation. In this application, the STAR 48BV motor is part of the primary load path to optimize mass efficiency. Orbital ATK 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.



STAR Stage 3700S for NASA's Lunar Prospector

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





Example Stage Design Based on the STAR 48BV Motor

ELECTROMECHANICAL THRUST VECTOR ACTUATION SYSTEM

Orbital ATK has developed the first in a family of thrust vector actuation (TVA) 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 TVA 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.

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 (LVDT) 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 (LVDT, 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

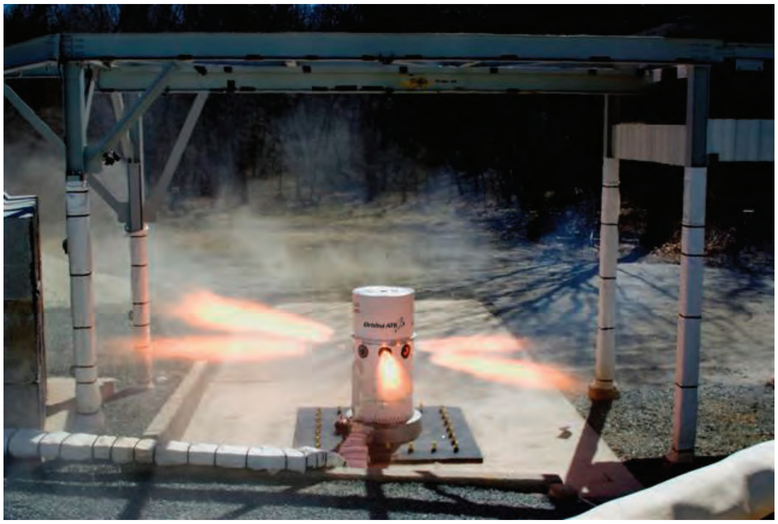
Design Capability

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

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

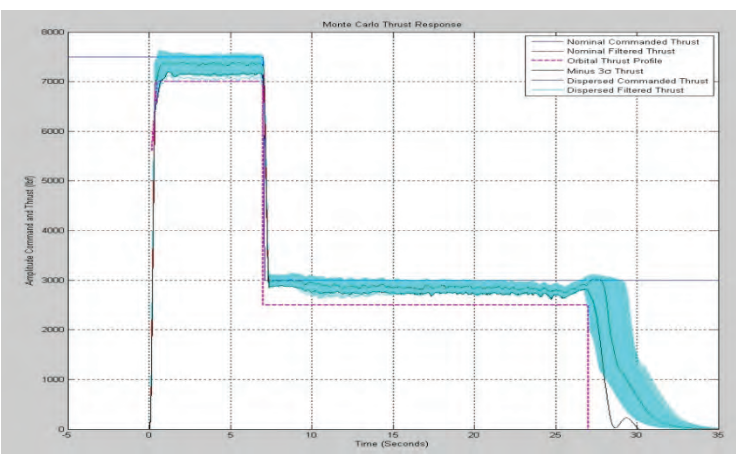
ORION LAS ACM

TE-M-1174-1



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.



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 EM 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

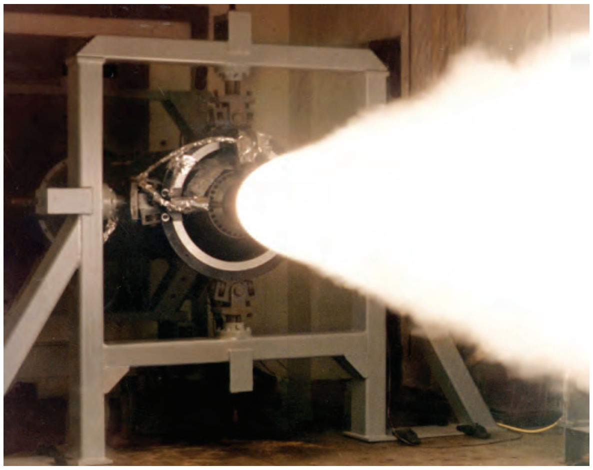
PROPELLANT DESIGNATION ... TP-H-3174

CASE MATERIAL ... D6AC steel

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

ADVANCED SOLID AXIAL STAGE (ASAS™) MOTORS

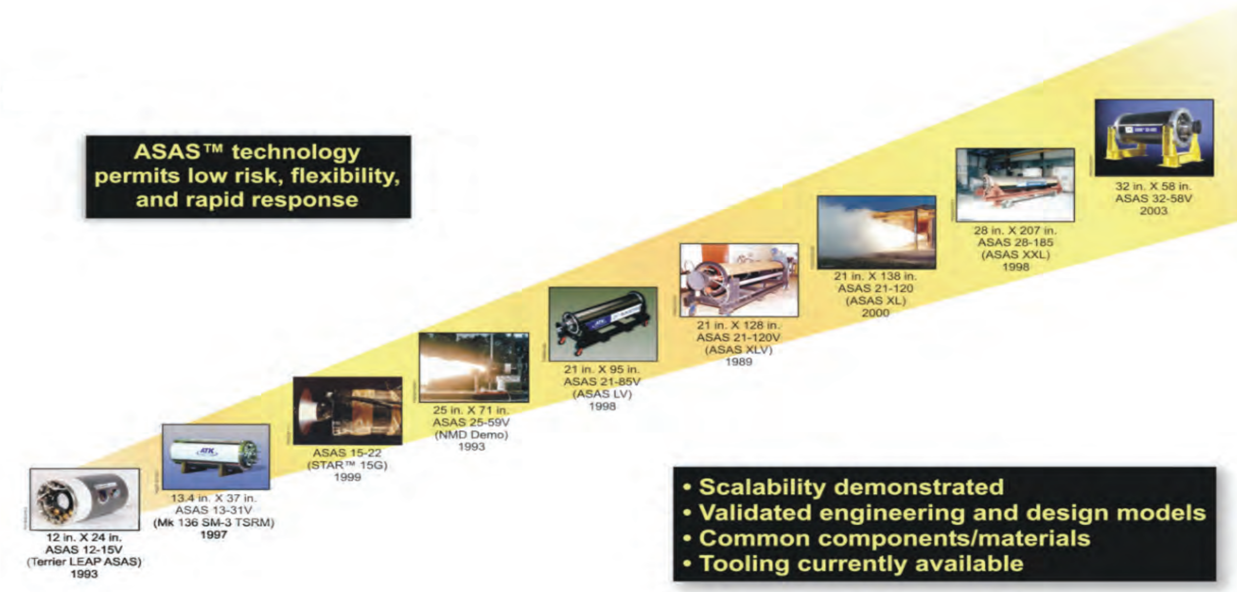
Orbital ATK's ASAS family of high-performance solid propellant motors is adaptable to a wide variety of applications. These designs incorporate proven design concepts, materials technology, and manufacturing techniques that provide enhanced operational performance. The technologies reflected in these 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 (MDA).



