SIERRA SPACE

SPACEFLIGHT HARDWARE CATALOG

SPACE SOLAR POWER · MECHANISMS AND MOTION SYSTEMS
ENVIRONMENTAL CONTROL AND LIFE SUPPORT
PROPULSION · THERMAL CONTROL
ORBITAL SYSTEMS AND SERVICES

INTRODUCTION

"To make cosmic exploration feasible for everyone, we must constantly innovate with safer tech, fuels, and comfortable living conditions. This is how we prepare humanity for its next great leap into space."

Tom Vice, Sierra Space Chief Executive Officer (CEO)

INTRODUCTION

Sierra Space is an established supplier of high reliability satellites and spacecraft hardware, with multiple areas of expertise, including space solar power generation, precision pointing and motion control, spacecraft docking and berthing, payload separation systems and multi-satellite dispensers, propulsion engines and systems, and spacecraft environmental and thermal control, and life support systems. For decades, our company has played a key role in space science and exploration, with a long legacy of contribution to government, commercial, and civil customers on a diverse set of missions. Thousands of products, supporting hundreds of missions, with 100% operational success. This is why our customers choose Sierra Space.

The following catalog is intended to highlight a sample of our portfolio that can be leveraged to support your next mission. And stay tuned for future additions, as Sierra Space is constantly innovating to expand mankind's ability to explore and use space to expand our knowledge of this amazing universe, and to benefit life here on Earth.

A Space Economy

With technologies that make space more affordable and accessible, Sierra Space is creating an ecosystem for a prosperous and secure space economy that benefits all humanity. Sierra Space originated within Sierra Nevada Corporation (SNC), the global aerospace and defense company led and owned by Eren and Fatih Ozmen. Sierra Space has provided more than 4,000 space systems, subsystems, and components to customers worldwide, and participated in more than 500 missions to space, including many to Mars. The company has technology in production and in development to enable space habitats for short- and long-duration space travel, a fleet of *Dream Chaser®* spaceplanes, and the first free-flying commercial space station.

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HISTORICAL TIMELINE OF SIERRA SPACE

Sierra Space was spun-off from the Sierra Nevada Corporation (SNC) in June 2021. Sierra Space is headquartered in Louisville, CO, and comprises several SNC acquisitions over the past 20 years into a single, wholly owned subsidiary, bringing together a complement of technical innovation and management expertise. A short summary of SNC/Sierra Space history follows.

1963	**SNC Founded.** *A handful of employees worked out of a hangar in Stead, Nevada*
1994	Acquired by CEO, Fatih Ozmen and President, Eren Ozmen, current owners
1998	Acquired Advanced Countermeasure Systems of Sacramento, CA
1999	Acquisition of Spectral Systems, Inc. of southwestern OH
2001	Acquisition of Plano Microwave, Inc.
2003	Acquisition of Turtle Mountain Communications, Inc. Acquisition of San Francisco-based military computer designer Inter-4
2004	Acquisition of California-based, WaveBand Corporation Acquisition of Aviation Resources De, Inc.
2007	Acquisition of Colorado-based Straight Flight, Inc and Straight Flight Conversions, Inc.
2008	Acquisition of MicroSat Systems, Inc. of Littleton, CO Acquisition of SpaceDev, Inc.
2012	Acquisition of 3S Engineering LLC (a wholly owned subsidiary of SNC)
2014	Acquisition of Orbital Technologies Corporation (ORBITEC) of Madison, WI
2015	Acquisition of 328 Support Services GmbH (328SSG) enabled global expansion of SNC's modern commercial aircraft technologies Acquisition of Kutta Technologies, Inc. and Kutta Radios, Inc.
2021	Sierra Space Corporation spin off from SNC

Our Expanded Portfolio

- High-end tactical, ground-based electronic warfare (EW) systems
- Non-tactical data collection/laser tag systems used in warfighter training and evaluation
- Aerospace engineering and product development capabilities in the areas of Intelligence, Surveillance and Reconnaissance (ISR)
- ISR sensor capabilities through integration and enhancement of sensor technologies
- Customized, secure communications and real-time video solutions for the Department of Defense, other government agencies and commercial customers
- Ruggedized computer and network solutions to the Department of Defense
- Electronic beam-steering antennas and imaging radar systems to address aircraft autonomous landing, Unmanned Aircraft Systems (UAS) detect, see, and avoid, concealed object detection and surface surveillance radar sensor systems
- Aircraft and systems integration capabilities
- Provided Federal Aviation Administration (FAA)/European Aviation Safety Agency (EASA) 14 CFR Part 145, *Air Agency Certification*, operations, and expansion of aircraft modification
- Spacecraft development that included better payload mass fraction, power, data processing and pointing accuracy
- Space heritage with products that had flown on more than 300 spacecraft over 20 years, and represented a dynamic expansion of space technology capabilities, proven system integration, communications, networking, and intelligence capabilities in the space sector
- Engineering design and support, compliance data development and documentation for aircraft modifications and avionics system integration
- Propulsion, propellant, and power systems
- Life support and environment control
- Bio-based products and production systems
- Interactive 3D simulation software
- Supplemental Type Certificates (STC), design, and build-and-certify solutions for large commercial customers
- Ownership of the type certificate and intellectual property rights for design, manufacture, maintenance and certification of existing Dornier 328 turboprop and jet aircraft; 328SSG also holds an EASA Type One Certificate, enabling responsive certification support for aircraft modification and design
- Communications and visualization capabilities for government and commercial clients in the areas of command-control-communications software applications and rugged, survivable communications systems

ABOUT SIERRA SPACE PRODUCTS AND CAPABILITIES

Space Products

Sierra Space is a leading commercial space company at the forefront of innovation and the commercialization of space in the Orbital Age®, building an end-to-end business and technology platform in space to benefit life on Earth. With more than 30 years and 500 missions of space flight heritage, the company is reinventing both space transportation with the *Dream Chaser*®, the world's only commercial spaceplane, and the future of space destinations with the company's inflatable and expandable space station technology. Using commercial business models, the company is also delivering orbital services to commercial, DoD and national security organizations, expanding production capacity to meet the needs of constellation programs. In addition, Sierra Space builds a host of systems and subsystems across solar power, mechanics and motion control, environmental control, life support, propulsion and thermal control, offering myriad space-as-a-service solutions for the new space economy.

Space Applications Product Line

Sierra Space is an industry leader in spacecraft and precision space mechanisms and complex spacecraft subsystems with a range of high-TRL (Technology Readiness Level) products including thousands of devices successfully flown on hundreds of spacecrafts. We are a supplier of choice with an expansive portfolio of space-qualified products and subsystems that include:

- Deployable Systems
- Docking and Berthing Systems
- Electrical Power Systems (EPS)
- Environmental Control and Life Support Systems (ECLSS)
- Flight and Thrust Vector Control Systems
- High Output Paraffin Actuators and Mechanisms
- Instrument Door and Cover Systems
- Launch Adapters and Separation Systems
- Pointing Systems and Motion Control
- Production and Test Capabilities
- Propulsion Engines and Systems
- Satellite Buses
- Thermal Control Systems (TCS)

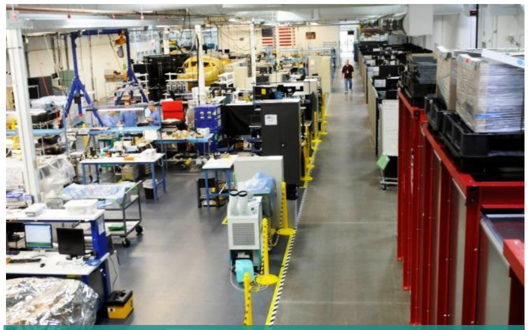
Facilities

LOUISVILLE, CO: MANUFACTURING/ASSEMBLY

Our primary manufacturing/assembly facilities are in Louisville, CO. We have more than 230,000 square feet of office and manufacturing space dedicated to spaceflight subsystem and component design, modification/customization, assembly and test, small satellite end-to-end production, and fabrication of the *Dream Chaser*® multi-mission space transportation system.

Our facilities feature:

- AS9100 certification
- Precision temperature and humidity control
- ISO 8 modular production floors
- ISO 7 clean rooms
- ISO 5 laminar flow benches
- Specialized equipment and tools for the handling, cleaning, assembly, and cleanliness-verification of optical-grade products
- End-to-end testing capabilities including vibration, shock, a rapid transition Thermal Test Chamber, radio frequency, thermal, thermal-vacuum and stiffness, as well as functional test support equipment
- Large Area Pulsed Solar Simulator for solar array testing



Louisville, CO ISO 8 Modular Production Floor

DURHAM, NC: ELECTROMECHANICAL MOTION CONTROL

Our Durham, NC location houses our highly skilled, aerospace industry-leading electromechanical motion control team. This team of engineers and technicians focus on the design, development, and production of spaceflight motors, actuators, and electromechanical devices with an unmatched, diverse product heritage. The Durham facility is located within minutes of the Raleigh-Durham International Airport and features:

Louisville, CO Thermal and Vacuum Chambers

- AS9100 certification
- ISO 8 modular production floor
- ISO 7 clean rooms
- ISO 5 laminar flow benches
- End-to-end testing capabilities including vibration, thermal, thermal-vacuum, stiffness, motor/actuator speed-torque-accuracy, dedicated micro-vibration lab for disturbance torque testing, and functional testing

The Durham and Louisville locations share personnel and facility resources to optimize program execution based on customer needs.

MADISON, WI: ENVIRONMENTAL SYSTEMS

Our primary Environmental Systems facility is in Madison, WI, with assembly and test facilities in nearby Middleton, WI. The Middleton assembly and test facility includes:

- AS9100 certification
- Technicians certified to NASA-STD-8739.1, *Polymeric Application on electronic Assemblies*; NASA-STD-8739.4, *Crimping, Interconnecting Cables, Harnesses, and Wiring*; and IPC J-STD-001, *Standard for Soldering*, for fabrication of hardware
- Precision temperature and humidity control environments
- Thermal and Vacuum Chambers
- ISO 8.5 controlled work areas
- ISO 8 clean rooms
- ISO 7 clean rooms
- ISO 5 laminar flow benches
- Specialized equipment and tools for the handling, cleaning, assembly, and cleanliness-verification of spaceflight products
- Specialized equipment for clean, orbital welding
- End-to-end testing capabilities including random vibration, mechanical shock, thermal test chambers, thermal-vacuum test chambers, humidity cycling, acoustics, and many other specific functional tests

Sierra Space Rocket Engine Test Facility

Testing of engine hardware is a critical step not only in system development, but also for flight acceptance testing of any new propulsion system. Sierra Space's dedicated rocket test facility located near our engineering and manufacturing facilities in Madison, WI is a state-of-the-art, multi-cell testing space for a wide range of propulsion, environmental, and material testing applications. From component and system risk reduction to hardware qualification and flight acceptance testing in a simulated vacuum environment, our facility and experienced test team are capable of operating engines using a wide range of propellants including hydrogen peroxide, oxygen, kerosene, methane, hydrogen, and numerous others over thrust ranges from 1-150,000 lbf. We also offer a specialized test cell for high temperature materials testing up to 2,200 °C which is especially useful for quickly evaluating materials used in hypersonic operating regimes, heat shields, and space radiator materials.

Aerial view of the Sierra Space Rocket Engine Test Facility.

Close-up of vacuum simulation test cell.

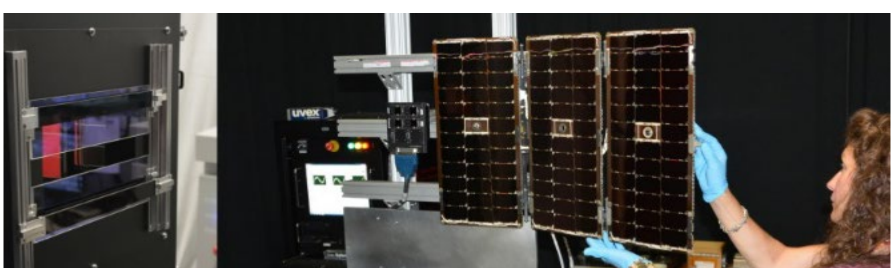
OTHER FACILITIES

Other facilities include a dedicated propulsion and environmental systems office located in Madison, WI. We serve our customers with business development offices in Houston, TX; Huntsville, AL; and Exploration Park, FL.

Test Simulator Capabilities

Our Louisville location houses state-of-the-art **production and test** facilities, including the Large Area Pulsed Solar Simulator (LAPSS), used to verify solar array performance. The LAPSS, located in a large-scale testing zone, simulates the Sun to obtain accurate electrical performance measurements of solar panels.

Our LAPSS is capable of measuring panels that are 3.5 m x 3.5 m square with the AM0 (air mass zero) spectrum at a rate of 10 pulses per minute. We verify all our solar array systems using supplementary industry measurement standards and equipment provided by solar cell manufacturers such as SolAero Technologies, SpectroLab, and Azur Space.



LAPSS Simulator. LAPSS accurately simulates the space solar environment to derive assembly performance measurements.

LAPSS Test Area. An in-house LAPSS solar array test area for secondary verification processes.

Component Engineering and Product Support

Sierra Space boasts industry leading expert teams who focus on a broad range of technical management and product support specialties. Our engineering practice's breadth and depth of experience sets Sierra Space apart in the space component industry, allowing us to respond efficiently to customer needs—on production-type programs, as well as custom-engineered solutions. Our talented personnel provide an array of engineering disciplines and tools as summarized below:

Disciplines	
Mechanical Engineering	Electrical Engineering
Structural Engineering	Software Systems Safety
Systems Engineering	Manufacturing Engineering
Project Engineering	Test Engineering
Combustion Engineering	Software Engineering
Safety and Mission Assurance	Fracture Control
Electromagnetic Compatibility/Electromagnetic Interference (EMC/EMI) Engineering	Integration Engineering
Electrical, Electronic, and Electromechanical (EEE) Parts Engineering	Materials and Process Engineering
Cryo-Management Engineering	Embedded Software Engineering
Thermal Engineering and Analysis	Quality Assurance
Radio Frequency Engineering	Structural Analysis
Guidance, Navigation, and Control Engineering	Reliability Engineering and Assurance
Thermal Analysis	Finite Element Modeling
Fluids Analysis	Systems Certification for Human Spaceflight

Tools			
CAD	**Siemens NX**	**Dassault Systèms SolidWorks**	**Autodesk AutoCAD**
Structural Analysis	MSC Nastran	Nei Autodesk Nastran 2015	NX Nastran 8.5
	NX CAE	Ansys	
Thermal	Thermal Desktop	Systems Improved Numerical Differencing Analyzer (SINDA) G	COMSOL
Numerical Analysis	MATLAB	Simulink	Mathcad
Electrical Simulations	PSpice		
Electrical Design	A	OrCAD	
Magnetic/Motor Analysis	SPEED	Infolytica MotorSolve	Infolytica Magnet
Bearing Analysis	MESYS	Cobra	AB Jones
Gear Analysis	KISSoft	UTS Integrated Gear	
Computational Fluid Analysis (CFA)	Converge CFD	SolidWorks	Star-CCM

CATALOG

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CREW SYSTEMS AND PAYLOADS

Sierra Space provides systems currently in use on the International Space Station (ISS) or planned for technology demonstration. These systems are designed for ease of use in a microgravity environment, stressing simplicity of operation. They are efficient in terms of mass, power use and physical footprint. We design our advanced systems with an eye toward future long-duration missions, incorporating features, which augment life support functions and resource recovery.

ISS PAYLOADS

Catalog data sheets for our ISS Payloads technology area include:

Astro Garden® System

Design Description

Sierra Space leveraged heritage space plant growth systems to develop the next generation of plant growth system for long-duration space missions. With eight individual plant growth volumes, Astro Garden can provide a crew with fresh food to augment current food systems and aid life support functions such as water purification, CO_2 removal, and O_2 production.

Sierra Space's next Generation Astro Garden® system, for long-duration missions

Applications	
• Food production on manned stations and outposts	• Dietary augmentation for personnel
• Reduced load of life support systems	

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	132 lbm	60 kg
Growth Module Envelope	24 in x 24 in x 60 in	61 cm x 61 cm x 152 cm
Growth Module Plant Area	885 in^2	5,710 cm^2
Electrical		
Maximum Power @ 24 Vdc	450 W @ maximum output growth volume	
Input Voltage Range	24 – 32 Vdc	
Environmental		
Operating Temperature Range	-40 to +140 °F	-40 to +60 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

SIERRA SPACE

Mass Measurement Device (MMD)

Design Description

Sierra Space designed, built, and flight-qualified the Mass Measurement Device (MMD). Currently in operation on the International Space Station (ISS), the MMD provides an accurate means to measure mass of samples within a sample restraint container. The MMD is gravity independent and provides a simple user interface to measure mass of samples. This unit was designed modularly, allowing additional mass ranges to be accommodated.

Mass Measurement Device Features
• Gravity independent mass measurement
• Modular design allows for future extensibility
• 0.1-to-100-gram range (increased range available)
• Simple user interface
• Flexible mounting options
• 0.1-gram accuracy

Mass Measurement Device in operation on ISS
Photo Credit NASA

Applications
• Sample measurement

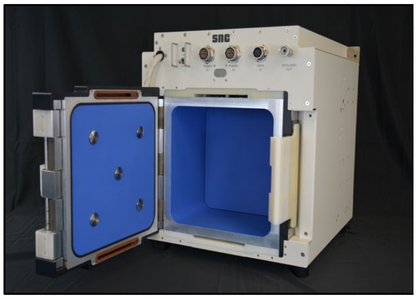
Heritage Programs
• International Space Station (ISS)

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	25 lbm	11 kg
Electrical		
Maximum Power @ 24 Vdc	15 W	
Input Voltage Range	24 – 32 Vdc	
Environmental		
Operating Temperature Range	-40 to +140 °F	-40 to +60 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Trash Compaction and Processing System (TCPS)

Design Description

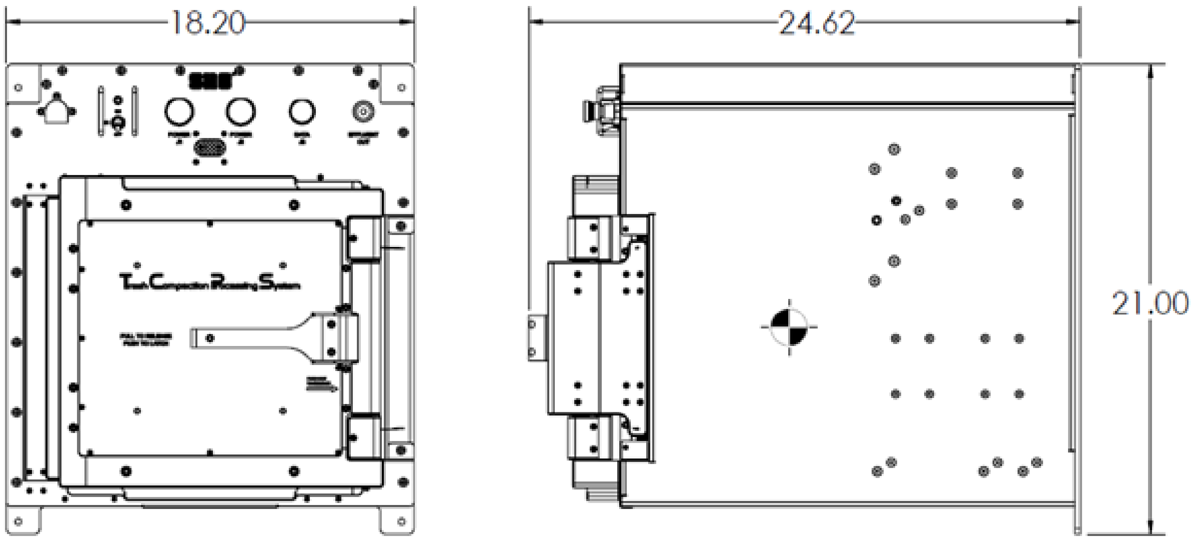
Sierra Space designed and built the Trash Compaction and Processing System (TCPS) to complement our environmental control product line. TCPS is designed to facilitate waste management in the next generation of space vehicles and habitats. We optimized TCPS to provide efficient waste sanitation, stabilization, and resource recovery, while reducing the mass, power, and physical footprint.



Trash Compaction and Processing System (TCPS)

Operation of TCPS is intuitive, and can be operated with one hand, allowing for a crew to easily load/handle waste. Waste is loaded into the waste compaction chamber where it is heated and compressed. Temperature and pressure sanitize waste, consolidate waste into a stable tile, and drive any moisture and gas out of the waste compaction chamber in the form of effluent (gas and water vapor) into a phase separator. The phase separator condenses water vapor into condensate, separates condensate into an attached receptacle or container, and transfers effluent gas into a gas processing sub-assembly. The gas processing sub-assembly conditions waste gas so it is safe and suitable for reintroduction to cabin. TCPS operation is similar to everyday terestial kitchen appliances such as running a dishwasher or microwave, while designed to accommodate micro-gravity operations.

Dimensions



Note: All dimensions are in inches.

Trash Compaction and Processing System (TCPS) Features	
• Proprietary chamber coating	• Allows for repeated and reliable waste processing at sanitation temperatures
• Passive phase separation technology	• Separates liquid process outflows for recovery and treatment
• Exhaust gas processing technology	• Processes gas process outflows for safe exhaust into crewed environments

Applications	
• Waste elimination	• Resource recovery

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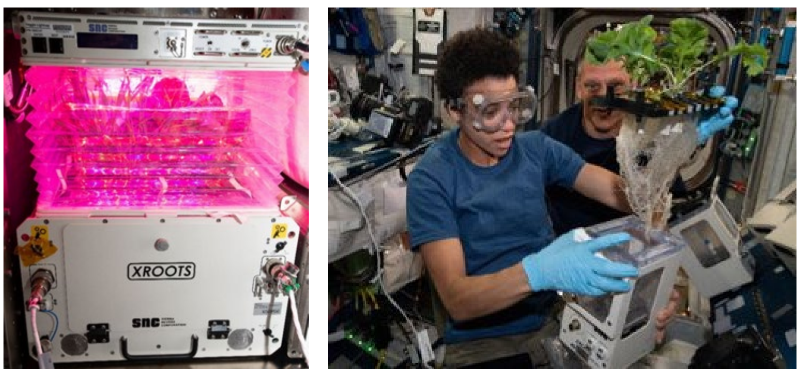
Product Specifications		
Metric	**U.S.**	**SI**
Mechanical		
Mass	95 lbs	43 kg
Volume	18.2 in X 21 in X 24.6 in	46.2 cm X 53.3 cm X 62.5 cm
Cooling (Air)	320 Watts	
Steady State Power	580 Watts @ 28 Vdc	
Waste Processing Rate	9.9 lbs/day	4.5 kg/day
Crew Members Supported	4	
Waste Volume Reduction	4:1	
Processing Temperature Range	68 to 356 °F	20 to 180 °C
Moisture Recovery	>95%	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

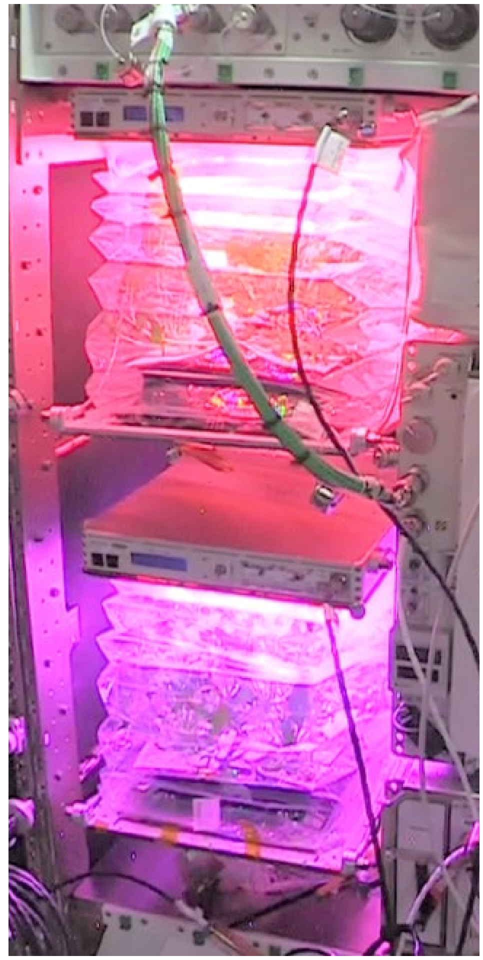
Vegetable Production Unit (VEGGIE)

Design Description

Sierra Space developed and provided the flight-qualified VEGGIE systems currently in operation on the International Space Station (ISS). VEGGIE provides an environment for plant growth by providing a programmable light source, ventilation with cabin air, and a passive water delivery via plant pillows. Since its first use on ISS, VEGGIE has seen regular utilization, proving a valuable science platform and favorite among the crew. VEGGIE was the first platform verified to provide ISS-grown produce for crew consumption and continues to provide data for systems that can one day be used on a long-duration mission that would be used to augment astronaut's diets with fresh food. Sierra Space has also flight-qualified an aeroponic/hydroponic plant nutrient delivery/recovery VEGGIE subsystem called XROOTS. XROOTS provides critical plant growth and germination functions while removing the need for soil/growth media thus reducing upmass/crew interaction.