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 (IM) characteristics for each of the motor designs
- Electromechanically actuated, flexseal, or trapped ball thrust vector control (TVC) nozzle technology
- Mission-specific component technology, including carbon-carbon exit cones, consumable igniters, semiconductor bridge (SCB)-based ignition systems, integrated hybrid warm/cold-gas attitude control systems, and isolation of multiple pulses with a barrier (rather than bulkhead) insulation system

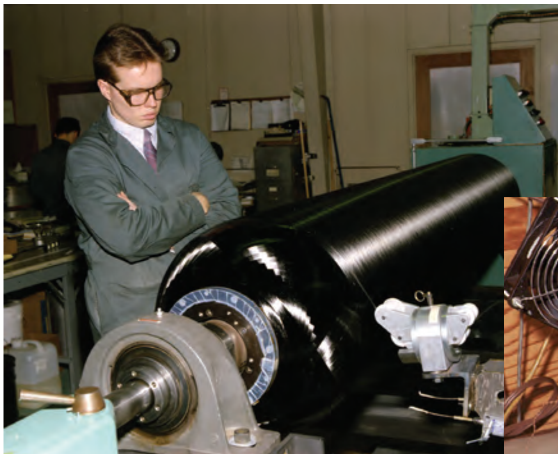


ASAS component and materials technology is mature, design scalability has been demonstrated, related engineering design models have been validated, and common components and materials are used in all of these booster configurations. These component technologies have been successfully demonstrated in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

By applying these proven technologies to new motor designs, Orbital ATK can offer:

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 will reduce development risk and ensure that performance will meet 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.



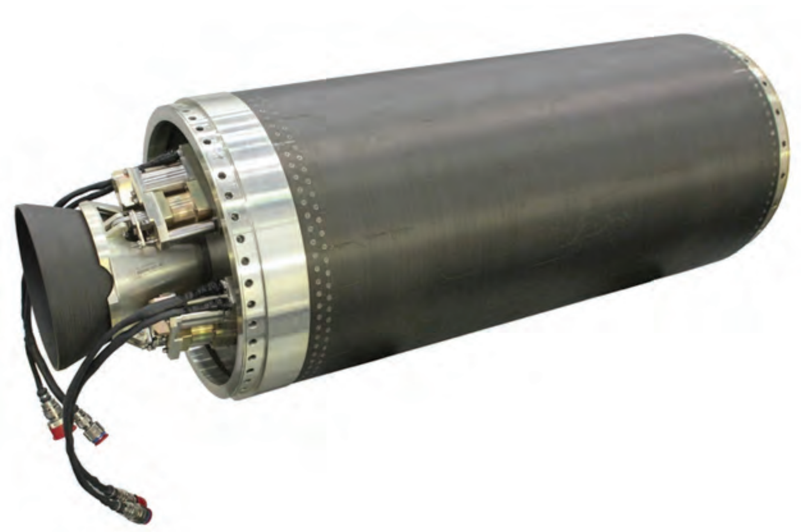
Graphite-Epoxy Composite Case Winding
(21-in. booster)

Flexseal TVC Nozzle Assembly

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

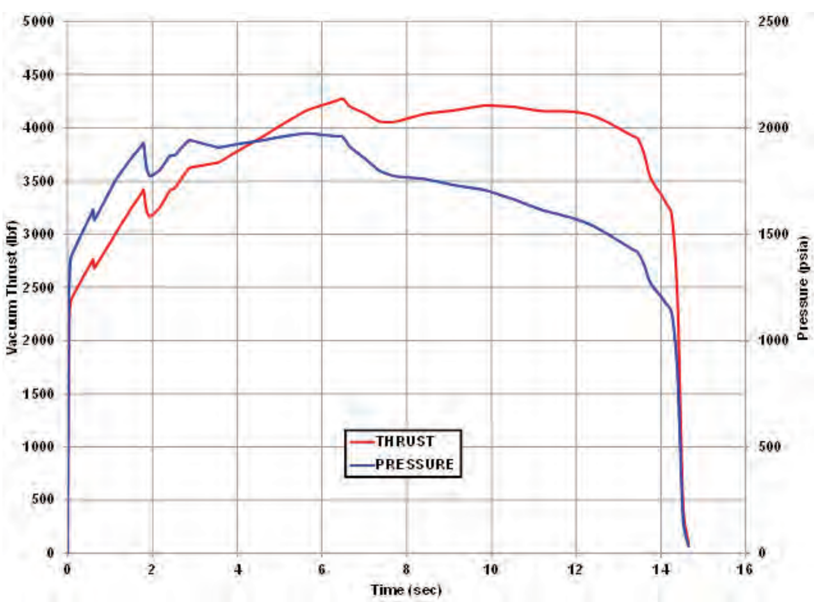
SM-3 FTR-1A Missile Launch with ATK TSRM
(January 25, 2001)