XROOTS installed into VEGGIE on ISS



VEGGIE units operating on the ISS.
Photo Credit NASA

VEGGIE Unit Features	
• Solid state lighting for high reliability	• Flexible deployment (1 or 2 EXPRESS rack locations)
• Spectral control (contact for additional details)	• Simple crew interfaces
• Programmable lighting	• Small stowage volume when not in use
• Variable ventilation capabilities	

XROOTS Subsystem Features	
• Aeroponic and hydroponic nutrient delivery/recovery	• Controlled nutrient solution delivery
• Media-less plant growth	• Reduced crew interfaces
• Reduced upmass needed for deep space habitability	

Applications
• Food production on manned stations and outposts
• Plant growth experimentation in microgravity environment

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Heritage Programs
• International Space Station (ISS)

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	31 lbm	14 kg
Electrical		
Maximum Power @ 24 Vdc	72 W	
Input Voltage Range	24 – 32 Vdc	
Performance		
Volume: Qualified up to	2.4 ft^3 (0.068 m^3)	
Reservoir Capacity: Qualified up to	0.79 Gallons (3 liters)	
Operating Temperature Range	Within 3 °C of ambient	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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SPACECRAFT LIGHTING

Sierra Space's lighting designs possess a decade-long heritage of use. They are customizable for a wide variety of customer requirements. All our lighting solutions are solid state for increased efficiency and lifetime.

Catalog data sheets for our Spacecraft Lighting technology area include:

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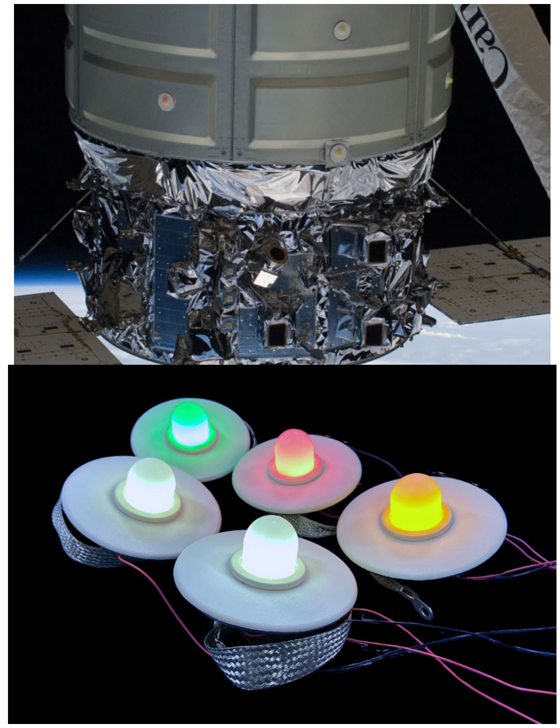
External Vehicle Lighting

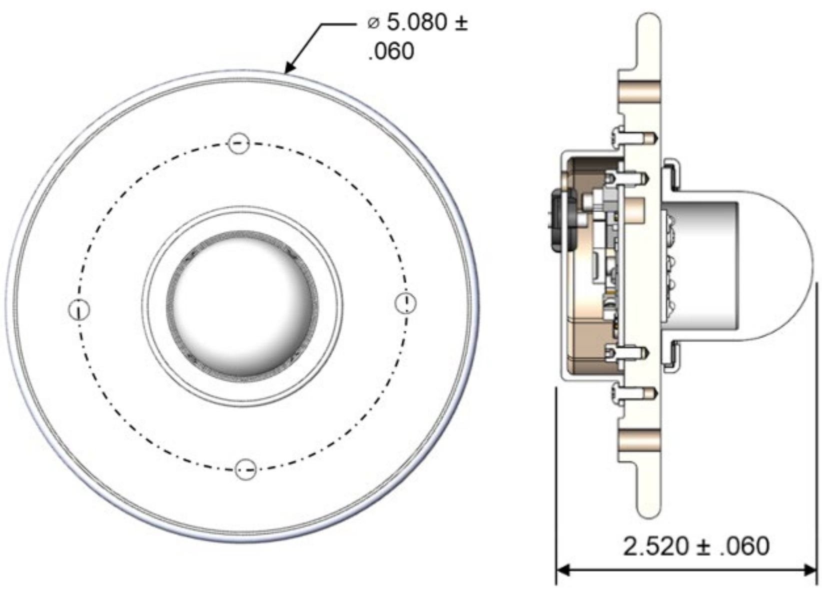
Design Description

Sierra Space has provided external vehicle lighting for over a decade and continues to provide standard lighting solutions as well as customized navigational lighting solutions. These solid-state lights provide required illumination, at a fraction of the power and mass over traditional lighting solutions. Sierra Space continually strives to provide the right solution for every application and encourages discussion for any application.



Navigation Lighting.

Dimensions



Note: All dimensions above are in inches.

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External Vehicle Lighting Features	
• Solid state lighting	• Technology readiness level (TRL) 9
• Available in all standard navigation lighting colors	• EEE Grade 2+

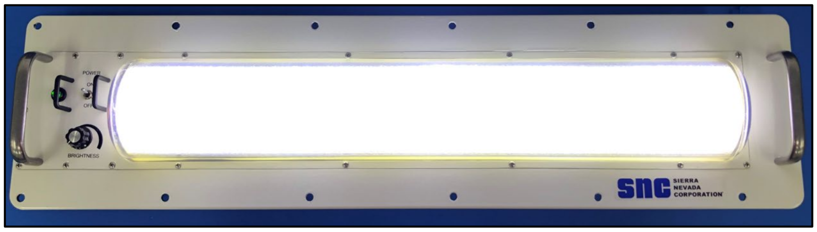
Applications	
• Navigational lighting	• Exterior illumination

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	0.6 lbm	0.278 kg
Electrical		
Maximum Power @ 24 Vdc	4.3 W	
Input Voltage Range	24 - 32 Vdc	
Environmental		
Vibration: Qualified to	50 Grms	
Shock: Qualified to	1,200 G	
Operating Temperature Range	-50 to +194 °F	-46 to +90 °C

Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.

Internal General Lighting Assembly

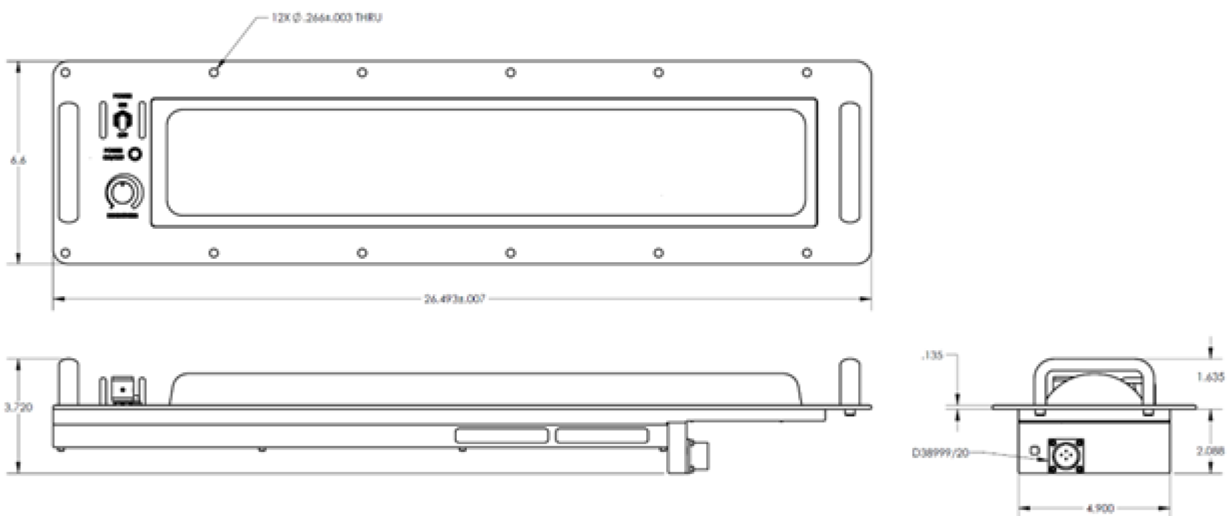
Design Description



General Lighting Assembly.

Sierra Space developed a flight-qualified Internal Lighting Assembly for use internal on spacecraft. The output meets the color spectrum and intensity requirements consistent with International Space Station (ISS) lighting. This light uses solid-state components, for increased efficiency and lifetime. This lighting assembly provides bright, white light for illuminating large spacecraft environments. Blue Depleted – Circadian Lighting Configurations and Embedded Software Control configurations are available. The Internal Lighting Assembly also can be assembled with Grade 2 or Grade 1 electronics to comply with low Earth orbit (LEO) or Deep Space radiation requirements.

Dimensions



Note: All dimensions above are in inches.

Internal General Lighting Assembly Features	
• Solid-state lighting	• EEE Grade 2+ or Grade 1
• Embedded Software and Data Handling Configurations	• Dimming capable
• Blue Depleted – Circadian Lighting Configurations	

Applications
• Long-lasting, efficient internal lighting

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	8 lbm	3.6 kg
Electrical		
Maximum Power @ 24 Vdc	30 W	
Input Voltage Range	24 – 32 Vdc	
Performance		
Output	2,300 Lumens	
Environmental		
Vibration: Qualified to	9.2 Grms	
Shock: Qualified to	1,000 G	
Operating Temperature Range	25 to 121 °F	-4 to 49 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

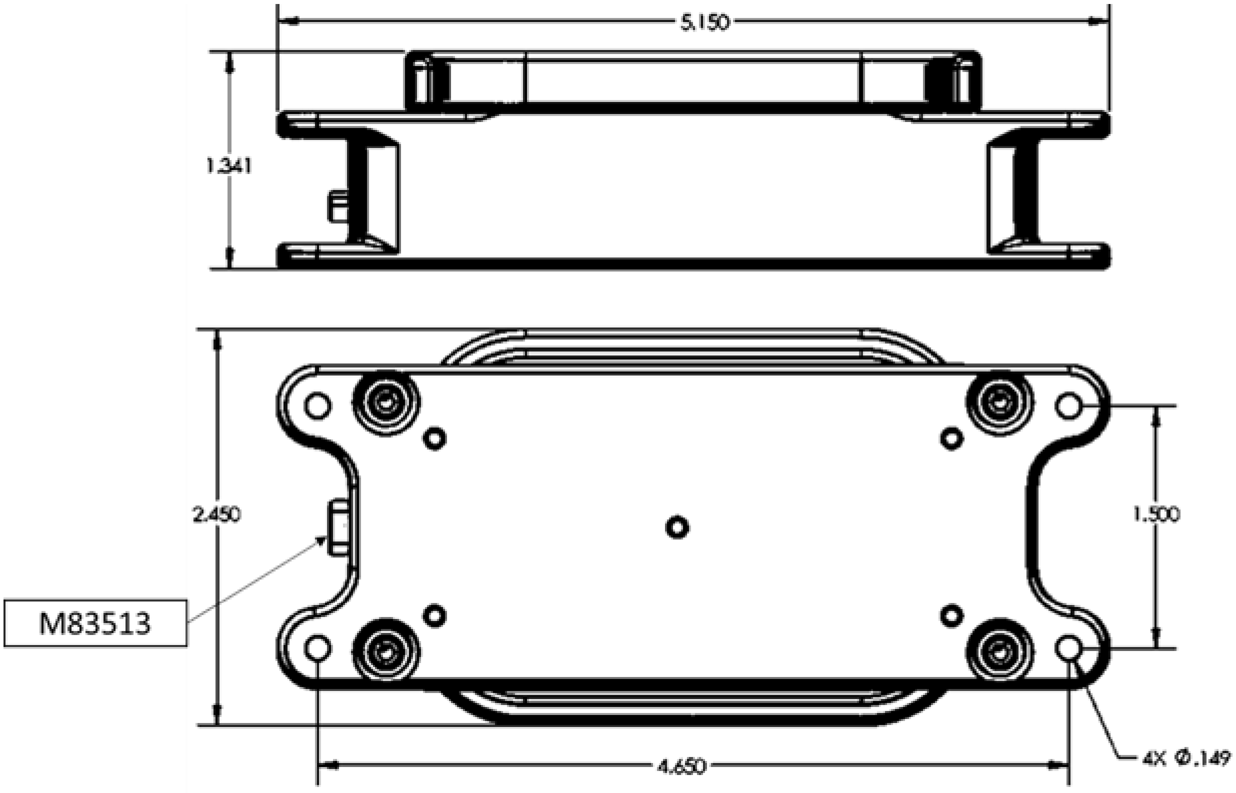
Internal Task Lighting

Design Description

Sierra Space developed a flight-qualified Internal Task Lighting unit for spacecraft environments. This solution leverages the benefits of solid-state lighting, while minimizing the electrical power and mass necessary. This light also provides a means to direct the generated thermal energy.

Internal Task Lighting.

Dimensions



Note: All dimensions above are in inches.

Internal Task Lighting Features	
• Solid state lighting	• Lights can be configured in multiple strings for higher distributed lighting
• Provides color required for spacecraft tasks	• EEE Grade 2+

Applications
• Efficient internal lighting

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	0.5 lbm	0.23 kg
Electrical		
Maximum Power @ 24 Vdc	5 W	
Input Voltage Range	22.4 – 32 Vdc	
Environmental		
Vibration: Qualified to	9.2 Grms	
Shock: Qualified to	1,000 G	
Operating Temperature Range	25 to +121 °F	-4 to + 49 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

DEPLOYABLE SYSTEMS

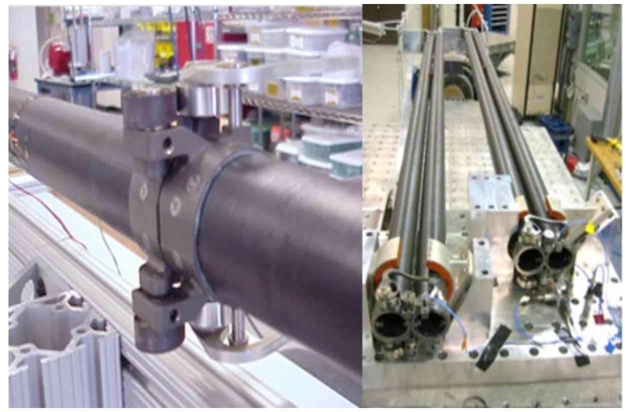
Sierra Space considers deployable structures to be a critical element in the future of microsatellite systems. Our Jackscrew boom system uses high-strength, high-stiffness articulated truss elements that ensure low-risk linear deployment. The structure and deployment systems are readily integrated into mass- and volume-efficient superstructures for planar arrays. Our K-truss booms are engineered with a strain-energy deployment system that reduces cost and is constructed with a nonconductive material that enables antenna integration.

Catalog data sheets for our Deployable Systems technology area include:

Articulating Booms

Design Description

Sierra Space's deployable boom capabilities include articulating booms that use tube structures and hinges for accurate and repeatable deployment of payloads. Hinged deployed booms meet many missions needs where stability and system simplicity are critical. Articulated booms are often used to deploy optical systems, radiation or magnetometer instruments, and other stability-sensitive payloads. Cabling, wave guides, multi-layer insulation (MLI), and other hardware can be firmly mounted along the length of the boom where an axially deployed boom could not be incorporated due to boom rotation or a risk of entanglement.



Articulated Boom. This deployed boom used a 90-degree base and 180-degree mid-length locking hinge to provide a 2:1 expansion ratio.

Articulated booms can use either a root/base stowed energy hinge or a motorized hinge to actuate the boom depending on mission requirements. Stowed energy hinges are simple, low-risk mechanisms that provide torsional force via redundant leaf springs while controlling the rate of deployment via integrated dampers. Stowed energy hinges are used on missions with a one-time boom deployment requirement and can include locking features if needed. We can also incorporate motors on the hinges to provide deployment torque for missions requiring more control of the boom to deploy multiple times or stop in multiple positions. Other features include:

- 180-degree hinges that can be incorporated along the length to increase the deployed-to-stowed expansion ratio as shown in the image above.
- Integrated Hold Down Release Mechanisms (HDRM) to provide support during launch and mission operations prior to deployment.
- Significant experience and heritage in hinge-deployed booms and collaboration with customers to determine the optimal solution required for their space missions.

Articulating Boom Features	
• Gentle, smooth deployment	• Allows for attachment of equipment along the length of the boom
• Excellent instrument stability and position accuracy	• Simple and redundant design provides low-risk deployment
• Motor or stowed-energy driven deployment	• Highly tailorable for thermal stability, strength, and stiffness
• High accuracy and stable	

Applications	
• Optical systems and instruments	• Deployed radar antennas
• Solar array deployment	• High-sensitivity instruments such as particle detectors and magnetometers

Jackscrew Deployed Boom

Design Description

Sierra Space's Jackscrew Deployed Boom, shown at the right under test, is a motor-deployed, high-stiffness and high-strength articulated truss. The jackscrew boom deploys in a purely linear/axial manner without the use of deployment canisters for de-spin as required for motorized coilable booms. Therefore, the jackscrew boom provides multiple payload or cabling attachment points along the length of the boom with a deadband-free, high mechanically advantaged deployment without the parasitic mass of a canister. The jackscrew drive system offers mass and volume efficiency improvements over canister-deployed booms.

Jackscrew Deployed Boom under test.

The jackscrew boom deployment method also provides full structural integrity throughout deployment, thus allowing mid-deployment spacecraft maneuvering or other loading without the risk of collapsing the boom. The jackscrew boom can be re-stowed after deployment by reversal of the deployer motor.

The main components of the boom system, illustrated below, consist of the deployable boom assembly and the deployer assembly. The deployer assembly uses a system of redundant belts driven by an electric motor to synchronize and drive a series of jackscrews. The deployer also includes four structural tubes that position the stowed boom and enclose the jackscrew drive shafts, a detent at each corner of the deployer, and four foldable jackscrews.

Triangular cross-section booms are also available using three jackscrews. During deployment, the jackscrews (aka elevator screws) and deployment detent work together to sequentially expand and form each bay of the boom as it is deployed. At least one batten frame of the boom is engaged with the jackscrews at any point in time during deployment providing full structural integrity throughout deployment. The deployer jackscrews are restrained in their folded, stowed configuration during launch and prior to boom deployment. Following a signal to initiate deployment, the jackscrews are released and transition to their deployed, locked configuration. A brushless direct current (DC) motor provides power to the system and limit switches identify first motion and successful deployment of the boom.

10-bay Jackscrew Deployed Boom (stowed).

Deployed boom cantilevered with 11-lb tip mass (no offloading).

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Jackscrew Deployed Boom Features	
• Purely linear/axial deployment	• High-force deployment/retraction
• Highly tailorable for thermal stability, strength, and stiffness	• Highly scalable and mass optimized
• Simple, high-reliability, high-tension deployment	• Full stiffness and strength during deployment
• Exposed payload interfaces throughout deployment and during pre-flight integration	

Applications	
• Solar array and solar-sail deployment and retraction	• Instrument deployment and retraction
• Antenna deployment/retraction	• Gravity gradient mass deployment and retraction
• Synthetic Aperture Radar (SAR) deployment and retraction	• Spacecraft separation

Product Specifications for a 10-Bay Jackscrew Boom		
• Dimensions: 190-in long x 15.5-in diameter	• 1st Bending Mode: 6.9 Hz	• Tip Torsion Stiffness: 13,594 in-lb/rad
• Mass: 11.7 lb	• 1st Torsion Mode: 16.4 Hz	• Tip Shear Stiffness: 25 lb/in

K-truss Boom

Design Description

Sierra Space's K-truss boom is an elastically deployed boom, which uses stowed energy for deployment. The K-truss boom deploys in a purely linear/axial manner unlike a conventional lanyard deployed coilable boom. Therefore, the K-truss boom provides multiple payload or cabling attachment points to allow the deployment of objects along the length of the boom before, during, and after deployment.

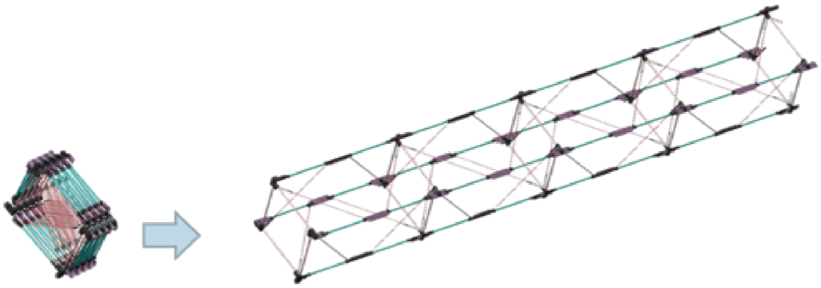
K-truss Boom with quadrifilar helical antenna under test.

This type of boom simplifies deployable structures on small satellites by eliminating the need for drive motor and electronics. The resulting boom provides a nonrotating deployment with unprecedented thermal stability, precision, and repeatability, in addition to high stiffness and high strength. This type of deployed structure is also applicable to many spacecrafts that have been traditionally limited to fiberglass coilable type booms. This enabling boom technology can increase satellite application capabilities, improve reliability, and reduce costs. The stowed and deployed K-truss boom is illustrated below.