ASAS™ 13-30V



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 (SM-3) Block IA/IB Third Stage Rocket Motor (TSRM). 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 an Orbital ATK Thrust Vector Electronic Control System (TVECS™) thrust vector actuation (TVA) system using electromechanical (EM) 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

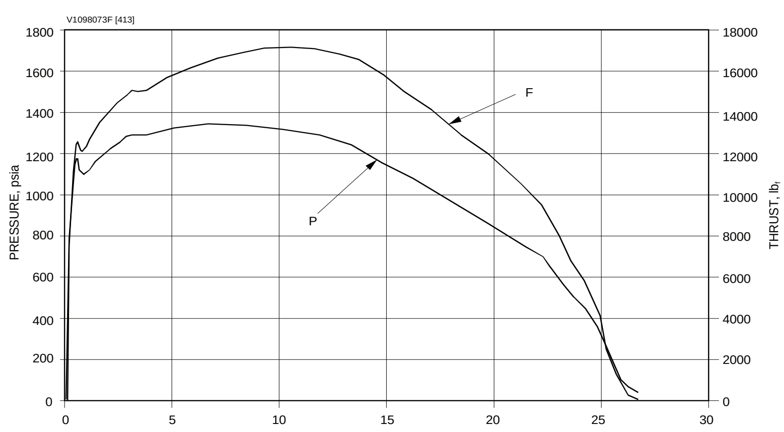
*Excludes ETA lines, safe and arm device, battery, and controller

ASAS 21-85V

TE-M-1031-1

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

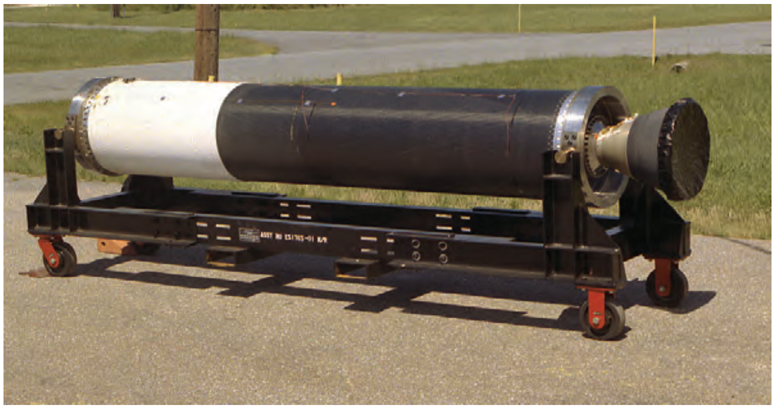
PROPELLANT DESIGNATION TP-H-3514A

CASE MATERIAL
.... GRAPHITE-EPOXY COMPOSITE

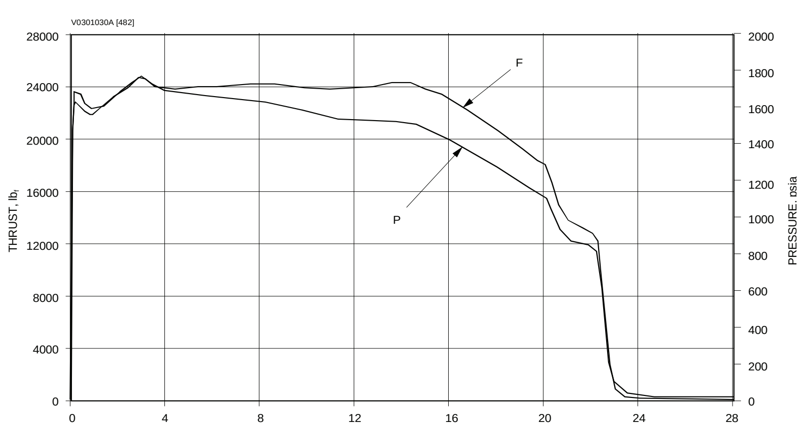
PRODUCTION STATUS ....DEVELOPMENT

ASAS 21-120

TE-M-1059-1



The ASAS 21-120 is a solid rocket motor with a graphite-composite case that was developed in 2000 for vertical launch system (VLS), 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

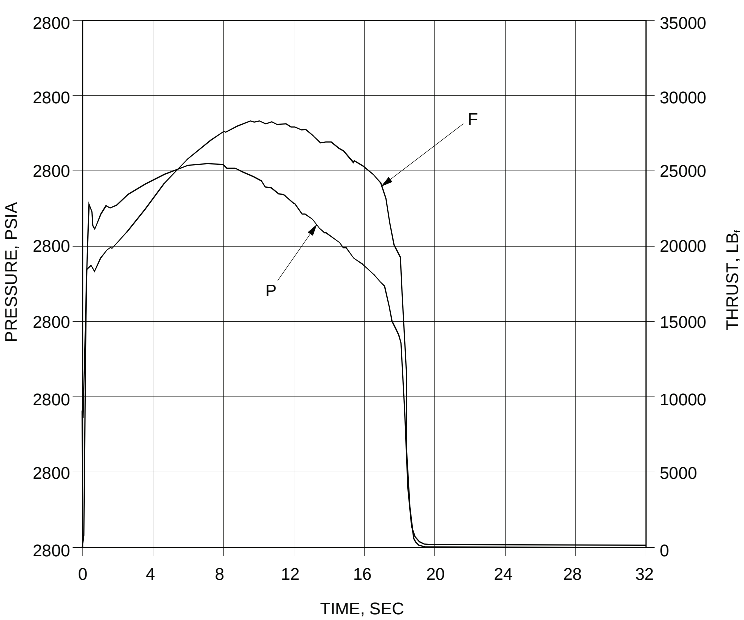
Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

Orbital ATK

ASAS 21-120V

TE-M-909-1

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 TVC 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 (VLS), 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