K-truss Boom Features	
• Exposed payload interfaces throughout deployment and during pre-flight integration	• Nonconductive/magnetically "clean" materials available for integrated antennae or magnetometers
• Highly tailorable for thermal stability, strength, and stiffness	• Highly scalable and mass optimized
• Predictable deployment behavior	• Zero deadband monolithic structure
• Elastically deployed "tape" joints eliminate motorized actuation mass	• Precision deployment and pointing accuracy of the payload

Applications		
• Solar array/solar-sail deployment	• Attitude control thrusters	• Gravity gradient mass deployment
• Antenna deployment	• Instrument deployment	• Magnetometer deployment

Product Specifications	
• Dimensions: 101.5-inch-long x 9.5-inch diameter	• 1st Bending Mode: 3.5 Hz
• System Mass: <15 lb	• Bending Stiffness: 1.14 lb/in



Stowed K-truss Boom Deployed K-truss Boom Section

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DOCKING, BERTHING, AND HATCH SYSTEMS

Sierra Space solidified our docking and berthing technology by being a major subcontractor on the Orbital Express program, providing the system that captured and docked two spacecraft together on-orbit to allow for remote servicing such as refueling and replacement of outdated and expended components. We then leveraged this mechanical system experience into becoming the go-to supplier for the industry standard Passive Common Berthing Mechanism (PCBM), required for spacecraft such as the Orbital Cygnus Advanced Maneuvering Vehicle and the Bigelow Expandable Activity Module (BEAM) to berth with the International Space Station (ISS).

Catalog data sheets for our Docking and Berthing Systems technology area include:

Passive Common Berthing Mechanism (PCBM)

Sierra Space Hatches

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Passive Common Berthing Mechanism (PCBM)

Design Description

Sierra Space has become the go-to supplier for the Passive Common Berthing Mechanism (PCBM), an industry standard mechanical and structural interface required to berth commercial or government spacecraft safely and reliably to the International Space Station (ISS).

Our PCBM is a flight-proven system that allows alignment and environmental sealing between the ISS and pressurized vehicles. It is a fully passive assembly (active side permanently attached to the ISS) with minimal moving parts.

National Aeronautics and Space Administration (NASA) vetted and approved the PCBM for compliance to the strict human-rating standards and pedigree that is required for ISS applications. It has been fully tested to ensure compliance with functional performance and sealed interface requirements.

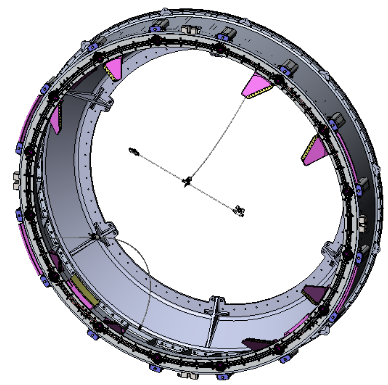
After delivery, we provide additional services to integrate the PCBM onto the vehicle and leak check the interface seals, as well as support NASA FE-1410 pressurized leak testing of the PCBM's Active Common Berthing Mechanism (ACBM) interface.

Passive Common Berthing Mechanism (PCBM).

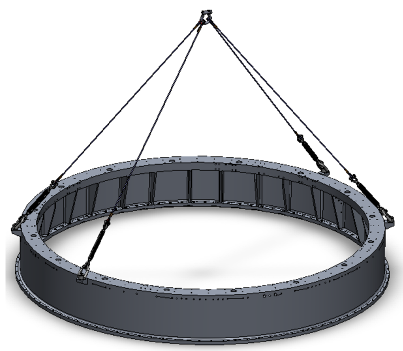
Docking, Berthing and Hatch Systems Features	
• Fully tested and verified powered bolt nut (PBN) assemblies, the main functional interface of the PCBM	• Alignment pin socket assemblies provide fine alignment and take shear loads between the PCBM and ACBM
• Thermal standoff assemblies maintain pre-load between the PCBM and the ACBM on the ISS	• Capture fittings provide an interface for the ACBM to grab and pull the PCBM to berth
• Skirt segment assemblies shield the PCBM from micrometeoroid debris	• Alignment guide assemblies provide gross alignment and clocking of the PCBM to the ACBM
• Positive grounding paths to main PCBM structure	

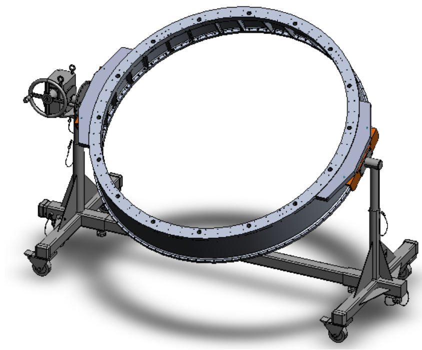
Applications
• Berthing to the ISS for commercial or government customer missions

Heritage Programs	
• Orbital ATK Cygnus Cargo Resupply Service (CRS)	• Cygnus OA-4 - OA-9E
• Cygnus CRS Orb-1 and Orb-2	• NG-10 thru NG-17
• Cygnus CRS Orb-3 (vehicle lost during launch)	• Bigelow Expandable Activity Module (BEAM)

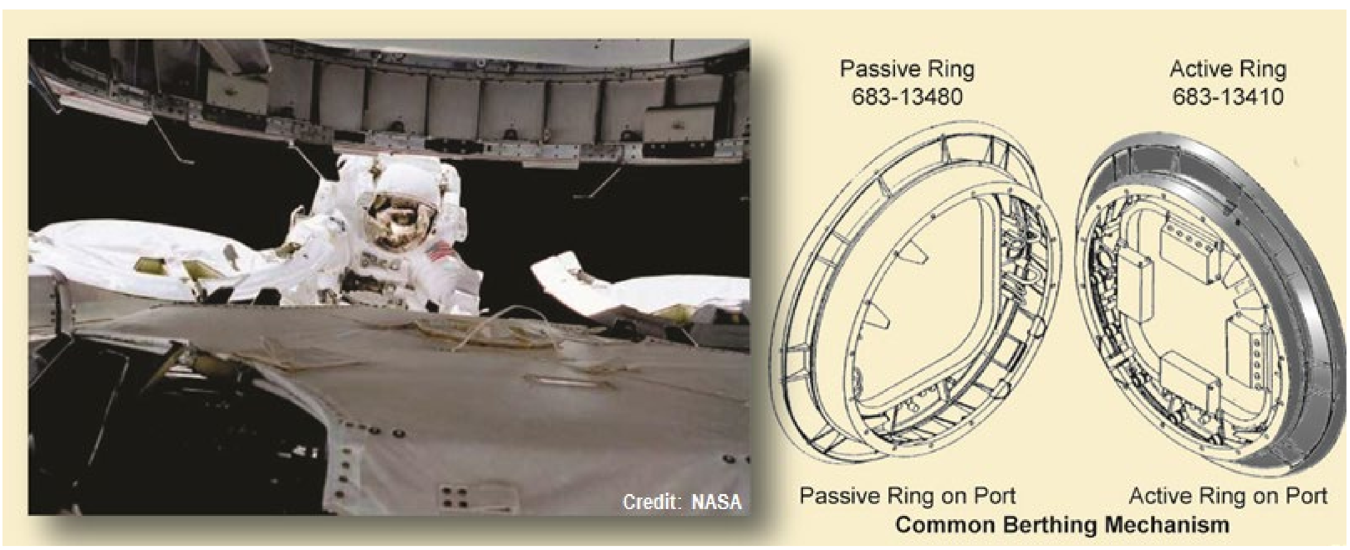


PCBM





PCBM Test Fixtures. PCBM lift fixture (shown above at left) used to move the ring during assembly, integration, and test (AI&T) and PCBM rotation fixture (shown at right).

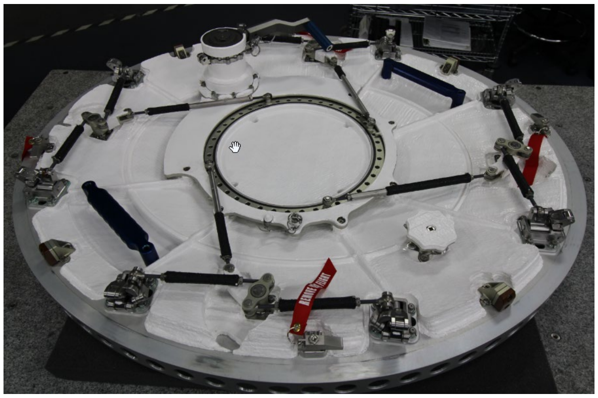


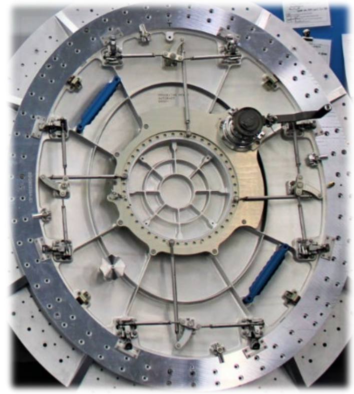
PCBM during in-flight mate with ACBM and drawing of Common Berthing Mechanism Subsystems.

Sierra Space Hatches

Design Description

Our hatches are designed for cost optimization as an elliptical shaped pressure hatch available with optional Thermal Protection System (TPS). The hatch can be either free floating or on rails for storage and is operable from one side.





Left photo is the Thermal Protected design and the right photo is the Non-Thermal Protected design.

Docking, Berthing and Hatch Systems Features	
• Two designs (Thermal Protected and Non-Thermal Protected)	• Either free floating or on rails for storage
• Single person operation	• Able to be closed within 2 minutes

Applications
• Docking space vehicles and stations

Product Specifications		
	U.S.	**SI**
Performance		
Maximum Outward Pressure	15.2 psid	
Maximum Gearbox (Opening) Torque	25 ft lbs	
Mechanical		
Mass (Thermal Protected and Non-Thermal Protected)	111.60 lbs/98 lbs	50.621 kg/44.452 kg
Major Diameter	46.018 in	1,168.867 mm
Minor Diameter	40.018 in	1,016.457 mm
Thickness	3.925 in	99.695 mm
Environmental		
Vibration (Thermal Protected and Non-Thermal Protected)	X (29.12/33.33 Grms) Y/Z (21/21 Grms)	
Maximum External Operating Temperature (Thermal Protected) Depending on the Number of Layers	800 °F Multiple Reentries 950 °F to 1,100 °F Single Reentry	427 °C Multiple Reentries 510 °C to 593 °C Single Reentry
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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ELECTRICAL POWER SYSTEMS

Sierra Space provides highly scalable power systems with power ranges from watts to multiple kilowatts. We offer end-to-end Electrical Power Systems (EPS) consisting of fully assembled and tested solar arrays, solar array drives, slip rings, hinges, hold down mechanisms, and motor control electronics. Our engineering teams have the expertise and experience to define, analyze, and test complete power systems using state-of-the-art tools and integration equipment. Our heritage and scalable power systems can be tailored to fit a wide variety of mission options with reduced cost and risk by incorporating existing qualified and flight-proven designs. Sierra Space has heritage EPS designs ranging from 28 V to 75 V, with power from 500 W to 3,500 W.

Industry-First Innovation – Surface Mount Technology (SMT) for Solar Array Construction

Sierra Space has developed an automated solar array manufacturing process using Surface Mount Technology (SMT) to significantly reduce the lead-time of space power. This patented technology enables an unprecedented improvement in watt density, reliability, and solar array lead-time. Our team of engineers, along with strategic industry partners, have developed an all-back-side-contact solar cell that enables solar array assembly through a standard commercial electronics manufacturing pick-and-place operation. This technology results in a zero-touch labor solution and a significant improvement in overall solar array performance.

The SMT solar technology has flight heritage and has been used on several missions to date.

Other Features of our SMT:

10% - 40% Increased Power Density

By using smaller cells and improved manufacturing techniques, the packing factor for both simple and complex solar array shapes improve significantly.

Panels can be optimized by placing cells closer together and reducing waste around panel mechanical interfaces.

Reduced Lead Time

Instead of using larger cells to reduce touch labor, our solution optimizes manufacturing using robotics, resulting in a zero-touch labor process. Using a "one-size-fits-all" solar cell strategy, Sierra Space can stock solar cells in large quantities to minimize design and manufacturing lead-time.

Lower Cost

Some power systems approach 50% of total satellite costs. With decreased design time, the ability to volume manufacture cells and human-free assembly, our SMT dramatically reduces solar array costs while increasing quality and reliability.

SMT Flight History

Maiden Flight

In 2017, the SMT became flight-proven onboard the Air Force Research Laboratory's (AFRL) Satellite for High Accuracy Radar Calibration (SHARC) mission. The 5U CubeSat solar array panel took 3 months from purchase order to delivery, with the pick-and-place process taking less than an hour. The functional testing for the SHARC panel included vibration testing, thermal cycling, large area pulsed solar simulator exposures, and numerous electrical verification tests.

The SMT solar array provided approximately 11 W of power to the SHARC spacecraft – 25% more power than a conventional array. The system showed no significant signs of degradation in performance throughout the mission life (~10 months).

Since the maiden flight, Sierra Space has delivered SMT solar arrays for several programs supporting geosynchronous Earth orbit (GEO), low Earth orbit (LEO), and Lunar Surface and all are performing as expected.

Catalog data sheets for our EPS technology area include:

Custom Applications

Deployable Rigid Solar Arrays

Surface Mount Technology (SMT) Flex

Surface Mount Technology Solar Panels

Surface Mount Technology (SMT) Solar Panels - Lunar Applications

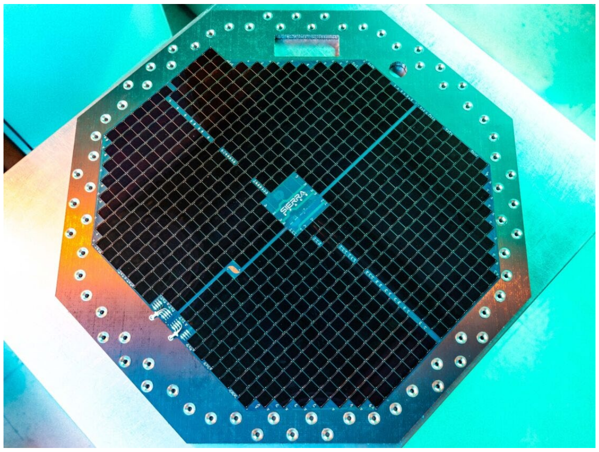
Custom Applications

Design Description

Sierra Space's custom solar applications leverage multiple in-house capabilities, including automated Surface Mount Technology (SMT) solar panels, composite substrate manufacturing, and mechanisms expertise. Our SMT approach to manufacturing of the solar power modules and panels offers significant flexibility and scaling options for solar power module and panel sizes, geometric shapes, electrical lay-out (sectioning and stringing), and bus voltages.

Our high efficiency Gallium Arsenide (GaAs), MWT (Metallized Wrap Through) "micro-cells" are designed to be robotically picked and placed onto an engineered printed circuit board (PCB), leveraging commercial electronics industry methods for very fast, high-volume production rates.

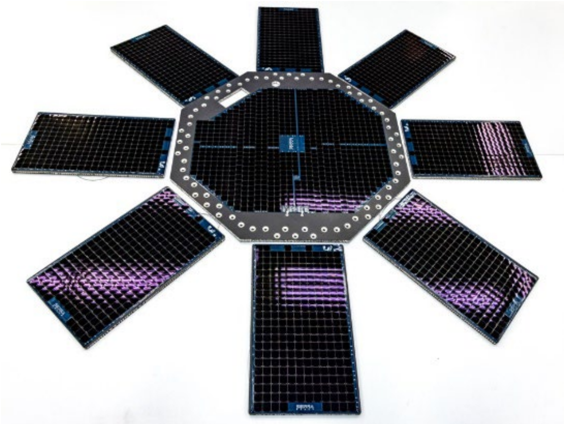
Sierra Space also manufactures rigid composite substrates in-house and leverages more than 35 years of spacecraft mechanisms expertise to offer our customers solutions to meet any custom need.



Sierra Space's custom solutions leverage multiple in-house capabilities, including our automated SMT solar panels, composite substrate manufacturing, and mechanisms expertise.

Custom Features	
• Build on a foundation of flight-proven technology reducing nonrecurring engineering (NRE) cost	• Solar power modules and panels produced in days or weeks, not months
• Solar power modules use SMT, high-efficiency GaAs micro-cells	• Significant flexibility and scaling of panel sizes, shapes, electrical lay-out (sectioning and stringing), and bus voltages
• In-house mechanisms including Solar Array Drive Assemblies (SADA), Solar Array Drive Electronics (SADE), beta axis mechanisms, Hold Down Release Mechanisms (HDRM), hinges and deployment booms	• SMT micro-cells provide packing densities >95%, increasing power generation per area by 10-40% depending on the geometry

Custom Example



Note: Custom panels shown as an example. Large range of sizes and power levels are available.

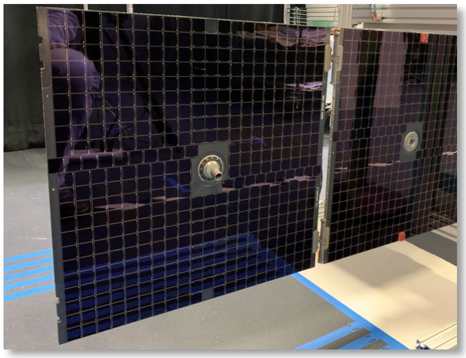
Deployable Rigid Solar Arrays

Design Description

Sierra Space's turnkey, bolt-on rigid solar arrays leverage multiple in-house capabilities, including automated Surface Mount Technology (SMT) solar panels, composite substrate manufacturing, and mechanisms expertise. Our SMT approach to manufacturing of the solar power modules and panels offers significant flexibility and scaling options for solar power module and panel sizes, geometric shapes, electrical lay-out (sectioning and stringing), and bus voltages.

Our high efficiency Gallium Arsenide (GaAs), MWT (Metallized Wrap Through) "micro-cells" are designed to be robotically picked and placed onto an engineered printed circuit board, leveraging commercial electronics industry methods for very fast, high-volume production rates.

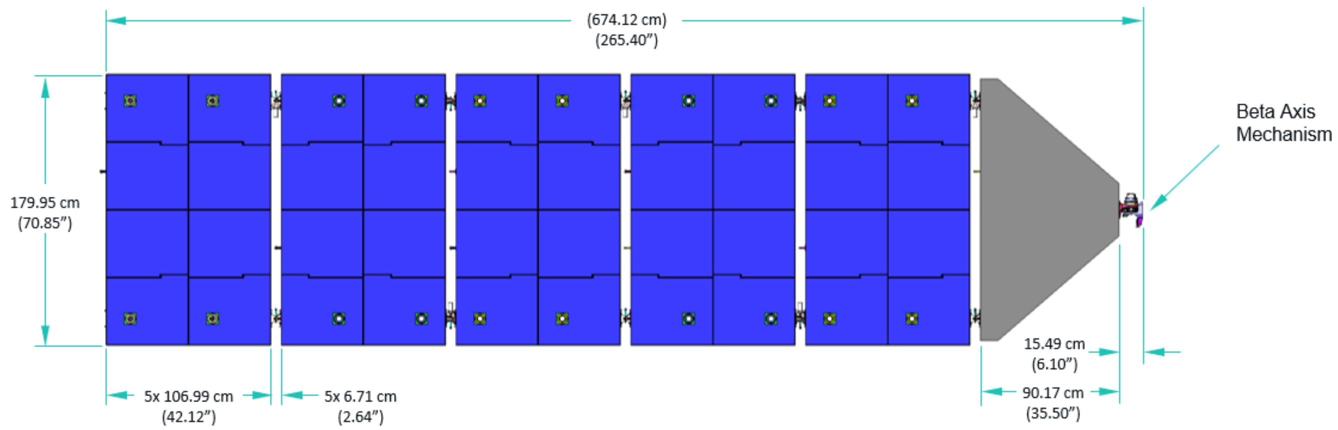
Sierra Space also manufactures rigid composite substrates in-house and leverages more than 35 years of spacecraft mechanisms expertise to offer our customers a bolt-on, turnkey solution.



Sierra Space's turnkey, bolt-on rigid solar arrays leverage multiple in-house capabilities, including our automated SMT solar panels, composite substrate manufacturing, and mechanisms expertise.

Deployable Rigid Solar Array Features	
• Turn-key bolt-on solar array	• Solar power modules and panels produced in days or weeks, not months
• Solar power modules use SMT, high efficiency GaAs micro-cells	• Significant flexibility and scaling of panel sizes, shapes, electrical lay-out (sectioning and stringing), and bus voltages
• In-house mechanisms including Solar Array Drive Assemblies (SADA), Solar Array Drive Electronics (SADE), beta axis mechanisms, Hold Down Release Mechanisms (HDRM), hinges and deployment booms	• SMT micro-cells provide packing densities >95%, increasing power generation per area by 10-40% depending on the geometry

Dimensions



Note: 3.2 kW wing shown as an example. Large range of sizes and power levels are available.

Surface Mount Technology (SMT) Flex

Design Description

Sierra Space's SMT Flex applications leverage multiple in-house capabilities, including automated SMT solar panels, composite substrate manufacturing, and mechanisms expertise. Our SMT approach to manufacturing of the solar power modules and panels offers significant flexibility and scaling options for solar power module and panel sizes, geometric shapes, electrical lay-out (sectioning and stringing), and bus voltages.

Like our standard solar panels, SMT flex uses our flight-proven Gallium Arsenide (GaAs) cells.

Our high-efficiency GaAs, MWT (Metallized Wrap Through) "micro-cells" are designed to be robotically picked and placed onto an engineered printed circuit board, leveraging commercial electronics industry methods for very fast, high-volume production rates.

The integrated solution of small micro-cells and flex printed circuit board (PCB) can be used to create a lightweight flexible solution ideal for roll out solar array products. With the ability to be successfully rolled onto a 4-inch diameter mandrel. This technology supports a wide range of non-standard and roll out applications.

Sierra Space's SMT Flex solutions can be applied to mandrel diameters as small as 4 inches.

SMT Flex is ideal for systems needing high-power production and can be applied to a variety of environments including low Earth orbit (LEO) and lunar.

SMT Flex Features	
• Build on a foundation of flight-proven technology reducing nonrecurring engineering (NRE) cost	• Solar power modules and panels produced in days or weeks, not months
• Solar power modules use SMT, high-efficiency GaAs micro-cells	• Significant flexibility and scaling of panel sizes, shapes, electrical lay-out (sectioning and stringing), and bus voltages
• In-house mechanisms including Solar Array Drive Assemblies (SADA), Solar Array Drive Electronics (SADE), beta axis mechanisms, Hold Down Release Mechanisms (HDRM), hinges and deployment booms	• SMT micro-cells provide packing densities >95%, increasing power generation per area by 10-40% depending on the geometry
• Supports high-power producing system	• Supports multiple deployment and stow systems
• Supports as small as 4-inch diameter mandrel	• Ideal for roll out array solutions
• Metallized polyimide	• Industry standard flexible circuit

Surface Mount Technology (SMT) Solar Panels

Design Description

Sierra Space offers a game-changing approach to spacecraft solar panel manufacturing using Surface Mount Technology (SMT). By using surface mount capable cells (high efficiency, triple junction, all-back contact), our panels are assembled by commercial electronics standard pick and place technology. This offers significant system advantages compared to conventional solar panels and arrays:

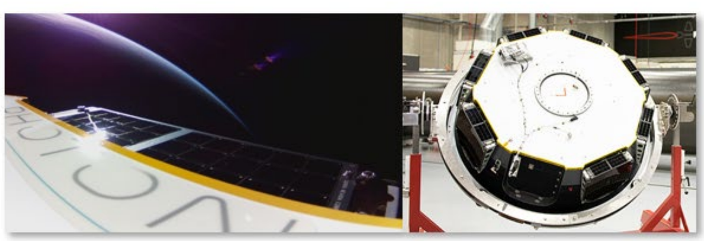
- Higher Power Density (10%-40% increase)
- Lower Cost (>20% savings)
- Fraction of lead time (from 18 months down to 6 months or faster)
- Higher Reliability (through automation and resilience)
- Cell stringing and wiring are integrated into the printed circuit board (PCB) representing a significant reduction in labor
- Ideal for High Volume Manufacturing (1 watt/min)

Sierra Space's SMT solar panels leverage multiple in-house capabilities, including our automated SMT solar power modules, and composite substrate manufacturing.