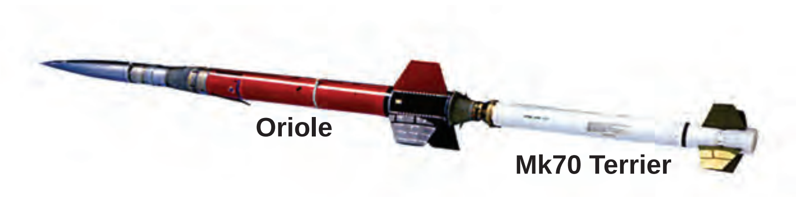
CASE MATERIAL

.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS ....DEVELOPMENT

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

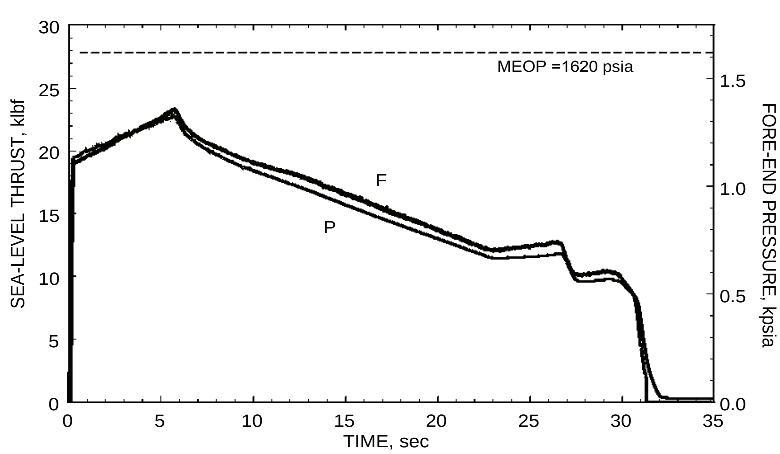
ORIOLE



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 (TVC) 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

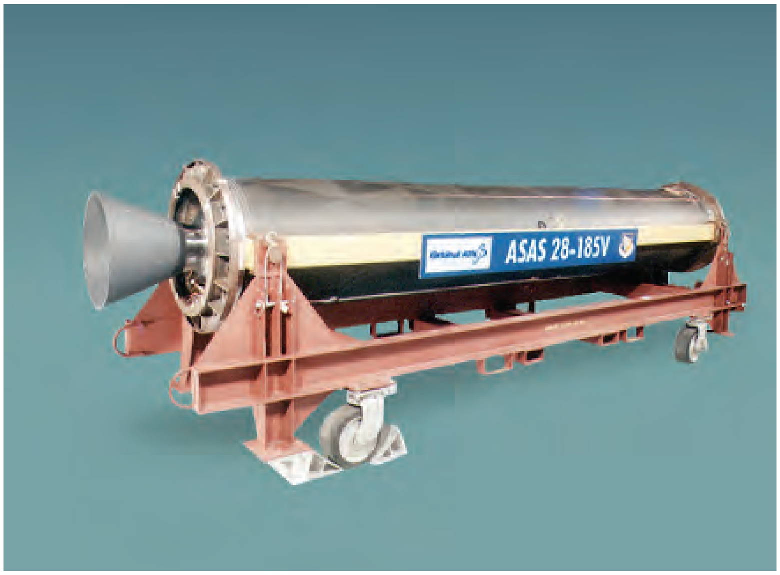
CASE MATERIAL
.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS ....IN PRODUCTION

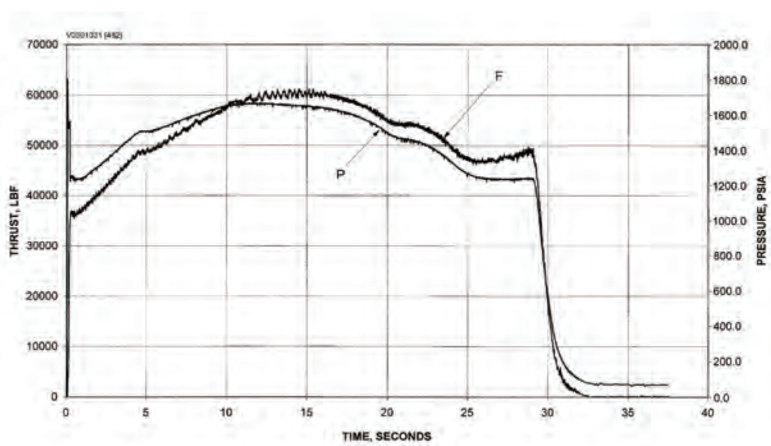
Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

ASAS 28-185/185V

TE-T-1032



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 (EOSA) device and a semiconductor bridge (SCB) initiator. The motor incorporated a TVC 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

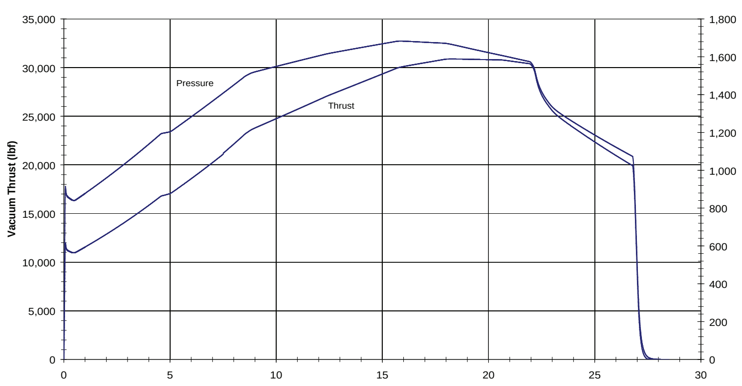
CASE MATERIAL
.... GRAPHITE-EPOXY COMPOSITE

PRODUCTION STATUS .... DEVELOPMENT

ASAS 32-58V (RAVEN)

TE-M-1106-1

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 Orbital ATK Elkton electronic safe-and-arm (ESA) 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

LAUNCH STRUCTURES

ATLAS V STRUCTURES

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.