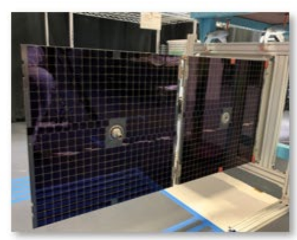
Surface Mount Technology Solar Panel Features	
• High efficiency triple junction micro-cells	• Significant flexibility and scaling of panel sizes, shapes, electrical lay-out (sectioning and stringing), and bus voltages
• Power modules and panels produced in days or weeks, not months	• SMT micro-cells provide packing densities >95%, increasing power generation per area by 10-40% depending on the geometry
• Ideal for high-volume manufacturing	• Turn-key solar arrays with mechanisms also available

Application Examples

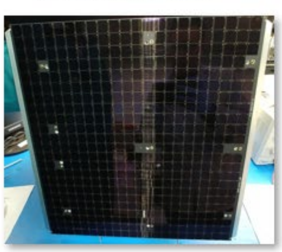
AFRL SHARC
Launched March - 2017



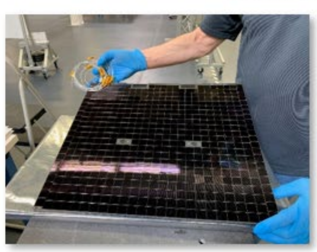
1 Year Demo Mission – 220 W
Launched Q3/2020



LEO Mission – 240 W
Launched Q2/2021

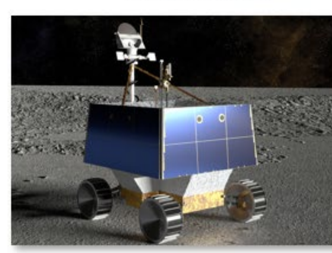


Total Power: 130 W (GEO)
Launched 2021



Total Power: 150 W (GEO)
Launched 2021

Total Power: 750 W
Launched Dec. 2023
(Solar Panels Performed Above Predict prior to Failure of Lunar Landing)



Delivery: Q2/2023
Total Power: 1,500 W
Lunar Lander Launch: 2024

Note: Multiple flight program examples shown. Large range of sizes and power levels are available.

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Surface Mount Technology (SMT) Solar Panels - Lunar Applications

Design Description

Sierra Space's Surface Mount Technology (SMT) solar panels have now been qualified for and flown on lunar surface missions. Our SMT technology was selected by NASA for the Lunar Volatiles Investigating Polar Exploration Rover (VIPER). As part of this program, Sierra Space's SMT panels (see figure to the right) were qualified for survival in extreme cold temperatures (-240 °C) and a 400-degree thermal range (-240 °C to +160 °C).

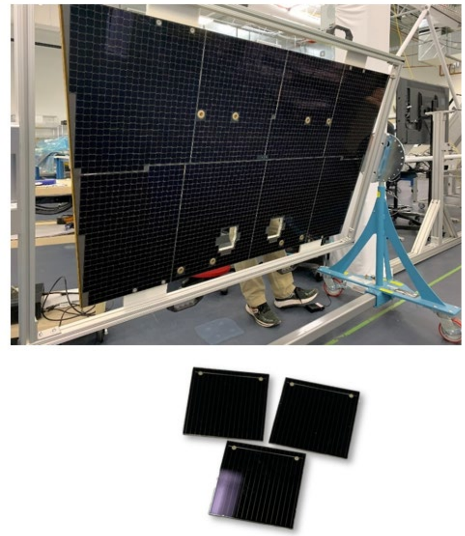

Image shows one of the flight solar panels for NASA's lunar VIPER rover mission.

This game-changing approach to solar panel manufacturing powers current and future robotic and human missions to the moon with increased power performance and system resiliency.

By using smaller surface mount solar cells (high efficiency, triple junction, all-back contact), our panels are assembled by commercial electronics standard pick and place technology. This offers significant system advantages compared to conventional solar panels and arrays:

- ✓ Higher Power Density (10%-40% increase)
- ✓ Lower Cost (>20% savings)
- ✓ Fraction of lead time (from 18 months down to 6 months or faster)
- ✓ Higher Reliability (through automation and resilience)
- ✓ Cell stringing and wiring are integrated into the PCB representing a significant reduction in labor
- ✓ Ideal for High Volume Manufacturing (1 watt/min)

Surface Mount Technology Solar Panel Features	
• High efficiency triple junction micro-cells	• Significant flexibility and scaling of panel sizes, shapes, electrical lay-out (sectioning and stringing), and bus voltages
• Power modules and panels produced in days/weeks, not months	• SMT micro-cells provide packing densities >95%, increasing power generation per area by 10-40% depending on the geometry
• Ideal for high volume manufacturing	• Turn-key solar arrays with mechanisms also available

Lunar Application Examples

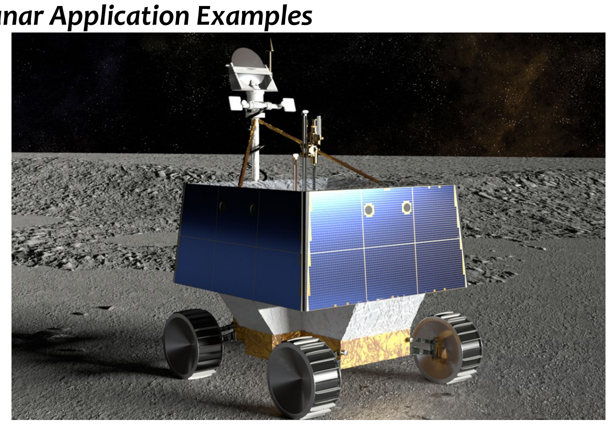

Image shows a computer-aided design (CAD) rendering of the Sierra Space SMT solar panels on the NASA Lunar Volatiles Investigating Polar Exploration Rover (VIPER).

Image shows Sierra Space SMT solar panels on the I-Space HAKUTO-R M1 Lander. Credit Space-X

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ENVIRONMENTAL CONTROL AND LIFE SUPPORT

ADVANCED LIFE SUPPORT SYSTEMS

Sierra Space is engaged in ongoing development of advanced life support systems. Emphasis on automation, ease of use and low maintenance make these systems ideal for use in manned and lunar missions. We incorporate reliability, scalability, and flexibility into our designs.

Catalog data sheets for our Advanced Life Support Systems technology area include:

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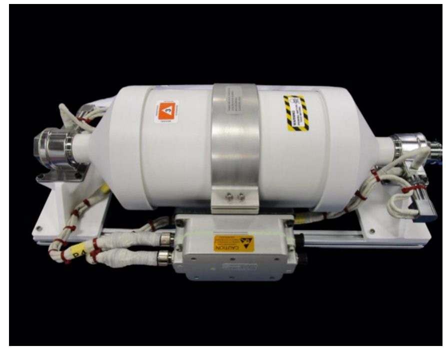
Carbon Dioxide (CO_2) Removal Package

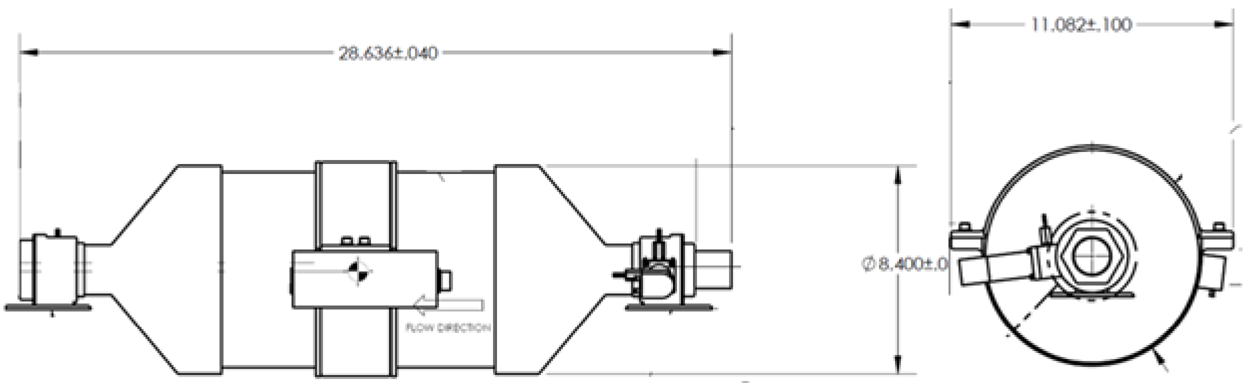
Design Description



CO_2 Removal Assembly

Sierra Space has designed and flight-qualified the CO_2 Removal Package to complement our Environmental Control and Life Support System (ECLSS) product line. The CO_2 removal package uses lithium hydroxide (LiOH) cartridges to convert CO_2 to lithium -carbonate (Li_2CO_3) and water vapor when installed into a pressurized ductwork system. The LiOH is non-regenerable but features a removable LiOH cartridge that is enclosed by filters to contain all LiOH dust. This feature enables a smooth cartridge change, without the risk of floating LiOH dust.

The isolation ball valves are actuated via brushless DC motors with a remote controller. Options include open/close or throttling control via an externally provided analog signal. This assembly is built in cleanrooms and is designed to operate within systems that require high levels of cleanliness. The valves provide position feedback and are intended to isolate the LiOH during flight phases when it is not required.



Note: All dimensions are in inches.

Carbon Dioxide (CO_2) Removal Package Features	
• Replaceable LiOH cartridge	• Low air pressure resistance
• Filter Encapsulated – LiOH Beds	• Band-clamp interfaces

Applications
• Atmospheric revitalization

Product Specifications		
	U.S.	**SI**
Mechanical		
Package Mass	35.5 lbm	16.1 kg
Mass of CO_2 Processing Capability	5.95 lbm	2.69 kg
Pressure Loss at Design Airflow Rate	1.8 inwc @ 5 CFM	448 pA @ 2.4 L/s
Electrical		
Maximum Power @ 28 Vdc	40 Watts	
Voltage Range	22-36 Vdc	
Environmental		
Vibration	20 Grms	
Shock: Qualified to	500 G	
Operating Temperature Range	58 to 93 °F	14 to 34 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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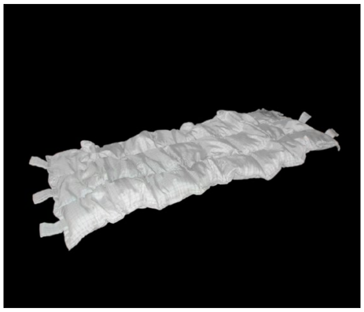
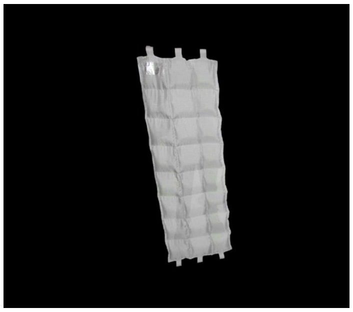
Desiccant Package

Design Description

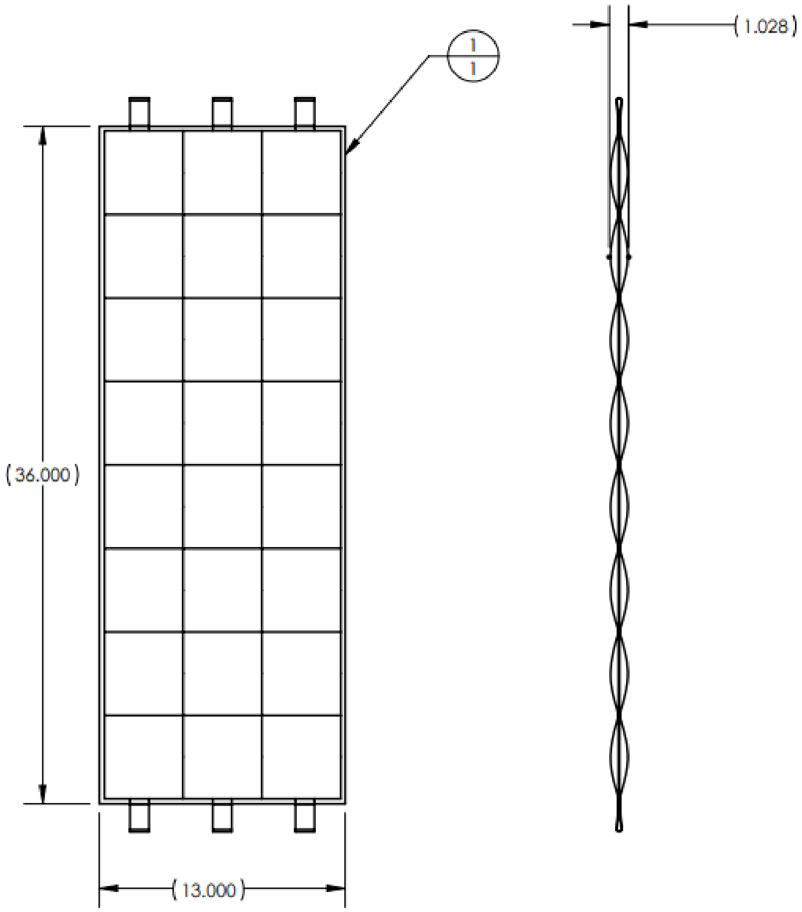
The Desiccant Package is a flight-qualified product that can deliver a fully passive humidity control system and can be fit for need for a variety of spacecraft volumes. The package uses safe, spaceflight approved materials and passes NASA toxicity, off-gassing, and flammability requirements. Applications might include pre-launch humidity control of spacecraft, payload transport to ISS, live cargo transport, or shipping sensitive equipment between facilities.

Desiccant Package

Desiccant Package Features	
• Passive Humidity Control	• Non-Toxic
• Customizable Form Factors - Fit for Need	• Non-Flammable
• Safe, Flight-Qualified Materials	

Dimensions



Note: All dimensions above are in inches

Product Specifications		
	U.S.	**SI**
Performance		
Controls humidity to above 25% relative humidity (RH) and below a 50 °F dewpoint for over 24 hours		
Mechanical		
Package loops support a wide range of mounting options		
Mass is variable depending on application		
Environmental		
Vibration	4.8 Grms	
Shock	500 G @ 10 kHz	
Temperature	37 to 113 °F	2.8 to 45 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

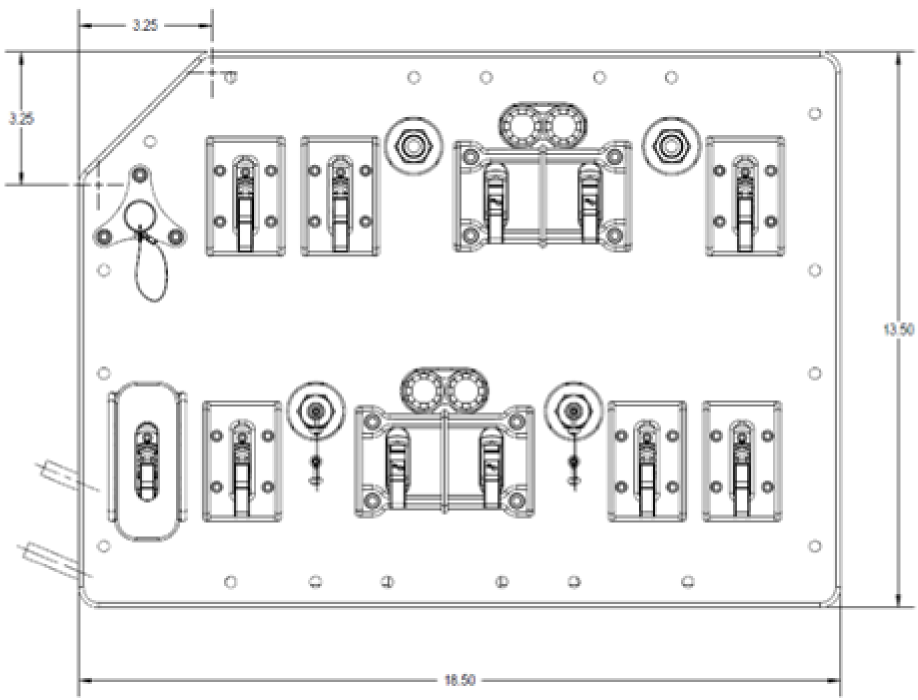
Dual Gas Flow and Regulation Panel Assembly

Design Description

Sierra Space designed and qualified a Dual Gas Flow and Regulation Panel Assembly for the control and pressure regulation of two gases. The panel assembly consists of several components mounted to a panel and joined by stainless steel tubing, welded together behind the panel. The functionality of the panel includes redundant, low-pressure regulation of two gases, a metered port through an orifice, and quick-disconnect connections. There are multiple manual toggle shut-off switches for fluid control.

Panel Assembly with dual, regulated gas exhaust and manual valves for fluid control.

The panel assembly comprises four low-pressure regulators (two for each gas) that exhaust to the front vents, seven manual toggle isolation valves, a quick-disconnect port, two input ports, and three exhaust ports. This assembly is built in cleanrooms and is designed to operate within systems that require high levels of cleanliness.



Note: All dimensions above are in inches.

Dual Gas Flow and Regulation Panel Assembly Features	
• Mounted on aluminum flat panel	• Low pressure regulation (~ambient)
• Two gas input ports	• Gas isolation and control
• Three exhaust ports	• Noise attenuation
• Four exhaust vents through regulators	• Quick-disconnect port

Applications
• Regulation and pressurization of two gases. Panel assembly with dual, regulated gas exhaust and manual valves for fluid control.

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	28 lbm	12.7 kg
Component		
Low Pressure Regulator #1	Qty 2, Primary Fluid: Dry Nitrox Input Pressure <200 psi, Regulated Pressure 8-10 psia	
Low Pressure Regulator #2	Qty 2, Primary Fluid: Oxygen Input Pressure <200 psi, Regulated Pressure 14-15 psia	
Manual Isolation Valves	Qty 7, Toggle-style, maximum design pressure of 220 psi	
Gas Port	Qty 1, Primary Fluid: Oxygen, maximum design pressure of 220 psia	
Environmental		
Vibration: Qualified to	9.9 Grms	
Shock: Qualified to	1,300 G	
Operating Temperature Range	40 to 120 °F	4 to 49 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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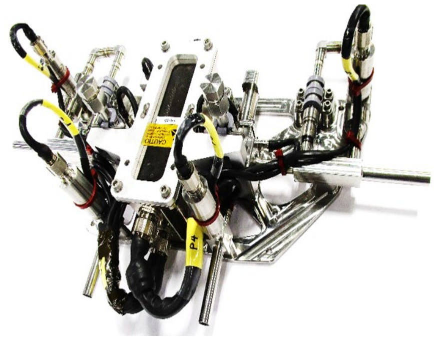
Dual Loop Temperature Control Valve (TCV) Package

Design Description

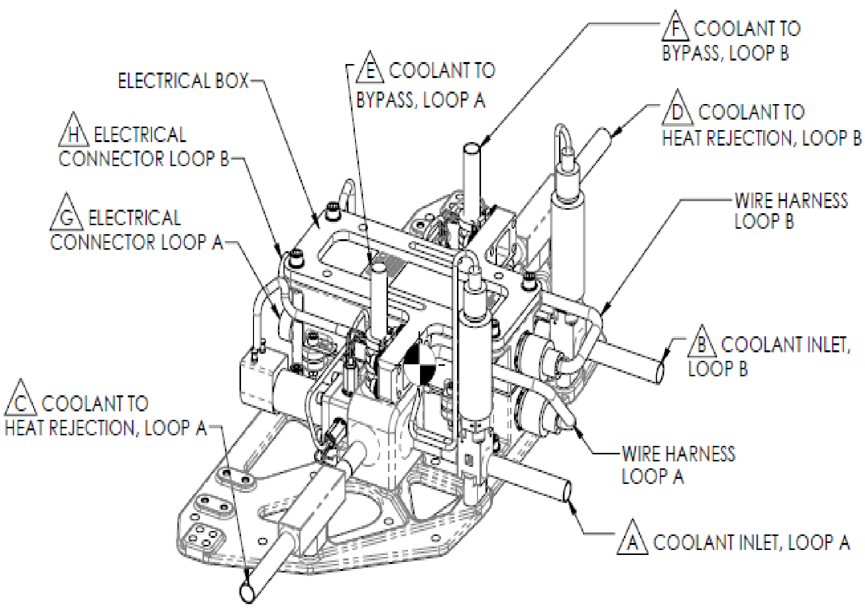
Sierra Space's Dual Loop Temperature Control Valve (TCV) Package is a flight-certified package containing two 3-way ball valves, pressure sensors, temperature sensors, driver boards, and motors. This package is designed to accommodate Thermal Control Systems (TCS) with redundant loops. The TCV Package is used to control the temperature of the coolant in a TCV loop. The TCV Package measures the temperature and pressure of coolant entering the TCV and the 3-way ball valve proportionally controls the amount of flow to the heat rejection leg or bypass leg of the TCS loop.