Orbital ATK's Role

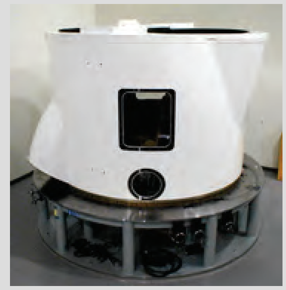
- Three part configurations
    1. Heat shield
    2. Centaur interstage adapter (CISA)
    3. Boattail
- Up to 5.4m in diameter (17.5 ft)
- Fabricated using automated fiber placement and advanced hand layup techniques
- Manufactured at the Large Structures Center of Excellence (COE) facility

Customer: United Launch Alliance

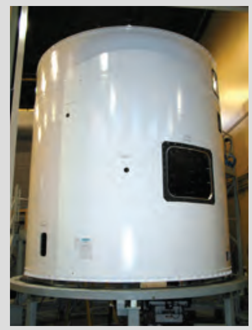
Prime Contractor: United Launch Alliance

Orbital ATK Aerospace Structures Division has pioneered the use of automated fiber placement for launch vehicle structures.

PRODUCTS



Heat Shield

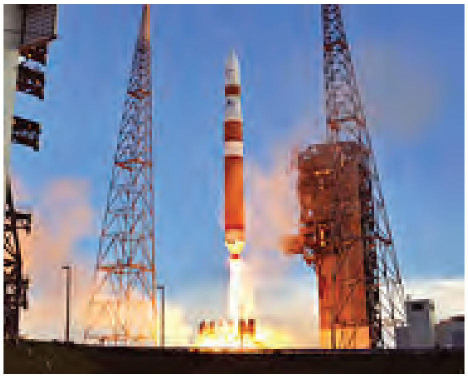


Interstage

Boattail

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.

Orbital ATK'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 COE facility

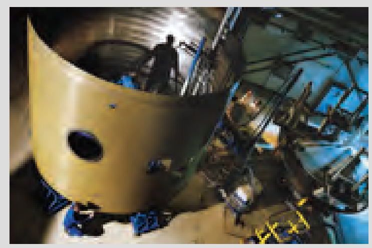
Customer: United Launch Alliance

Prime Contractor: United Launch Alliance

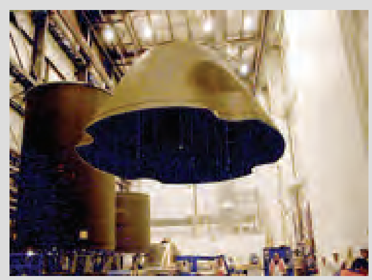
Orbital ATK provides over 17 different part configurations for the Delta IV family of launch vehicles.

PRODUCTS

Nose Cone



Centerbody



Thermal Shield

Approved for Public Release
OSR No. 16-S-1432;
Dated 05 April 2016

GEM

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 Orbital ATK's facility in Clearfield, Utah by computer-controlled winding machines using high-strength graphite fiber and durable epoxy resin.

Orbital ATK'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: Orbital ATK

Prime Contractor: United Launch Alliance

PRODUCTS

Orbital ATK's Aerospace Structures Division uses proven hand layup techniques to produce GEM 60 nose cones

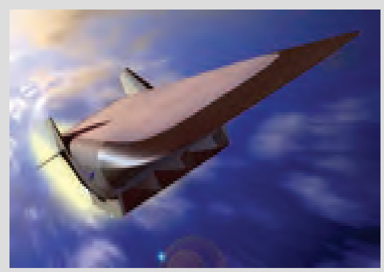
GEM cases are produced using advanced filament winding techniques developed and refined by Orbital ATK's Aerospace Structures Division for over 40 years

ORION

PRODUCTS

Pegasus

Taurus



X-43C

GMD

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.

Orbital ATK Aerospace Structures Division'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 (GMD) Orbital Boost Vehicle (OBV) - First, second, and third stage rocket motor cases
- Proven filament winding and hand layup techniques
- Demonstrated reliability and repeatability

Customer: Orbital ATK

Prime Contractors: Orbital ATK

PEGASUS

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 (LEO).

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 Orbital ATK separates approximately 110 seconds into flight, following second stage ignition.

Orbital ATK'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: Orbital ATK

Prime Contractor: Orbital ATK

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

A proven hand layup process developed by Orbital ATK Composites is used to fabricate the fairing components

ORDNANCE PRODUCTS

Orbital ATK Elkton has produced a wide variety of ordnance products since the 1960s including:

- Conventional electromechanical safe-and-arm (S&A) devices for STAR series space motor initiation and launch vehicle/stage destruct functions
- Conical-shaped charge (CSC) assemblies for booster destruct applications on STAR, CASTOR, Titan, Atlas, and Delta
- Semiconductor bridge (SCB)-based initiators for precise control of ordnance events for military applications such as the universal water activated release system (UWARS) 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.

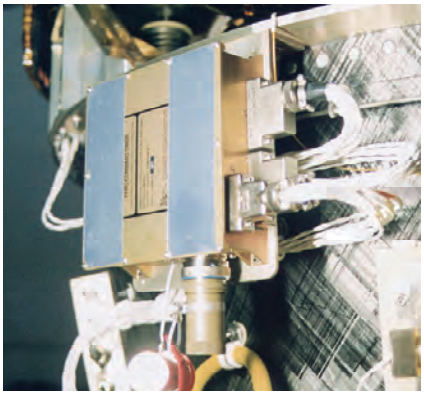
SCB Initiator

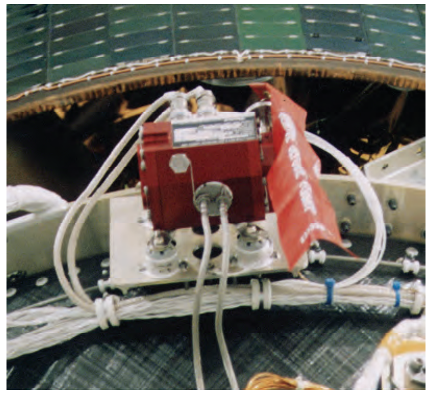
Model 2134B Electromechanical S&A Device

Model 2011 CSC

Electronic Safe-and-Arm (ESA) Device

Orbital ATK ordnance production facilities at Elkton include equipment for S&A assembly, initiator manufacturing, igniter manufacture, pyrotechnic and explosives loading, and laser welding. In addition to ordnance manufacture, Orbital ATK has facilities at Elkton 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 Orbital ATK

Electromechanical S&As. The development and production heritage for electromechanical S&A 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 (EWR) 127-1 compliant and has flown successfully from ETR, WTR, and Kourou and on vehicles such as Titan, Delta, Ariane, and Space Shuttle.