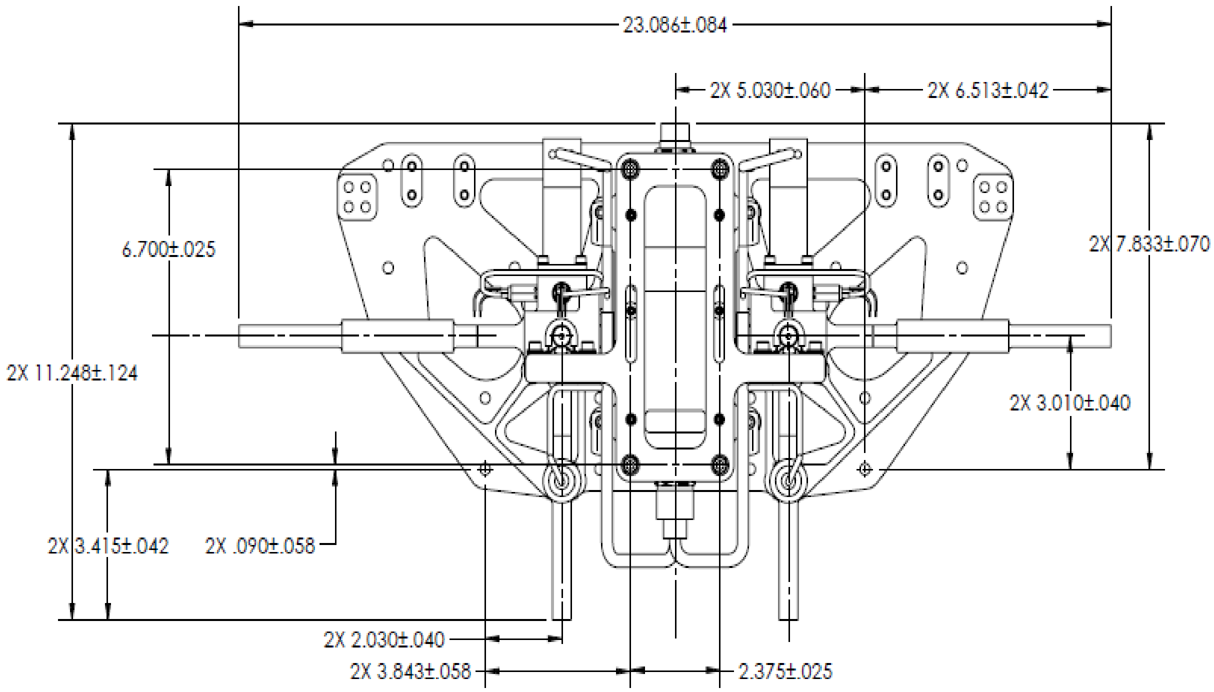
Dual Loop Temperature Control Valve (TCV) Package

Dual Loop TCV Package Features	
• Customizable ball geometry and flow profile	• End of travel indication
• Scales to meet a variety of flow rates	• EEE components are radiation hard and suitable for deep space
• Compatible with a variety of coolants	• Designed for dual loop cooling systems

Dimensions



FLUID INTERFACE		
PORT	FLOW CONDITION	FITMENT
A	COOLANT INLET, LOOP A	Ø0.500±0.003 OD X 0.028±0.0028 WALL NITRONIC 40 WELDMENT TUBE STUB
B	COOLANT INLET, LOOP B	Ø0.500±0.003 OD X 0.028±0.0028 WALL NITRONIC 40 WELDMENT TUBE STUB
C	COOLANT OUTLET TO HEAT REJECTION, LOOP A	Ø0.500±0.003 OD X 0.028±0.0028 WALL NITRONIC 40 WELDMENT TUBE STUB
D	COOLANT OUTLET TO HEAT REJECTION, LOOP B	Ø0.500±0.003 OD X 0.028±0.0028 WALL NITRONIC 40 WELDMENT TUBE STUB
E	COOLANT OUTLET TO BYPASS, LOOP A	Ø0.500±0.003 OD X 0.028±0.0028 WALL NITRONIC 40 WELDMENT TUBE STUB
F	COOLANT OUTLET TO BYPASS, LOOP B	Ø0.500±0.003 OD X 0.028±0.0028 WALL NITRONIC 40 WELDMENT TUBE STUB



Note: All dimensions above are in inches

Product Specifications		
	U.S.	**SI**
Performance		
Pressure Drop (primary)	<2.0 psid @ 500 lbm/hr PGW Full open primary direction	<13.8 kPad @ 0.063 kg/s PGW Full open primary direction
Pressure Drop (bypass)	<8.5psid @ 500 lbm/hr PGW Full open bypass direction with primary blocked	<58.6 kPad @ 0.063 kg/s PGW Full open bypass direction with primary blocked
External Leakage	<1.9e-4 ssc/s GHe @ 85 psid Zero liquid leakage	
Mechanical		
Mass	≤22 lbm	≤10 kg
Maximum Design Pressure	150 psid	1,034.3 kPad
Proof Pressure	225 psid	1,551.4 kPad
Burst Pressure	375 psid	2,585.6 kPad
Electrical		
Maximum Power Consumption	20 W while actuating	
Voltage Range	22-32 Vdc	
Environmental		
Vibration: Qualified to	X-Axis: 15.09 Grms, Y-Axis: 44.2 Grms, Z-Axis: 21.61 Grms	
Shock: Qualified to	120 G (100 Hz), 1,560 G (740 Hz), 1,560 G (10,000 Hz)	
Operating Temperature	50 - 117 °F	10 to 47.2 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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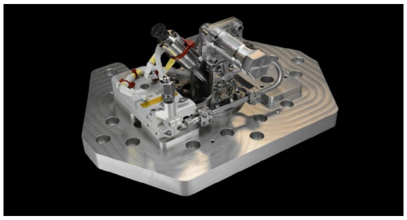
Gas Delivery Assembly (GDA)

Design Description



Gas Delivery Assembly (GDA) - Oxygen Configuration installed on a Test Plate

The Gas Delivery Assembly (GDA) is a flight-qualified product that can deliver nitrox or oxygen gas from a high-pressure gas source to an atmospheric pressure environment. The GDA also allows fill and drain of the gas source through a manual fill/drain valve and includes pressure measurements with a pressure transducer.

The GDA - Oxygen configuration contains redundant solenoid isolation valves to prevent accidental oxygen release. The GDA's high-pressure gas source interface is designed to mate with a tube stub and O-rings. The system's maximum structural design pressure is 4,600 psia and a maximum oxygen compatibility pressure of 3,000 psia.

Gas Delivery Assembly (GDA) Features	
• Delivers nitrox/oxygen gas from a high-pressure source to an ambient environment	• Oxygen compatible configuration
• Manual fill/drain capabilities	• Oxygen configuration includes redundant solenoid isolation valve

Product Specifications		
	U.S.	**SI**
Performance		
Nitrox Nominal Flowrates	0.03 lbm/hr @ 150 psia 2.01 lbm/hr @ 4,600 psia	
Oxygen Nominal Flowrates	0.03 lbm/hr @ 150 psia 1.33 lbm/hr @ 3,000 psia	
Sensor Accuracy	± 45 psi	
Mechanical		
Mass	5.5 lbm	2.5 kg
Max Design Pressure	4,600 psia	31,717 kPa
Max Oxygen Compatibility Pressure	3,000 psia	20,685 kPa
Electrical		
Latching Solenoid Performance	12 W @ 32 Vdc for <1 sec	
Pressure Transducer	<0.2 W continuous	
Environmental		
Vibration	18 Grms	
Shock	500 G @ 10 kHz	
Operational Temperature Range	55 to 96 °F	12.8 to 35.6 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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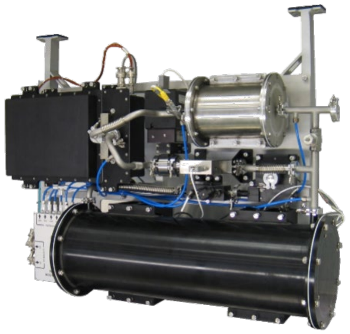
Gaseous Trace Contaminant Removal (GTCR) System

Design Description

Sierra Space's Gaseous Trace Contaminant Removal (GTCR) system removes trace amounts of harmful and/or unpleasant gases from the system environment. The primary purpose is to remove Volatile Organic Compounds (VOC) below concentrations in accordance with SSP 20584, *Spacecraft Maximum Allowable Concentrations (SMAC) for Airborne Contaminants*. The GTCR does this by using a combination of granular filter beds and a catalytic oxidation bed. The granular filter beds contain a blend of activated charcoals that absorb contaminants. The catalytic oxidizer bed contains multiple reactors with catalyst that are heated, which break down lower molecular weight contaminants and converts them into known gases such as carbon dioxide and water vapor.



GTCR Engineering Demonstration Unit

GTCR System Features	
• Variable speed fan	• Under-speed and overheat fault detection
• Variable temperature oxidizer bed	• Scalable based on longevity need
• Fully automated	• Ethernet-based controller

Single Pass Efficiencies		
Compound	**Loading**	**S-P Removal Efficiency**
Ammonia (NH_4)	2x ISS	70%
Carbon Monoxide (CO)	30x ISS	82%
Methane (CH_4)	1x ISS	35%
Acetone	1x ISS	98%
Dichloromethane	1x ISS	75%
Ethanol	1x ISS	99%
Toluene	1x ISS	97%

Applications	
• Atmospheric scrubbing for trace gases	• Removal of Volatile Organic Compounds (VOC)
• Removal of airborne contaminants	

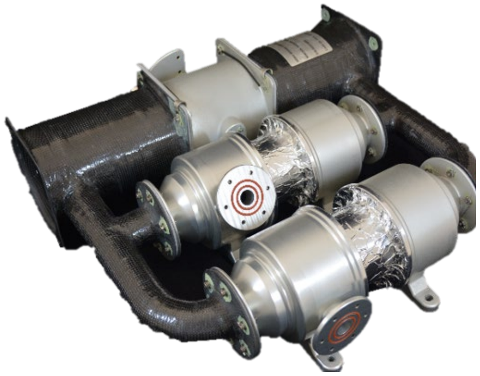
Product Specifications		
Engineering Development Unit (EDU) sized for 3 crew, 6 mT hardware, 5 yrs	**U.S.**	**SI**
Performance		
Air Flow Rate	1.5-5.5 CFM	
Single-Pass Efficiency	30-99% low molecular weight, 95-99% mid- to high-molecular weight	
Catalytic Oxidizer Temperature, Maximum	750 °F	400 °C
Mechanical		
Mass	198 lbm	10.7 kg
Volume	6 ft^3	0.17 m^3
Electrical		
Steady State Power (Nominal)	175 Watts @ 28 Vdc	
Voltage Range	22-32 Vdc	
Environmental		
Vibration	12 Grms	
External Operating Temperature Range	40 to 120 °F	4 to 49 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Humidity Removal Package (HRP)

Design Description

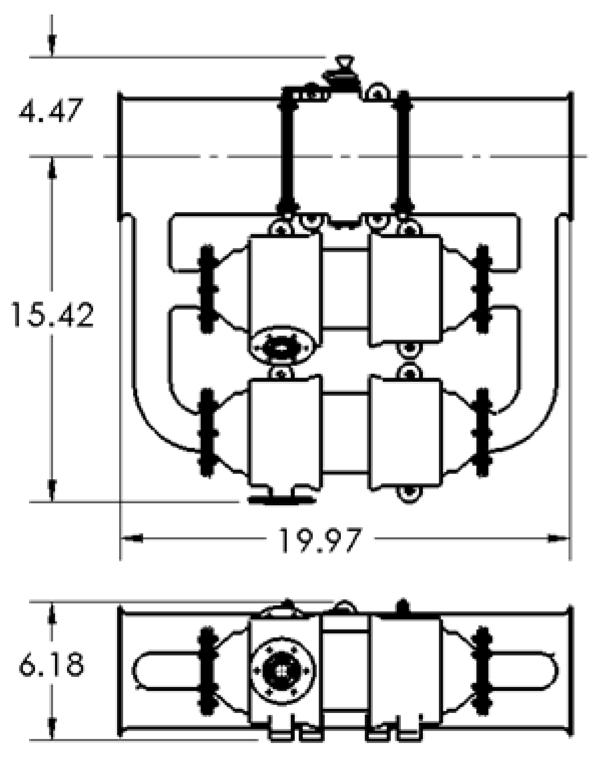
Sierra Space designed and flight-qualified a Humidity Removal Package (HRP) to complement its atmospheric revitalization line. The system can operate continuously without electronical power. The humidity removal package also contains a bypass line that can be opened by crew to minimize the pressure drop of the hardware when it is not in use.

The hardware has high reliability due to the lack of moving parts while removing humidity from the atmosphere. Reliability is further increased through the inclusion of two redundant flow paths and redundant sets of humidity removal media. The technology used in the humidity removal package is easily scaled to meet a variety of customer size and application requirements.



Humidity Removal Package (HRP)

Humidity Removal Package (HRP) Features	
• No electrical power required	• Lightweight aluminum and composite construction
• Adjustable pressure drop	• Low pressure drop
• Can be operated with one hand	• Built in redundancy
• No regeneration required	• High reliability



Note: All dimensions above are in inches.

Applications	
• Humidity removal in manned stations and outposts	• Atmospheric revitalization

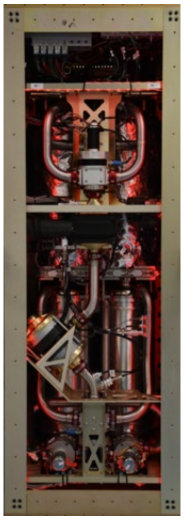
Product Specifications		
	U.S.	**SI**
Performance		
Continuous Humidity Removal Capacity	0.129 lbm/hr @ 250 CFM and 50 °F dew point	
Mechanical		
Mass	13.2 lbm	6.0 kg
Environmental		
Vibration: Qualified to:	9 Grms	
Shock: Qualified to	180 G	
Operating Temperature Range	60 to 102 °F	16 to 39 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Regenerable Carbon Dioxide Removal Assembly (RCRA)

Design Description

Sierra Space's Regenerable Carbon Dioxide Removal Assembly(RCRA) is designed to remove CO_2 continuously from space environments. The RCRA uses zeolite as the sorbent material to scrub carbon dioxide from the airstream flowing through one of its two granular packed beds and hardware to provide a toxin-free, breathable atmosphere.

The RCRA is a self-contained system, requiring no planned maintenance to operate. It provides its own air movement via a blower, CO_2 and humidity removal beds, air-save pump, valves, heat exchanger, controller, and sensors.



The RCRS uses zeolite to scrub CO_2 from the atmosphere.

Regenerable Carbon Dioxide Removal Assembly (RCRA) Features	
• Four-bed design, leveraging extensive process history and lessons learned from CDRA and 4BCO2	• System capable of full air-save and CO_2 capture for CO_2 reuse
• Air-save operation reduces air lost to space vacuum	

Applications
• Continuous maintenance of atmospheric conditions

Product Specifications		
Sized for 4 crew, 2 mmHg inlet CO_2 concentrations	**U.S.**	**SI**
Performance		
Air Flow Rate	Up to 36 CFM	
CO_2 Scrubbing Capacity	~4.8 kg/day @ 27 CFM and 2 mmHg CO_2 input	
Bed Heater Operation, Maximum Temperature	450 °F	230 °C
Mechanical		
Mass	462 lbm	210 kg
Volume	28 in x 20 in x 64 in	
Electrical		
Steady State Power (Nominal)	1,004 Watts @ 120 Vdc	
Voltage Range	120 Vdc and 28 Vdc inputs	
Data	Ethernet (dual connections)	
Environmental		
Tailored to specific launch requirements		
External Operating Temperature Range	40 to 120 °F	4 to 49 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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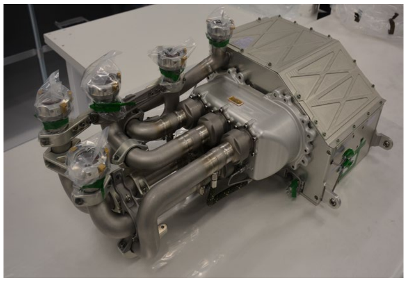
Spacesuit Manifold

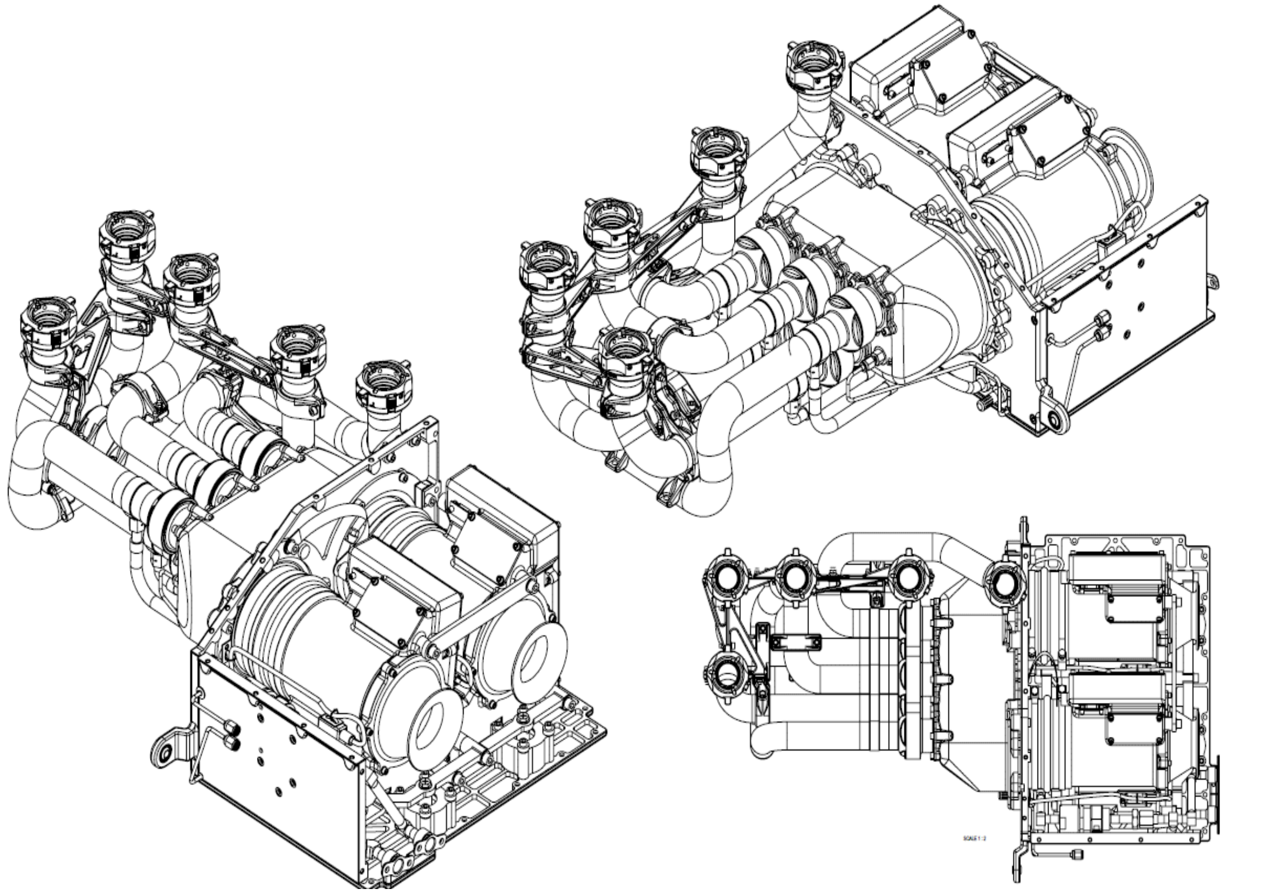
Design Description

The flight-proven Spacesuit Manifold manages the air supply to intravehicular spacesuits from the atmosphere revitalization system or pressure control system. The manifold can distribute air to up to five spacesuits to provide oxygen (O_2) supply, carbon dioxide (CO_2) washout, and cooling. A series of check valves and filters within the manifold ensure air is delivered to each spacesuit and remains balanced between each suit. The airflow from the Spacesuit Manifold is driven through the system by a set of fans; there are no other moving parts within the manifold. Equal flow is provided to all crew whether a suit is "visor up" and regardless of ambient pressure. There are two subsystems within the Spacesuit Manifold, one to circulate cabin air to each suit and one to provide O_2 or nitrox in off-nominal situations.



Spacesuit Manifold

Dimensions



Spacesuit Manifold Features	
• Manage airflow and contingency gas for up to five crew	• Provides flow adequate for oro-nasal washout as well as cooling for the body
• Provides breathable air, nitrox, or O_2	• TRL 9

Product Specifications		
	U.S.	SI
Performance		
Airflow from Air Revitalization System (ARS) (Cabin)	≥7 ACFM (14.9 psia ambient) at each suit interface	
O_2 Flow Rate	≥6.5 ACFM (evacuated cabin) at each suit interface	
Nitrox Flow Rate	≥3.2 ACFM (14.9 psia ambient) at each suit interface	
Mechanical		
Package Mass	≤43 lbm	≤19.5 kg
Maximum Design Pressure	Varies based on components within manifold	
Electrical		
Maximum Power	135 W	
Voltage Range	22-37 Vdc	
Environmental		
Vibration: Qualified to	X-Axis: 4.5 Grms, Y-Axis: 4.5 Grms, Z-Axis: 4.5 Grms	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

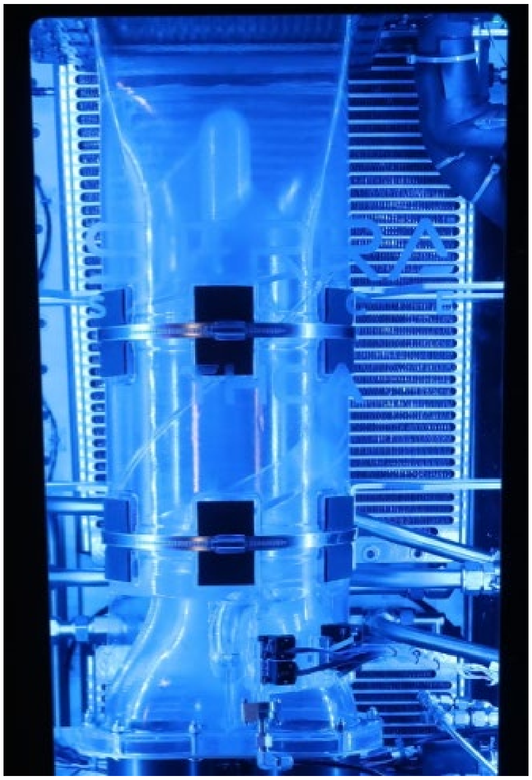
Water Capture Device (WCD)

Design Description

Sierra Space developed the Water Capture Device (WCD) to provide reliable microgravity gas/liquid separation. The separation uses patented technology to separate 2-phase flow into two process separation streams, which results in less system power and maintenance than traditional separation systems. This technology has been successfully demonstrated on multiple parabolic flights and the flight WCD system is currently being tested at NASA as it prepares to be delivered to the ISS as a technology demonstrator. The WCD technology is fully scalable to fit small low-flow systems up to condensate recovery for large habitable volume.

WCD Features
• Contact for additional details
• Specifications are dependent on application

Applications
• Condensation recovery
• Gas/liquid separation



Water Capture Device (WCD) being tested on parabolic flight

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	TBD lbm	TBD kg
Electrical		
Maximum Power @ 24 Vdc	TBD W	
Input Voltage Range	TBD Vdc	
Environmental		
Operating Temperature Range	-40 to +140 °F	-40 to +60 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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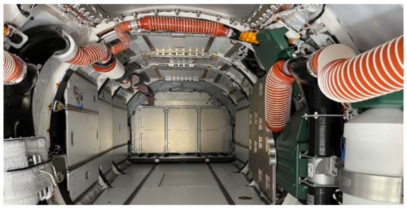
DUCTING

Ducting Application

Ducting Applications


Sierra Space's Ducting Applications

Design Description

At Sierra Space, we provide specialized design and manufacturing services for aerospace ductwork applications. Our expertise includes conducting detailed analyses to determine optimal ductwork dimensions balancing acoustic considerations, tight volumes, efficient fan power requirements. We offer extensive testing and analysis services to ensure the structural integrity of both rigid and flexible ductwork. Furthermore, Sierra Space can provide comprehensive spacecraft acoustic analysis services to analyze the entire fan and duct system acoustics to determine optimum acoustic attenuation design including duct silencers. Our technical proficiency ensures that each ductwork solution is both efficient and reliable, meeting the rigorous demands of modern aerospace applications.