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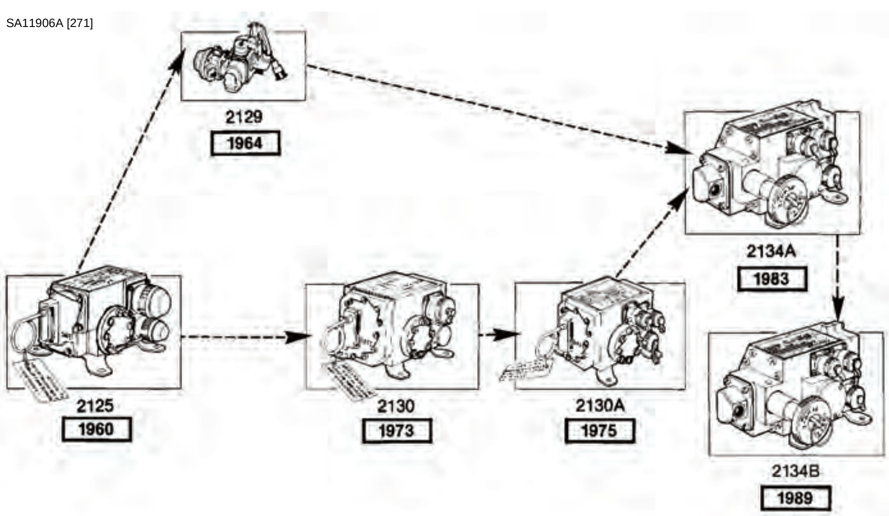
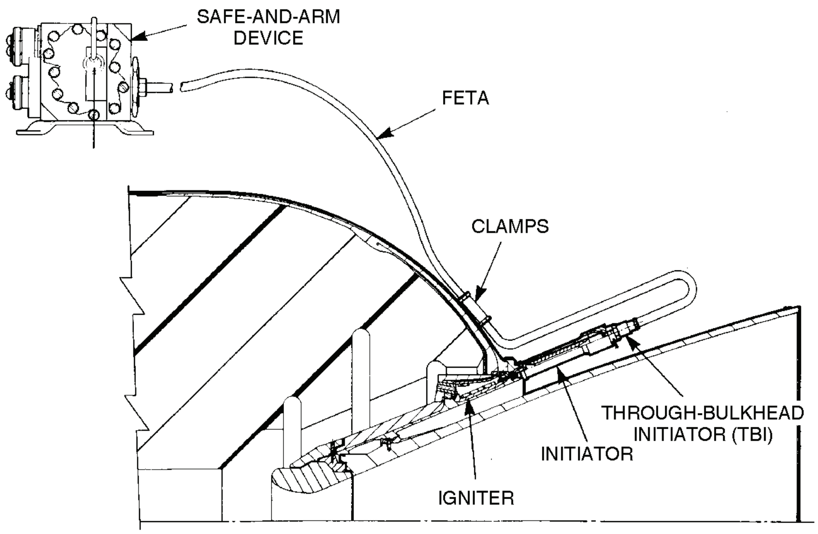


S&A Development Heritage Supports Product Reliability in Operation



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

Orbital ATK also supports S&A and ordnance system development having updated the documentation package and manufacturing instructions for the Space Shuttle S&A device. Orbital ATK also developed and qualified the Army Tactical Missile Systems (TACMS) arm/fire device for motor ignition and the S&A device for Army TACMS warhead initiation and has rebuilt or refurbished existing Minuteman III arm/disarm (A/D) switches for the U. S. Air Force. For the Minuteman III A/D switch, six-sigma principals 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 A/D switch. In addition, Orbital ATK has integrated complete ordnance systems, which include Elkton-fabricated wiring harnesses for missile defense boosters such as the Terrier lightweight exoatmospheric projectile (LEAP) Advanced Solid Axial Stage (ASAS) and the SM-3 Mk 136 Third Stage Rocket Motor (TSRM). In the area of upper stages, Orbital ATK 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

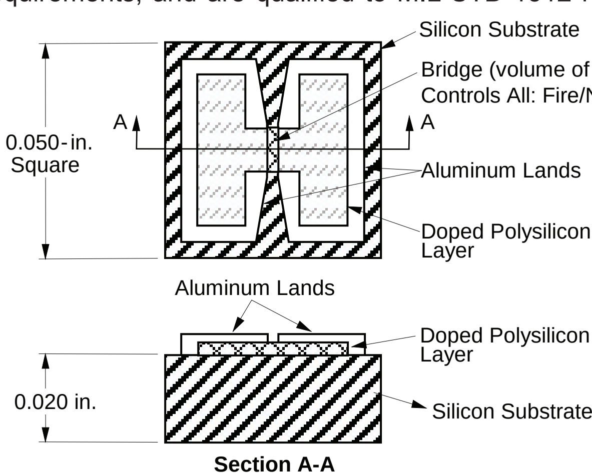
Conical-Shaped Charge (CSC) Assemblies. CSCs produced at Orbital ATK provide a concentrated destructive jet of energy for flight termination applications on a variety of propulsion systems, including boosters used on Titan and Atlas as well as CASTOR and STAR series motors. Orbital ATK conducts in-house testing for CSC lot acceptance and has integrated destruct ordnance for stages including Lunar Prospector for Lockheed Martin and NASA. CSCs produced at Orbital ATK 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 CSC.