Dimensions

(nothing in excel)

Ducting Features	
• Customizable Rigid Ducting	• Low Pressure Losses
• Flexible Acoustic Silencers	• Space Flight Materials

Product Specifications		
	U.S.	**SI**
Performance		
Pressure Rating	-0.5 psi to 1 psi	-3.4 kPa to 6.9 kPa
Acoustic	NC50	
Mechanical		
Tube Outer Diameter	1 inch to 5 inch	2.54 cm to 12.7 cm
Construction Materials	Carbon Fiber Rigid Ductwork and Silicone Fiberglass Flexible Ducting	
Environmental		
Vibration	11.5 Grms	
Shock	360 G	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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FANS

Cabin Fan Assembly (CFA)

Modular Ventilation Fan (MVF)

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Cabin Fan Assembly (CFA)

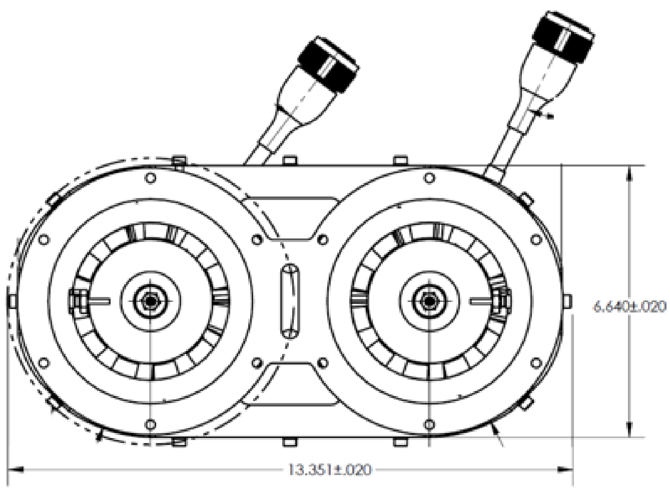
Design Description

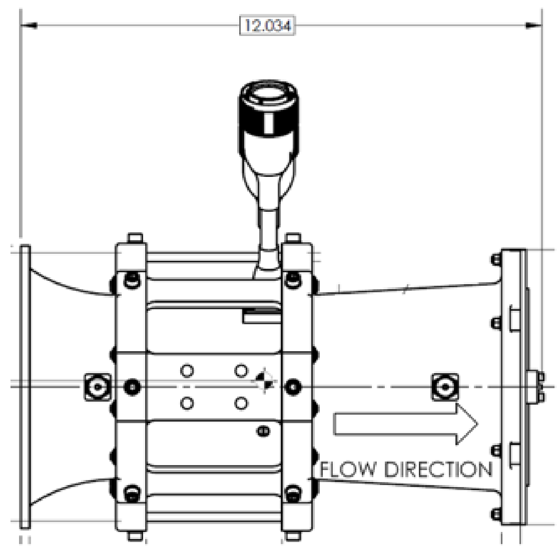
Sierra Space designed and flight-qualified a Cabin Fan Assembly (CFA) to complement our environmental control product line. This CFA is designed to provide airflow throughout an Environmental Control System (ECS) onboard a closed environment within a spacecraft. This package has been optimized to provide a lightweight, compact profile, which uses variable speed fans and self-contained pressure-sensing hardware to allow the package to operate in a multitude of different applications.

Cabin Fan Assembly Undergoing Acoustic Testing.

The package contains two vane-axial fans, which allow for a wide range of performance options. This can be used to provide redundancy to a single fan operation, making it easy to meet safety and mission assurance requirements, or in a dual fan configuration to increase the performance range and capabilities of the package. Each fan operates in its own air path, specially designed to increase performance, and minimize pressure drop, and uses an automatically sealing independent check valve to allow for single or dual fan operation without the need for physical modifications to the package. Each fan has sensors to monitor fan health and differential pressure without the need for additional hardware. Acoustics are dependent on enclosure and ducting, both of which Sierra Space can also provide.

Dimensions





Note: All dimensions above are in inches.

CFA Features	
• Variable speed fans	• Under-speed and overheat fault signals
• Self-contained pressure measuring	• Self-sealing check valves
• Small acoustic signature	• High-strength aluminum housing design
• Grade 2+ electrical, electronic, and electromechanical (EEE) electronics	• Flight-qualified

Applications	
• Environmental controls	• Provision of airflow

Product Specifications		
(Nominal speed = 80% PWM, 1 Fan)	**U.S.**	**SI**
Mechanical		
Mass	23.6 lbm	10.7 kg
Pressure (Nominal Speed)	8.84 inwc	2,200 pA
Air Volume (Nominal Speed)	275 CFM	130 l/s
Electrical		
Steady State Power (Nominal)	546 Watts @ 28 Vdc	
Voltage Range	22-32 Vdc	
Environmental		
Vibration: Qualified to	13.94 Grms	
Shock: Qualified to	360 G	
Operating Temperature Range	38 to 129 °F	3 to 54 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Modular Ventilation Fan (MVF)

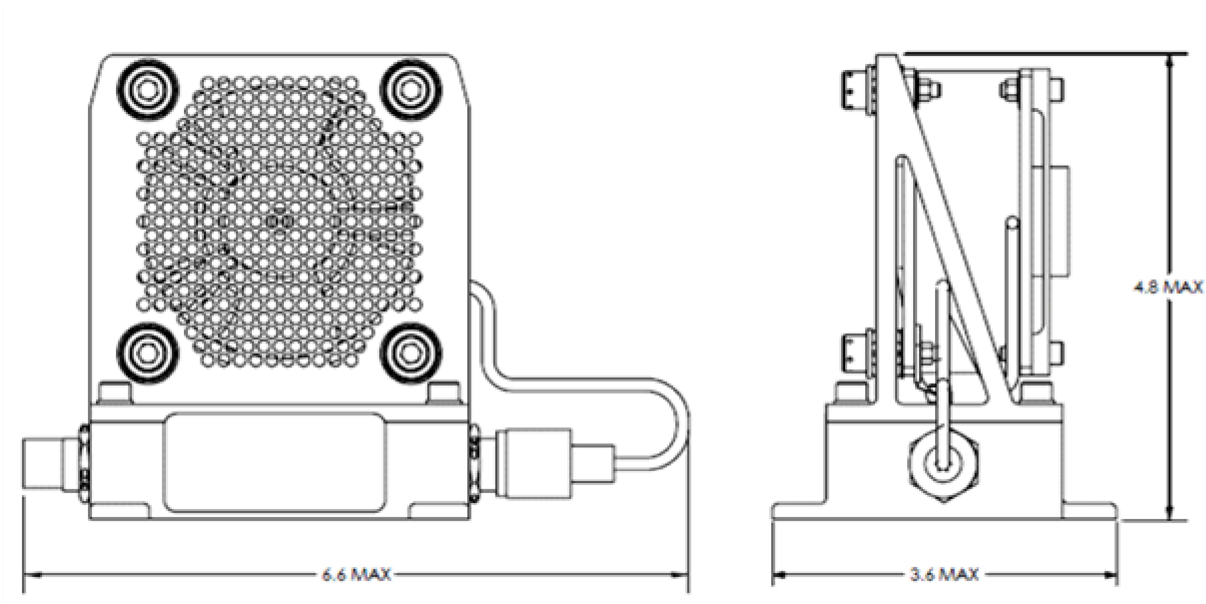
Design Description

Sierra Space designed and flight-qualified a Modular Ventilation Fan (MVF) to complement our environmental control product line. This MVF assembly is designed to provide airflow throughout a relatively small (<30-ft^3 free volume) Environmental Control System (ECS) onboard a closed environment within a spacecraft. This package has been optimized to provide a lightweight, compact profile with a simple isolation mount for ease of mechanical interfacing.

The fan assembly comprises a single fan, set at a single speed, mounted through vibration isolation dampeners. Power is provided via a single connector. Acoustics are dependent on enclosure and ducting, both of which Sierra Space can also provide.

MVF undergoing random vibration testing.

Dimensions



Note: All dimensions above are in inches.

Modular Ventilation Fan Features	
• Single speed fan (speed is customizable)	• Under-speed and overheat fault signals
• Grade 2+ EEE electronics	• Vibration dampening interface available
• Single electrical connecter interface	• Flight-qualified

Applications	
• Environmental Control	• Atmospheric Circulation

Product Specifications		
(Nominal speed = 80% PWM, 1 Fan)	**U.S.**	**SI**
Mechanical		
Mass	2.3 lbm	1.0 kg
Air Volume (Maximum Speed)	95 CFM	2,690 LPM
Air Volume (Minimum Speed)	40 CFM	132 LPM
Electrical		
Steady State Power (Maximum Speed)	40 W @ 28 Vdc	
Steady State Power (Minimum Speed)	6 W @ 28 Vdc	
Voltage Range	22-32 Vdc	
Environmental		
Vibration: Qualified to	10.6 Grms	
Shock: Qualified to	975 G	
Operating Temperature Range	40 to 103 °F	7 to 39 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

FLUID COMPONENTS

Sierra Space's Fluid Component technology stresses flexibility. They offer precision build quality and scalability to meet a wide range of customer specifications and requirements.

Catalog data sheets for our Fluid Components technology area include:

Fluid Accumulator

In-Line Fluid Filter

Coolant Pump

Coolant Pump Package

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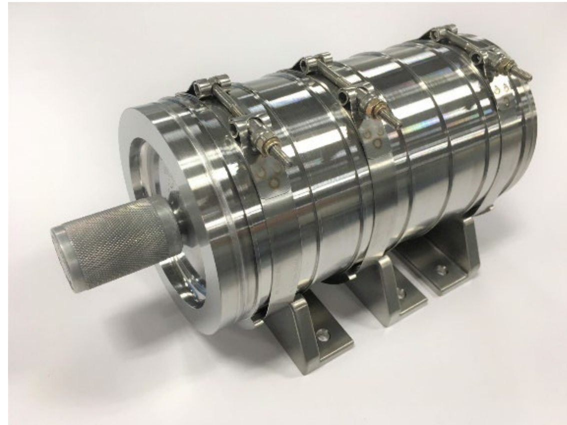
Fluid Accumulator

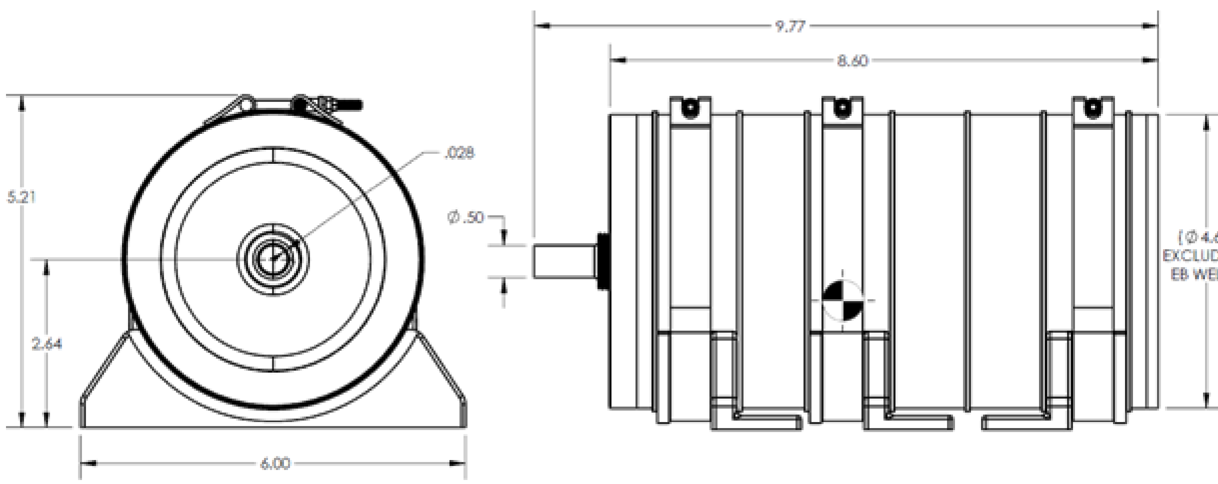
Design Description

Sierra Space collaborated with a fluid component manufacturer to design and provide a space-qualified fluid accumulator to complement our fluid control product line. These accumulators are designed to maintain pressure when subjected to volumetric changes. Built under precision cleanliness controls, the approach is easily scaled to meet a variety of size and pressure requirements. One example specification is provided below.



Fluid Accumulator for maintaining liquid coolant system pressure.

Dimensions



Note: All dimensions above are in inches.

Fluid Accumulator Features	
• Cylindrical stainless steel and titanium package	• Low pressure variation
• Includes edge welded bellows: hermetically sealed	• Large displacement volume
• Accommodates system volume changes	• Qualified for 50/50 propylene glycol/water (PGW)

Applications
• Fluid control

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Product Specifications		
	U.S.	**SI**
Performance		
Displacement Volume	40 in^3 (min)	0.66 liter (min)
Operating Pressure	18 to 38 psia	1.2 to 2.6 atm
Qualified to	19,500 pressure cycles	
Maximum Design Pressure	150 psid	10.2 atm
Mechanical		
Mass (dry, with charge)	11.4 lbm	5.2 kg
Size	4.6 in dia., 8.6 in length	117 mm dia., 219 mm length
Environmental		
Vibration: Qualified to	14 Grms	
Shock: Qualified to	160 G	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

In-Line Fluid Filter

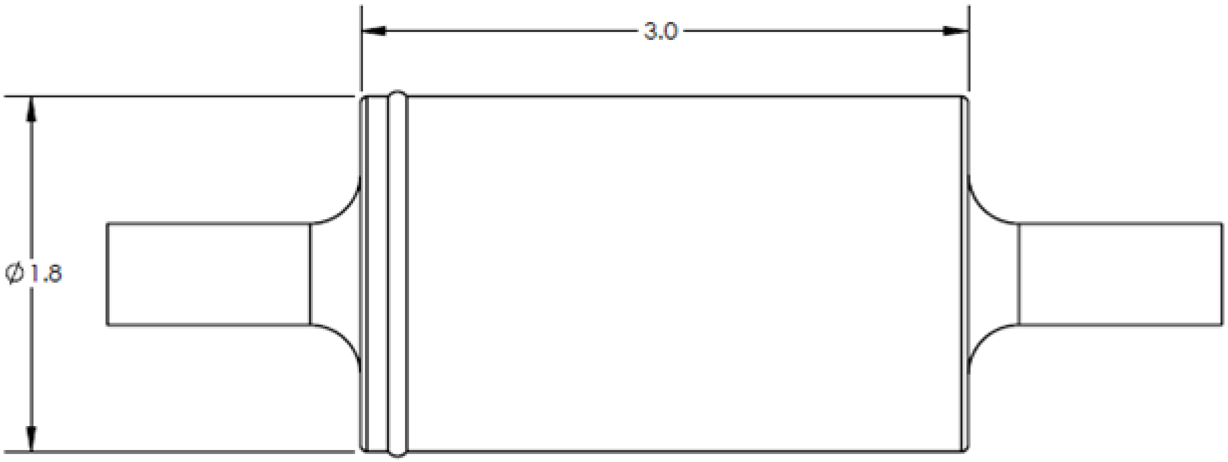
Design Description

Sierra Space collaborated with a fluid component manufacturer to design and qualify the in-line fluid filter to complement our fluid control product line. These filters are designed to limit resistance in high-flow and low-pressure applications while also having high capacity to protect the system from contamination. The construction is designed for simplicity and compatibility using common materials.

These filters are built under precision cleanliness controls and are designed to maintain system cleanliness. The approach is easily scaled to meet a variety of size and filtration requirements. One example specification is provided below.

In-line fluid filter with woven wire mesh having 20-micron nominal, 40-micron absolute rating.

Dimensions



Note: All dimensions above are in inches.

In-Line Fluid Filter Features	
• In-line cylindrical mechanical package	• High capacity
• 316/316L corrosion-resistant steel (CRES) welded construction	• Contamination resistant
• Rigid supporting structure and dual layer mesh	• Minimal pressure drop
• Pleated mesh for increased open area	• Built precision clean

Applications
• Fluid filtration

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass (dry)	0.8 lbm	0.36 kg
Size	1.8 in dia., 3.0 in length	45 mm dia., 76 mm length
Filtration Rating	0.0008 in nom, 0.0016 in abs	0.020 mm nom, 0.040 mm abs
Effective Area	10.5 in^2	68 cm^2
Pressure Rating	225 psia	15.5 bar
Qualified Fluid	Propylene glycol water mix (50/50)	
Environmental		
Vibration: Qualified to	14 Grms	
Shock: Qualified to	160 G	
Temperature	50 to 113 °F	10 to 45 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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Coolant Pump

Design Description

The Coolant Pump provides the motive force to circulate working fluid of an Active Thermal Control System (ATCS). The Coolant Pump is a centrifugal pump with hydrodynamically supported bearings. A primary benefit of this design is that it eliminates the need for pressure relief valves as the function is inherent in the design. The hydrodynamically supported journal/bearing configuration provides for virtually no wear and long unit operational life, lowering replacement needs/costs. Electrical components are few; the brushless DC motor includes a temperature sensor in the windings to flag overtemperature conditions, and pump speed is controlled with Hall Effect Devices (HED).

Coolant Pump

Coolant Pump Package Features	
• Centrifugal pump	• Brushless DC motor
• Long operational life	

Product Specifications		
	U.S.	**SI**
Performance		
Nominal Flow Rate	600 lbm/hr with >35 psid head rise	0.076 kg/s with >241 kPad head rise
Filtration	20 microns nominal, 40 microns absolute	
External Leakage	<1e-5 scc/s GHe with ≥68 psid between internal and external Zero liquid leakage	
Mechanical		
Dry Mass	≤5 lbm	≤2.3 kg
Maximum Design Pressure	150 psid	1,034.3 kPad
Proof Pressure	225 psid	1,551.4 kPad
Burst Pressure	375 psid	2,585.6 kPad
Electrical		
Nominal Power	≤165 Watts @ 32 Vdc	
Maximum Power	330 Watts, 11,000 rpm @ 32 Vdc	
Voltage Range	24-32 Vdc	
Motor	3-Phase, Trapezoidal Drive, 4-Pole Brushless DC	
Environmental		
Vibration: Qualified to	X-Axis: 14.05 Grms, Y-Axis: 14.13 Grms, Z-Axis: 15.85 Grms	
Shock: Qualified to	20 G (100 Hz), 160 G (750 Hz), 160 G (10,000 Hz)	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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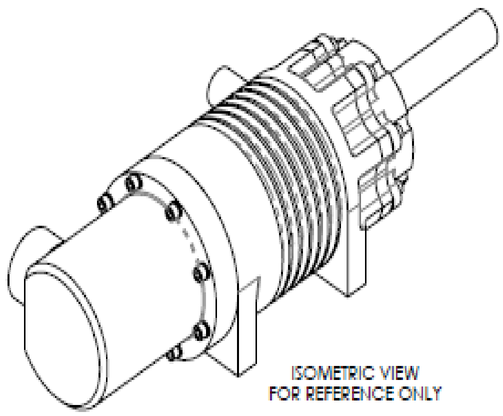
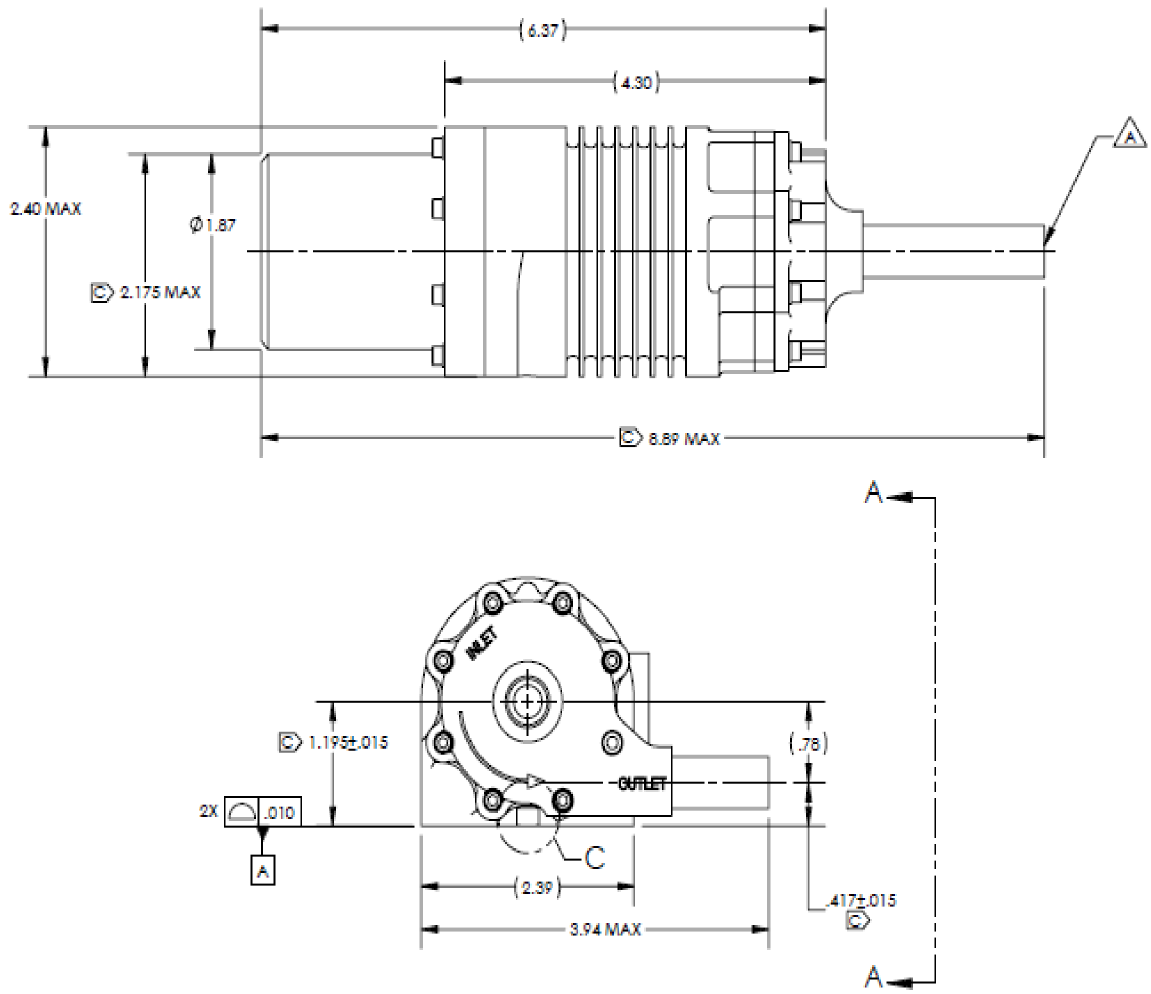
Dimensions



FLUID INTERFACE		
PORT	FLOW CONDITION	FITMENT
A	INLET C	Ø .500 ± .004 OD X .028 ± .0028 WALL 316L SS WELDMENT TUBE STUB, BUTT WELD PREPPED
B	OUTLET C	Ø .500 ± .004 OD X .028 ± .0028 WALL 316L SS WELDMENT TUBE STUB, BUTT WELD PREPPED



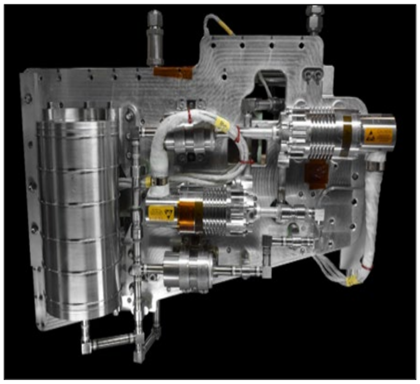
Coolant Pump

Note: All dimensions above are in inches

Coolant Pump Package

Design Description

The Coolant Pump Package provides the motive force to circulate the working fluid of an Active Thermal Control System (ATCS). There are two variants of the package available, one with redundant pumps and one with a single pump. The package with redundancy contains two pumps, two filters, two pressure sensors, a shuttle valve, and an accumulator. The other package contains one pump, one filter, two pressure sensors, and an accumulator. In both packages, the accumulator provides a reservoir for coolant thermal expansion and maintains the minimum suction head pressure for the pump. In the package with redundancy, the primary pump runs continuously while the second pump is activated only upon failure of the primary pump. The pump used in both packages contains an RTD in the windings to sense for an over-temperature condition.