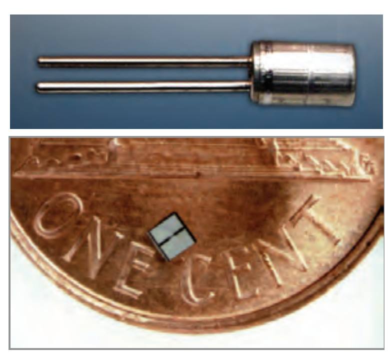
CSC Installed on Lunar Prospector TLI Stage

STAR 48 Destruct Test Using Model 2011 CSC

SCB Initiators. Since 1989, Orbital ATK 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 (UWARS) program following qualification of the device in 1994 (figure on following page). The flexibility and robustness of the basic SCB initiator configuration enables Orbital ATK to tailor pin designs, output charges, and design features for specific applications.

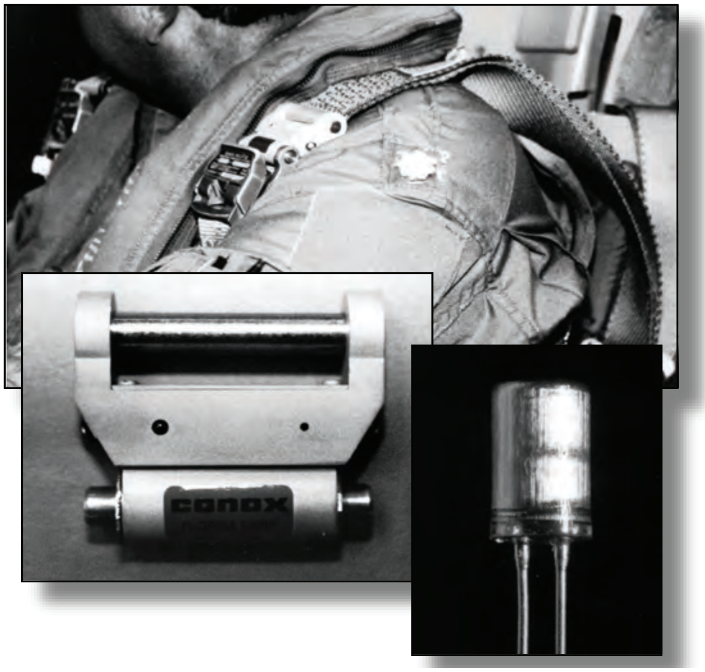
The SCB initiator provides advantages over other initiator technologies by providing low, consistent initiation energy with fast and highly repeatable function times. These devices enhance safety by readily passing no-fire requirements (>1 amp/1 watt/5 minutes), are electrostatic discharge (ESD)-tolerant, can be tailored to meet MIL-STD-1385B HERO requirements, and are qualified to MIL-STD-1512 requirements. This device produces a





SCB Chip and Initiator

Approved for Public Release OSR No. 16-S-1432; Dated 05 April 2016



Universal Water Activated Release System (UWARS)

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 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 Orbital ATK will further reduce unit costs and provide compatible electronic initiation systems that can reduce overall ordnance system weight.

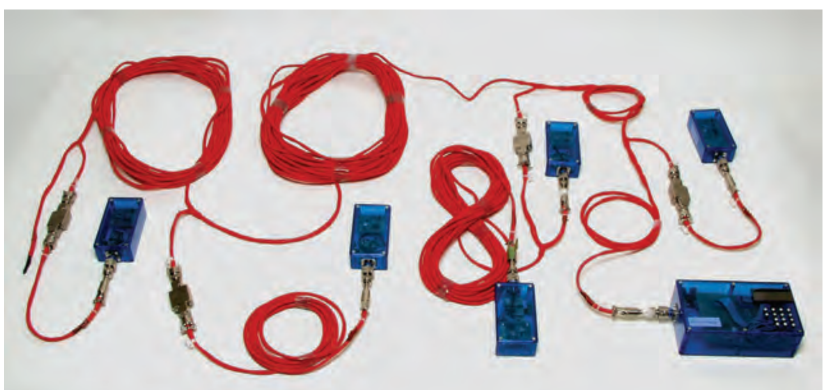
Advanced Electronics-Based Ordnance. Traditional launch vehicle and spacecraft ordnance systems use dedicated, direct-wire systems. These systems employ bridgewire-type squibs, shielded twisted pair cable harnesses dedicated to each squib, and an electronic ordnance controller. Because the safety functions 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, Orbital ATK has developed ordnance products that can replace the conventional S&A, explosive transfer assemblies (ETA), and through-bulkhead initiators (TBI) 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.

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 (NSI). 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 S&A permits direct installation into the igniter and eliminates the need for ETAs and TBIs. 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.

Orbital ATK 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 an Orbital ATK technology demonstration rocket motor in November 2000 and Orbital ATK's rapid vectoring nozzle (RAVEN) motor in 2003.

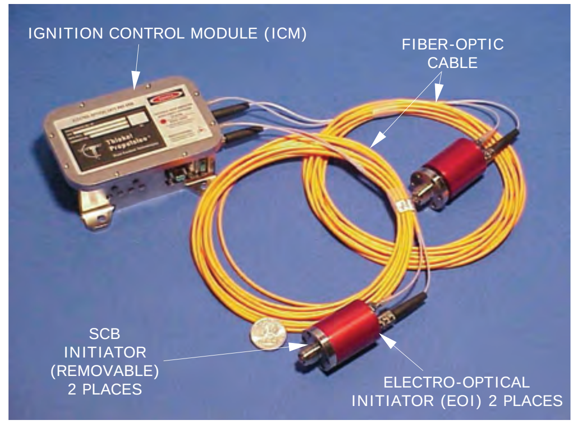
Addressable Bus Ordnance System. Under a 2001 and 2002 Advanced Ordnance Development program, Orbital ATK designed, fabricated, and demonstrated a breadboard addressable bus ordnance system based on ESA designs. The program also demonstrated implementation of communication protocols allowing individual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