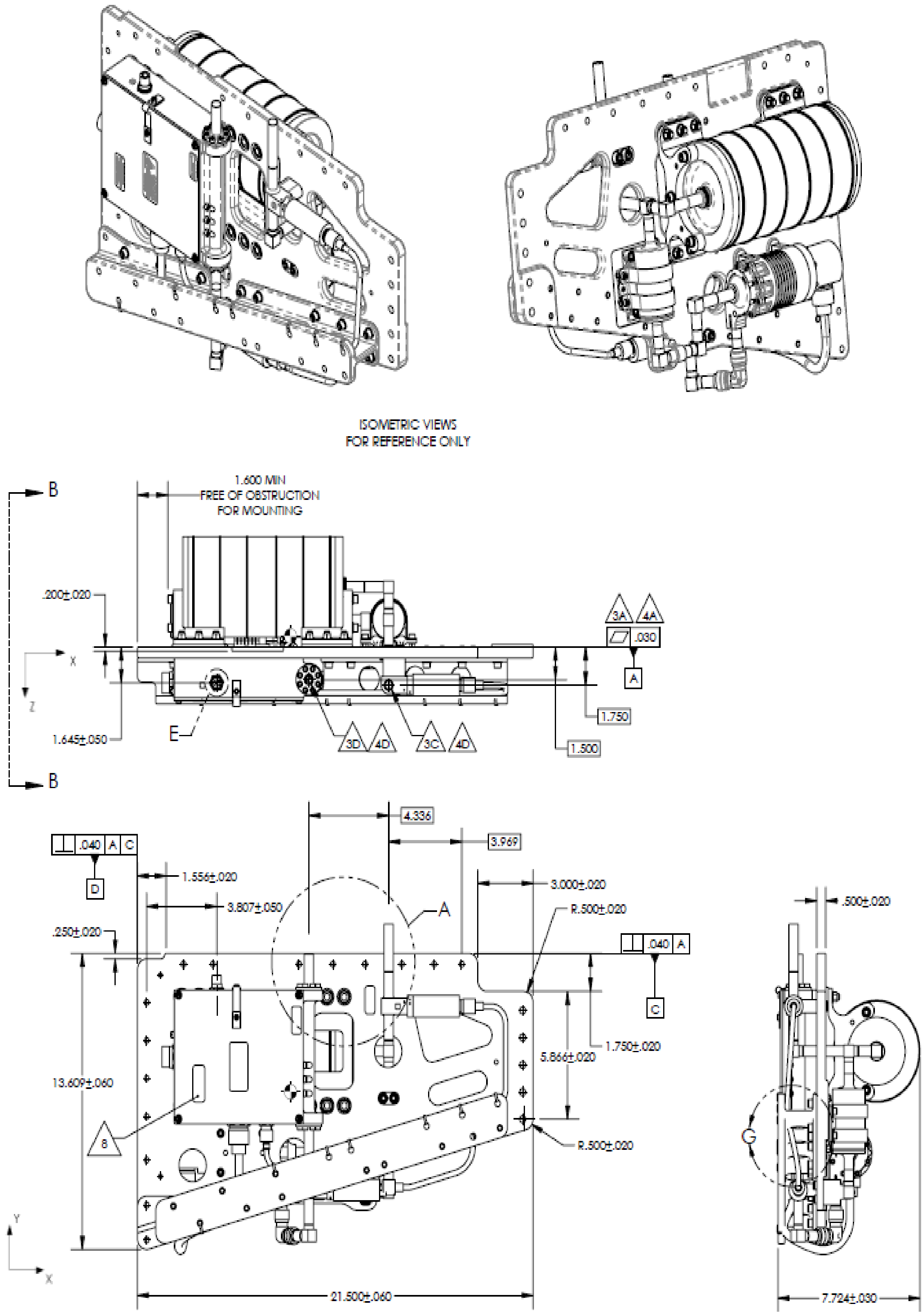


Coolant Pump Package with Redundancy

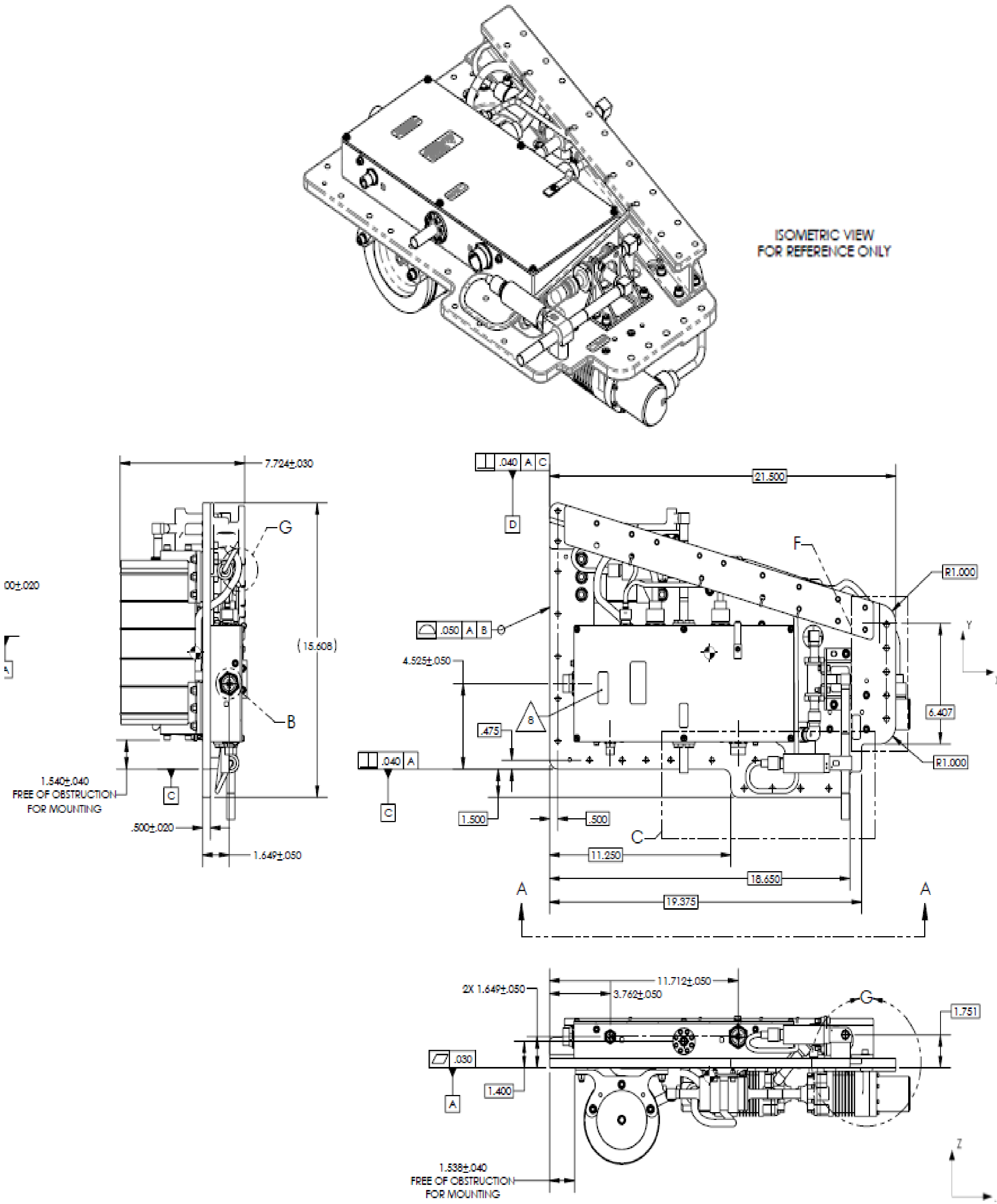
Coolant Pump Package Features	
• Flight qualified package	• Accumulator accommodates thermal expansion of working fluid
• Option for internally redundant pumps or single pumps	• Shuttle valve provides automatic switching between active pumps in internally redundant configuration

Product Specifications		
	U.S.	**SI**
Performance		
Nominal Flow Rate	600 lbm/hr with >35 psid head rise	0.076 kg/s with >241 kPad head rise
Filtration	20 microns nominal, 40 microns absolute	
External Leakage	<3e-5 scc/s GHe with ≥68 psid between internal and external Zero liquid leakage	
Accumulator Volume Expansion Capacity	40 in^3	655.5 cm^3
Mechanical		
Package Dry Mass	<50 lbm	<22.7 kg
Maximum Design Pressure	150 psid	1,034.3 kPad
Proof Pressure	225 psid	1,551.4 kPad
Burst Pressure	375 psid	2,585.6 kPad
Electrical		
Nominal Power	≤165 Watts @ 32 Vdc	
Standby Power	≤3 Watts	
Voltage Range	24-32 Vdc	
Environmental		
Vibration: Qualified to	X-Axis: 14.05 Grms, Y-Axis: 14.13 Grms, Z-Axis: 15.85 Grms	
Shock: Qualified to	20 G (100 Hz), 160 G (750 Hz), 160 G (10,000 Hz)	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Dimensions



Coolant Pump Package



Coolant Pump Package with Redundancy

Note: All dimensions above are in inches

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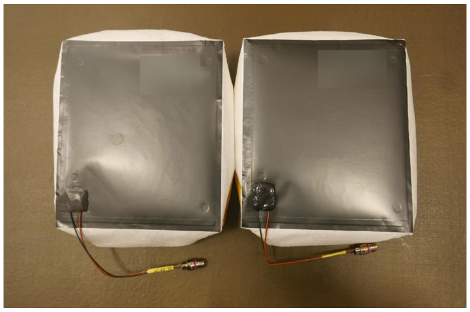
HEAT

Shell Heaters

Shell Heaters

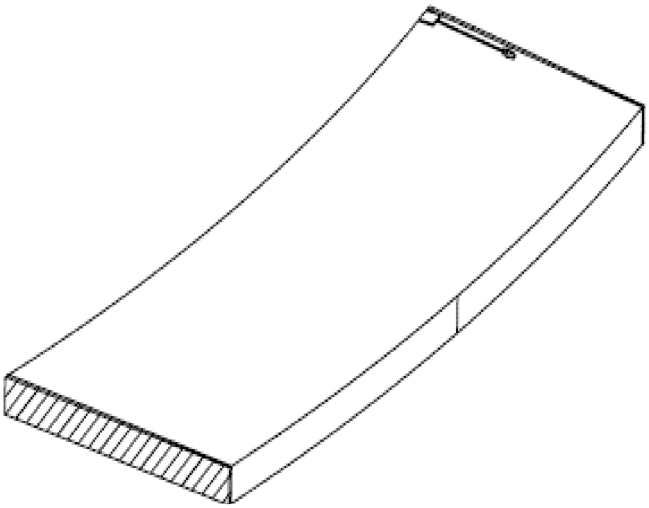
Design Description

The flight-qualified Shell Heaters are used to maintain vehicle wall temperature and prevent condensation. Shell Heaters include a flexible powered heating element and bulk insulation. The Shell Heaters are not structural components, and their flexible nature means they can be mapped to vehicles with varied geometries. These Shell Heaters are a unique design that can be used with a variety of vehicle materials, including composites. Shell Heaters can be controlled on an individual basis or by group to maintain the desired temperature at the vehicle wall.



Shell Heater

Dimensions



Example of Shell Heater – Various Form Factors Available

Shell Heater Features	
• Flexible and customizable to various geometries	• Flight qualified
• Durable and tolerant to punctures	

Product Specifications		
	U.S.	**SI**
Performance		
Shell Heater Surface Temperature	50 - 75 °F	10 - 23.9 °C
Mechanical		
Mass	Typically, <0.5 lbm per heater Varies by configuration	Typically, <0.2 per heater Varies by configuration
Surface Area	Up to 1,200 in^2	Up to 0.77 m^2
Electrical		
Input Voltage	24-32 Vdc	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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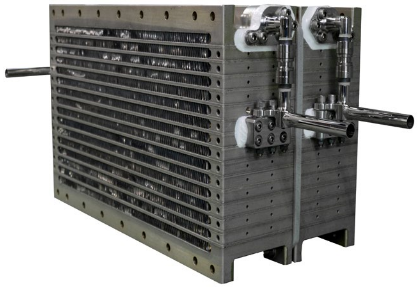
HEAT EXCHANGER

Air-Liquid Heat Exchanger (HX)
Liquid-to-Heat Exchanger (LLHX)
Thermal Cold Plate (CP3)

Air-Liquid Heat Exchanger (HX)

Design Description

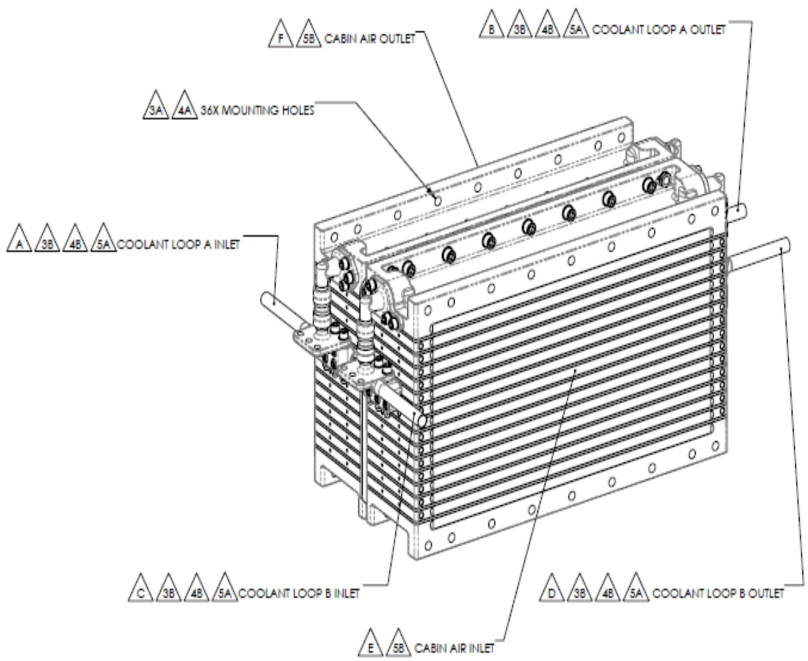
The Air-Liquid Heat Exchanger (HX) is a fin-and-tube crossflow heat exchanger that transfers heat from cabin air into coolant. Warm cabin air is drawn across the heat exchanger surface by a fan (external to the HX). The package consists of two separate HX cores to support dual loop Thermal Control System (TCS) architectures. The two HX cores are mounted back-to-back such that the cabin air flows sequentially through both cores. The Air-Liquid HX can also be manufactured in a single core configuration.



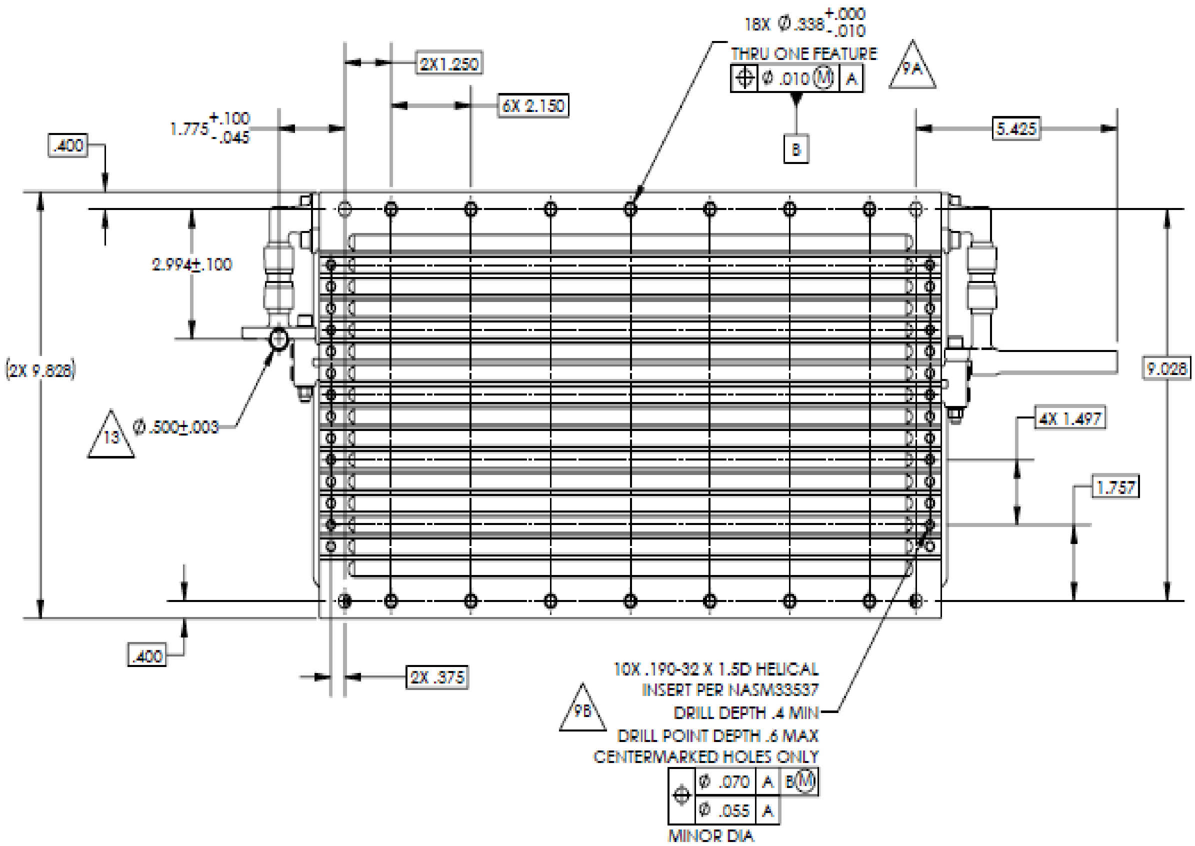
Air-Liquid Heat Exchanger

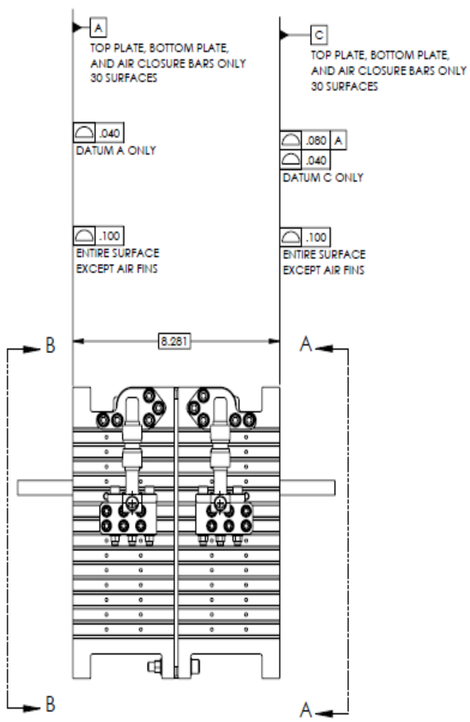
Air-Liquid Heat Exchanger Features	
• Crossflow heat exchanger	• Brazed aluminum construction
• Flight Qualified	

Dimensions



FLUID INTERFACE		
PORT	FLOW CONDITION	FITMENT
A	COOLANT LOOP A INLET	Ø .500±.003 X .028±.0028 ↧ 3.00 MIN TUBE STUB
B	COOLANT LOOP A OUTLET	Ø .500±.003 X .028±.0028 ↧ 3.00 MIN TUBE STUB
C	COOLANT LOOP B INLET	Ø .500±.003 X .028±.0028 ↧ 3.00 MIN TUBE STUB
D	COOLANT LOOP B OUTLET	Ø .500±.003 X .028±.0028 ↧ 3.00 MIN TUBE STUB
E	CABIN AIR INLET	SEE DETAILED DRAWING
F	CABIN AIR OUTLET	SEE DETAILED DRAWING





Note: All dimensions above are in inches

Product Specifications		
	U.S.	SI
Performance		
Heat Transfer: Qualified to Air Flow: PGW Flow:	1,880 W ≤1,090 lbm/hr @ ≤8 5 °F ≤500 lbm/hr @ ≥ 53 °F	1,880 W ≤0.137 kg/s @ ≤29.4 °C ≤0.063 kg/s @ ≥11.7 °C
Coolant Pressure Drop	<1.2 psid @ 500 lbm/hr PGW and 50 °F	< 8.3 kPad @ 0.063 kg/s PGW and 10 °C
Air Pressure Drop	<0.3 inches of water column with 1,090 lbm/hr at 60 ±5 °F and 90 ±5 °F	<74.7 Pa with 0.137 kg/s PGW at 15.6 ±2.8 °C and 32.2 ±2.8 °C
External Leakage	Zero liquid leakage	
Mechanical		
Dry Mass	<40 lbm	<18.1 kg
Maximum Design Pressure	150 psid	1,034.3 kPad
Proof Pressure	225 psid	1,551.4 kPad
Burst Pressure	375 psid	2,585.6 kPad
Environmental		
Vibration: Qualified to	X-Axis: 14.33 Grms, Y-Axis: 14.22 Grms, Z-Axis: 16.8 Grms	
Shock: Qualified to	40 G (100 Hz), 360 G (750 Hz), 360 G (10,000 Hz)	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

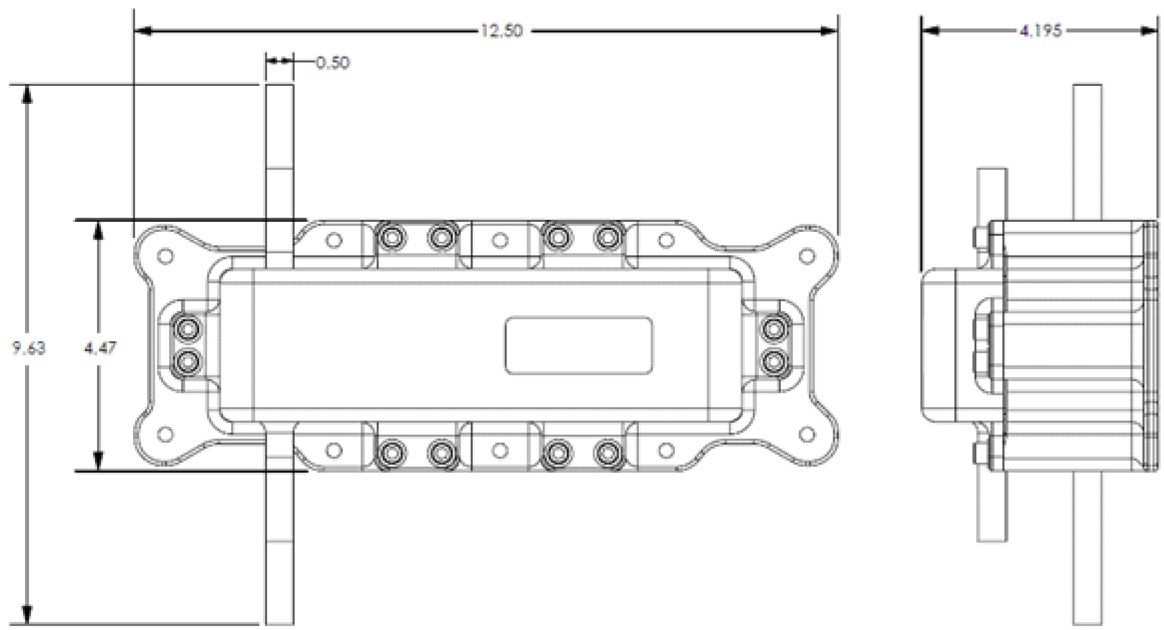
Liquid-to-Liquid Heat Exchanger (LLHX)

Design Description

Sierra Space designed and flight-qualified the Liquid-to-Liquid Heat Exchanger (LLHX) to complement our thermal management products. The heat exchanger is designed to be integrated into a coolant loop via weld tube-stubs. This unit is designed with two inputs and two outputs, one for each fluid.