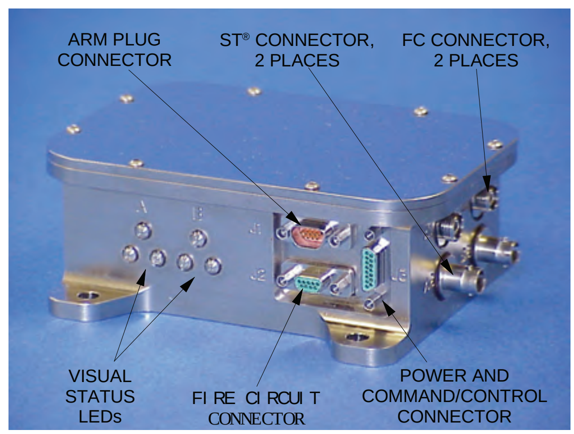
Addressable Bus Ordnance System Breadboard Prototype

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



EOSA



ESOA ICM

MODEL 2011

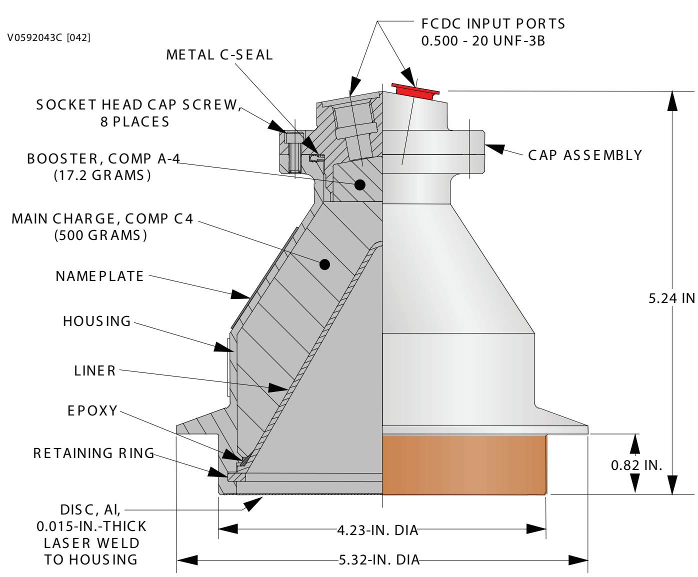
TE-0-958-1

DESTRUCT CONICAL SHAPED CHARGE (CSC)

Orbital ATK'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.

Orbital ATK 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. Orbital ATK'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

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 (ETA). The ETAs 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

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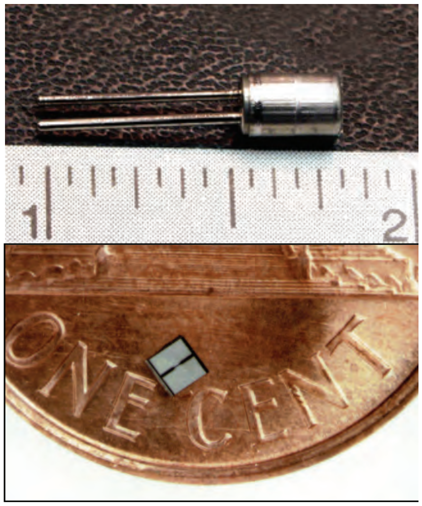
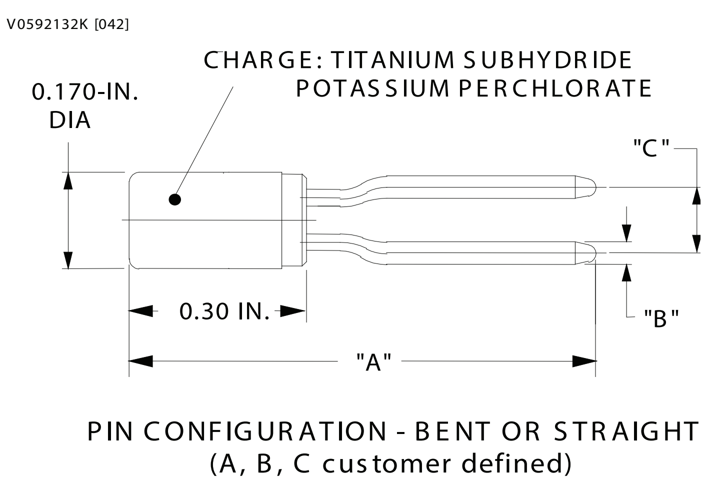
SCB INITIATOR

TEM-I-902



Orbital ATK Elkton'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 (UWARS). 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.



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

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Orbital ATK

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 Orbital ATK'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 (BIT) 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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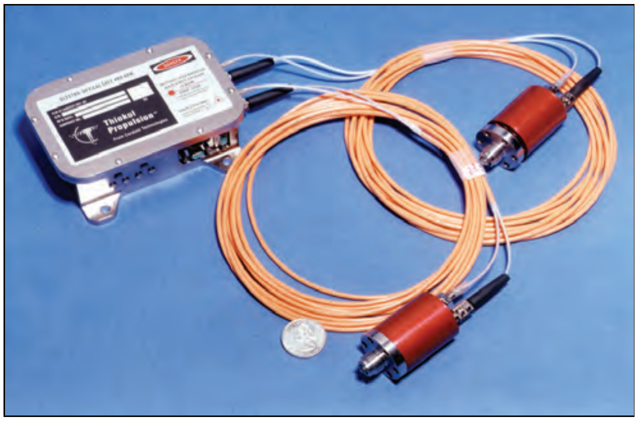
EOSA

TE-O-1054-1



Orbital ATK 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 (BIT) 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 Orbital ATK's patented MIL-STD-1512 qualified semiconductor bridge (SCB) 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

Orbital ATK

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