Liquid-to-liquid brazed plate heat exchanger in housing.

Dimensions



Note: All dimensions above are in inches.

Liquid-to-Liquid Heat Exchanger (LLHX) Features	
• Stainless steel tube ends	• Brazed plate design
• All wetted materials corrosion-resistant steel (CRES)	• High Conduction
• Spacecraft-qualified	

Applications
• Thermal management

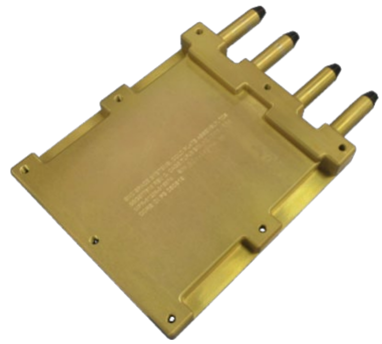
Product Specifications		
	U.S.	**SI**
Performance		
Heat Rejection	3,600 W	
Hot Side: Flow Rate	790 lbm/hr, Inlet Temperature 82 °F, Outlet Temperature 52 °F	
Cold Side: Flow Rate	780 lbm/hr, Inlet Temperature 36 °F, Outlet Temperature 55 °F	
Mechanical		
Mass (Dry/Wet)	18.5/20.0 lbm	8.4/9.1 kg
Pressure Drop, Line 1	1.9 psid (@ 515 lbm/hr of 50/50 PGW)	
Pressure Drop, Line 2	5.4 psid (@ 820 lbm/hr of 50/50 PGW)	
Leakage (Internal @ 80 psid)	<0.0006 sccm He; Liquid Leak-tite	
Maximum Design Pressure	150 psid	
Environmental		
Vibration: Qualified to	7 Grms	
Shock: Qualified to	2,680 G	
Operating Temperature Range	-11 to 142 °F	-24 to 61 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Thermal Cold Plate

Design Description

Sierra Space designed and qualified Cold Plates to complement our thermal management products. The cold plates are designed to be integrated to the thermal generating device via a flat surface. This unit is designed with two parallel coolant loops but can be modified for a single coolant loop operation. The cold plates are manufactured and tested in an environment to maintain precision-level cleanliness. Several sizes are available, with one example provided below.

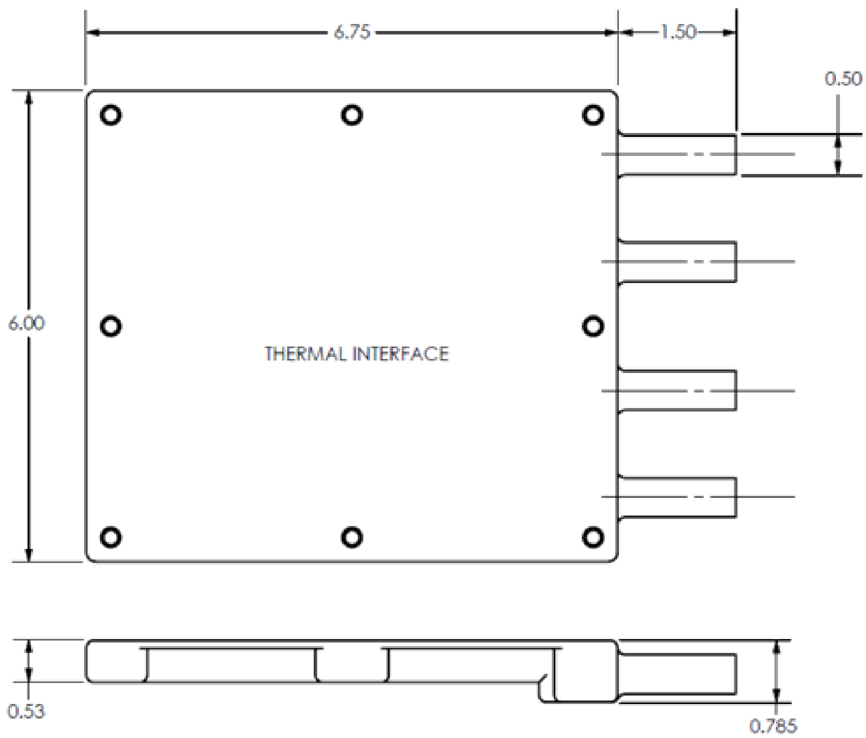
Cold Plate sizing can be tailored to requirements and customer need. Additional sizes (not detailed in this product specification include:



Cold Plate with dual flow paths.

- 16.93 in x 15.63 in
- 9.2 in x 9.2 in
- 9.5 in x 19.5 in
- 3.456 in x 6.22 in
- 6.22 in x 8.976 in
- 8.976 in x 6.22 in

Dimensions



Note: All dimensions above are in inches.

Thermal Cold Plate Features	
• Aluminum tube ends	• Dual flow paths
• All wetted materials Aluminum	• Optimized Heat Transfer
• Space-qualified	

Applications
• Thermal management

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass (wet/dry)	1.5/1.8 lbm	0.7/0.8 kg
Pressure Drop	0.2 psid (@ 250 lbm/hr 50/50 PGW)	
Leakage (Internal @ 80 psid)	0.0006 sccm He; Liquid Leak-tite	
Maximum Design Pressure	150 psid	
Environmental		
Vibration: Qualified to	57 Grms	
Shock: Qualified to	3,300 G	
Operating Temperature Range	-11 to 142 °F	-24 to 61 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

HEAT SWITCH

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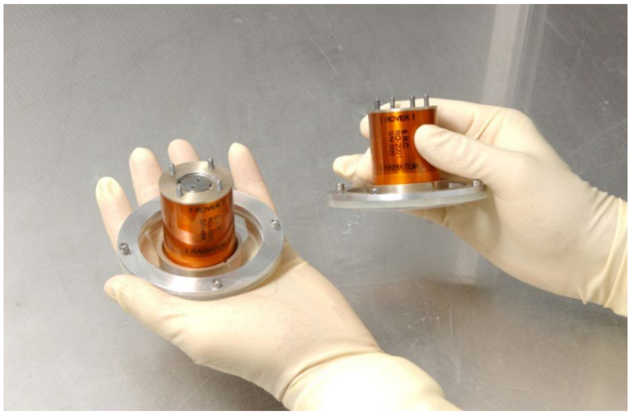
Passive Thermal Control Heat Switch

Design Description

Sierra Space's Passive Thermal Control Heat Switch is a device for controlling the temperature of electronics and instrumentation on satellites and spacecraft. These devices are part of our family of tools for spacecraft thermal control. They reduce spacecraft power requirements while providing improved control and better reliability at a lower cost than conventional thermal control schemes.

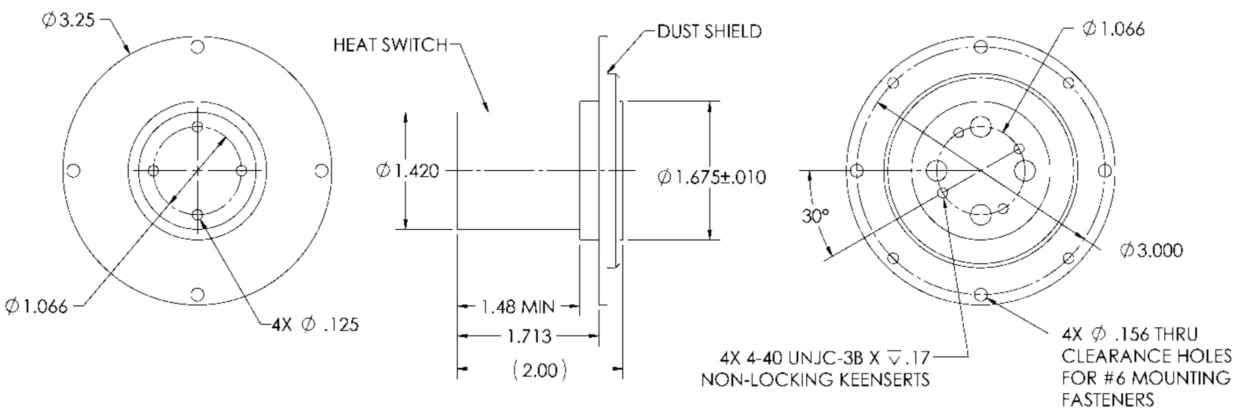

Passive Thermal Control Heat Switch. Shown here are heat switches with dust cover shields.

We delivered two flight and one qualification heat switch units to the NASA Jet Propulsion Laboratory for the Mars Exploration Rover (MER) program. The heat switches were designed for use in the Martian atmosphere to control the temperature in the electronics and power enclosure of the rovers. Given the wide fluctuations in environmental temperature during the Martian day and night cycle, switchable thermal conductance between the electronics enclosure and the body-mounted radiators was required to optimize thermal performance and minimize heater power. The switchable conduction path provided a controlled operating environment for the MER electronics and batteries.

These passive control heat switches are another example of our ability to design a passive thermal mechanism that operates at a specific temperature. The device includes an autonomously created mechanical action that first senses the temperature, and then provides mechanical motion at a pre-determined set point. This type of device is key in creating a thermally initiated, completely passive (no electrical power or controls) switch.

Passive Thermal Control Heat Switch Features	
• Low cost	• Robust construction
• High turndown ratio	• Precise narrow control band
• Passive operation	• Linear conductance between open/closed valves
• Numerous set points available	• Large gap for use in Mars atmosphere

Dimensions



Note: All dimensions above are in inches.

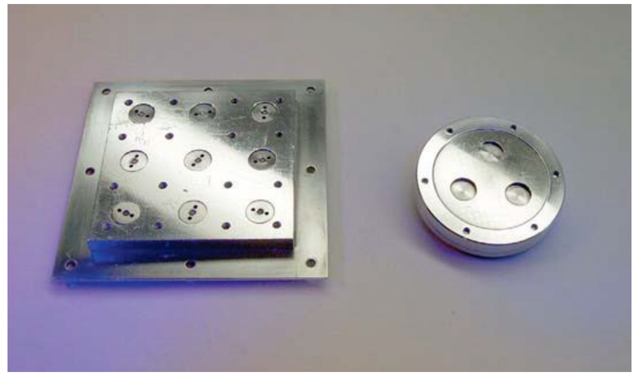
Applications	
• Dissipate heat from spacecraft components such as electronics	• Thermally isolate critical areas of spacecraft from cold space environment
• Integrate switches into arrays to control larger areas, odd geometries and/or create adjustable radiating areas	• Passively change conductance of thermal path based on temperature
• Thermally connect and disconnect a radiator based on thermal system needs	

Heritage Programs
• Mars Exploration Rovers, "Spirit" and "Opportunity”

Product Specifications		
	U.S.	**SI**
Mechanical		
Height and Thickness	2.0 in (high) x 1.42 in (diameter)	50.8 mm (high) x 36.1 mm (diameter)
Mass	3.87 oz	~110 g
Life Cycles (Tested)	>350 tested; >4,000 on MER	
Redundancy	No	
Operation Time	Depends on heating rate	
Thermal		
Operating Temperatures	-139 °F to +68 °F	-95 °C to +20 °C
Available Set-point Temperatures (Typical; Others Available)	14 °F to 122 °F	-10 °C to +50 °C
Conductance (Total)	Closed: 6.14 BTU/hr-K Open: 0.14 BTU/hr-K	Closed: 1 W/K Open: 0.015 W/K
Turndown Ratio	67:1	
Maximum Q (Power)	20.48 BTU/hr	6 W
Note: These specifications can be modified to meet the customer’s requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Thin Plate Heat Switch

Design Description



The High-Performance Thin Plate Heat Switch (at left) and the Diaphragm Thin Plate Heat Switch (at right) provide reliable low-cost thermal control.

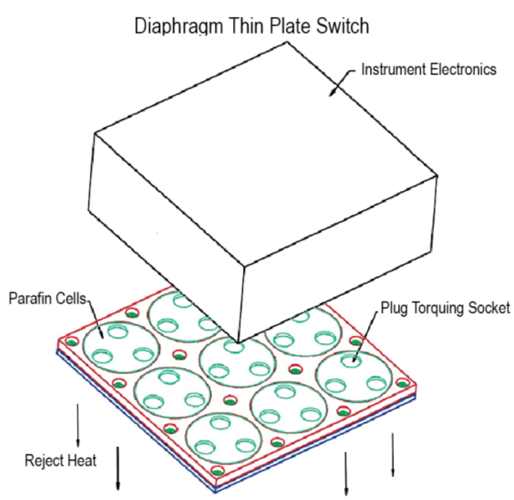
Sierra Space's Thin Plate Heat Switch devices passively control the temperature of electronics and instrumentation on satellites and spacecraft. These devices are part of our family of tools for spacecraft thermal control. They can potentially reduce spacecraft power requirements while providing improved control and better reliability at a lower cost than conventional thermal controls.

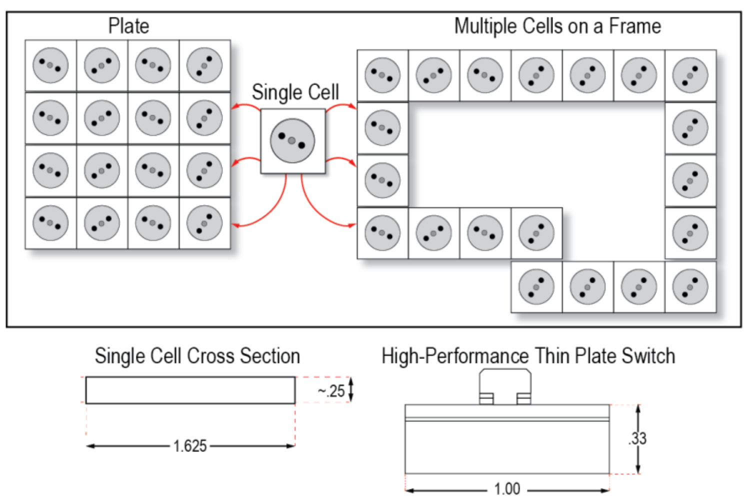
The devices provide a variable conduction heat path from the warm electronics or instruments to which they are mounted, to a cold panel or cold sink. The temperature of the electronics is controlled by the passive change in thermal conductance of the heat switch. Thermal conductance is adjusted internally and passively based on the temperature of the warm side of the switch. A self-regulating design allows precise, reliable temperature control.

In a typical application, the thin plate is mounted between an instrument or electronics box and a cold sink, such as a panel that radiates to space. When the electronics get too warm, the switch conductance increases, allowing the excess heat to be transferred through the switch to the cold sink. When the electronics get too cold, the switch conductance decreases, insulating the electronics and allowing them to stay warm using their own heat on a low level of standby power.

Two designs are available—the *High-Performance Thin Plate Heat Switch* (shown top left) and the *Diaphragm Thin Plate Heat Switch* (shown top right). Both designs have multiple cells and a footprint that is customized to each specific application; they can be used singly, in a plate form in an array, or in a more complex frame style. The High-Performance Thin Plate Switch is lightweight and has excellent thermal performance. The Diaphragm Thin Plate Switch is designed for extreme high reliability. Both designs are rugged and robust. They provide their own structural support in addition to structural mounting for the electronics or instrument.

Dimensions





Note: All dimensions above are in inches. Cell sizes are provided in table.

Thin Plate Heat Switch Features	
• Low cost	• Robust construction
• High turndown ratio	• Precise narrow control band
• Passive operation	• Linear conductance between open/closed values
• Numerous set points available	• Self-regulating design

Applications	
• Dissipate heat from spacecraft components such as electronics	• Thermally isolate critical areas of spacecraft from space vacuum
• Integrate switches into arrays to control larger areas, odd geometries and/or create adjustable radiating areas	

Heritage Programs
• Qualification hardware delivered to customer

Product Specifications—High Performance Thin Plate		
	U.S.	**SI**
Mechanical		
Thickness	0.32 in	8.13 mm
Mass (Approximate Average Density)	0.1 lb/in^3	2.72 g/cm^3
Life Cycles (Tested)	>100,000	
Redundancy	Yes, multi-cell	
Operation Time	Varies with heating rate	
Single Cell Size	1.00 in x 1.00 in	25.4 mm x 25.4 mm
Thermal		
Operating Temperatures	-202 °F to +212 °F	-130 °C to +100 °C
Maximum Thermal Conductance Ratio	78:1	
Available Set Point Temperatures	-14 °F to +122 °F	-10 °C to +50 °C
Conductance (Maximum)	Closed: 0.743 BTU/hr-in^2-F Open: 0.0095 BTU/hr-in^2-F	Closed: 607 W/m^2 - °C Open: 7.8 W/m^2 - °C
Maximum Q (Power) per Cell	41 BTU/hr	12 W

Product Specifications—Diaphragm Thin Plate		
	U.S.	**SI**
Mechanical		
Thickness	0.25 in	6.35 mm
Mass (Approximate Average Density)	Approximately 0.1 lb/in^3	Approximately 2.72 g/cm^3
Life Cycles (Tested)	>1,000	
Redundancy	Yes, multi-cell	
Operation Time	Varies with heating rate	
Single Cell Size	1.625 in x 1.625 in	41.3 mm x 41.3 mm
Thermal		
Operating Temperatures	-202 °F to +212 °F	-130 °C to +100 °C
Maximum Thermal Conductance Ratio	92:1	
Available Set Point Temperatures	-14 °F to +122 °F	-10 °C to +50 °C
Conductance (Maximum)	Closed: 0.743 BTU/hr-in^2-F Open: 0.0095 BTU/hr-in^2-F	Closed: 607 W/m^2 - °C Open: 7.8 W/m^2 - °C
Maximum Q (Power) per Cell	41 BTU/hr	12 W
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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LOUVERS

Passive Thermal Louvers

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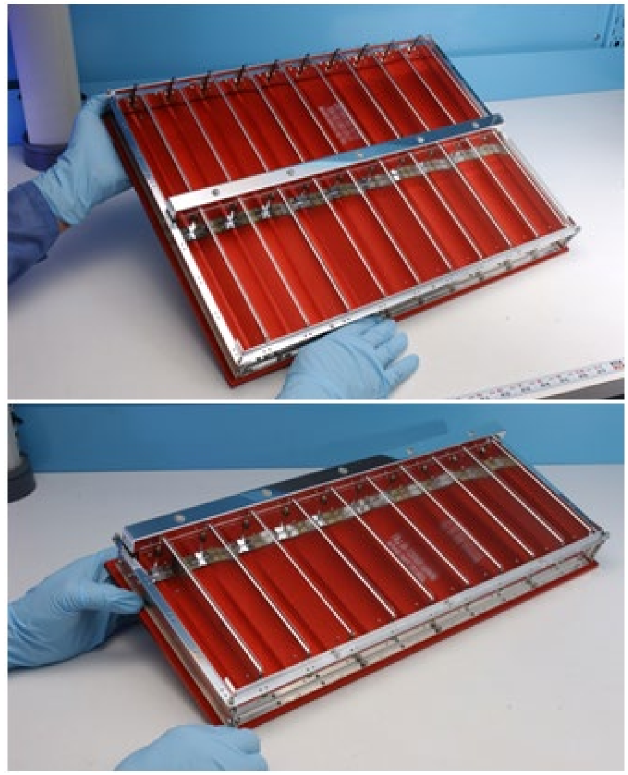
Passive Thermal Louvers

Design Description

Sierra Space's Passive Thermal Louver is based on decades of NASA/Jet Propulsion Laboratory (JPL) flight heritage. The louver provides thermal radiation with a pivoting aluminum blade design that is supported within a lightweight frame. The blades are driven with bimetal actuator springs that are thermally linked with the mounting surface.

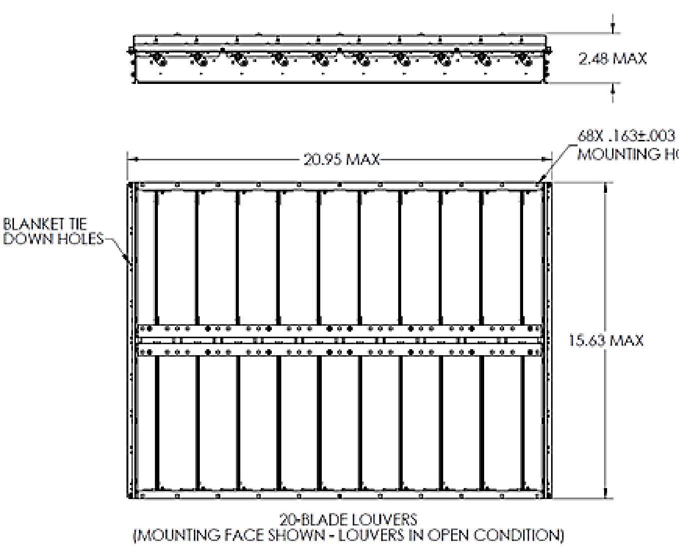
A standard louver enables radiation from a mounting surface by opening the blades when the mounting surface temperature exceeds a set point. Mounted to a heat source, the louver faces a cold sink (usually space vacuum). The blades operate from fully closed to fully open within approximately 20 °C. The set point, defined as the point where the blades begin to open, can be set between –20 °C to +50 °C.

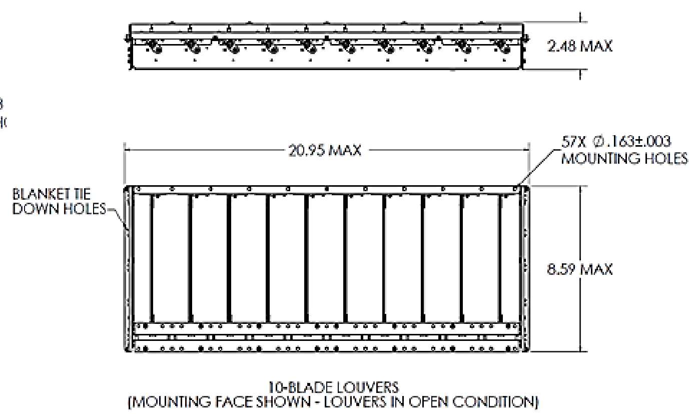
Effective emissivity of the louver is defined in terms of the effective combined thermal emissivity of the mounting surface and louver. A louver provides an effective emissivity of 0.14 or less when all blades are closed and have an effective emissivity of 0.74 or greater when all blades are open. These values assume a radiator mounting surface with emissivity of 0.85 in the infrared (IR) spectrum. The ratio of the two values is called the turndown ratio, which represents the effectiveness of the louver/radiator combination. The high-temperature blade design allows for intermittent direct solar exposure to 0.6 AU. Options such as reverse operation and custom sizing are available.



Passive Thermal Louvers 20-blade and 10-blade examples.

Dimensions





Note: All dimensions above are in inches.

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Passive Thermal Louvers Features	
• Lightweight, simple design	• Multiple sizes to fit many applications
• High solar irradiance capability	• Extensive flight heritage
• Passive thermal control	• Fully redundant mechanics
• Grounded to prevent electrostatic discharge (ESD) build up	• Wide range of operational temperature band and set points

Applications
• Passive thermal control of spacecraft during interplanetary missions

Heritage Programs	
• Juno Mission	• New Horizons Pluto
• QuickBird Earth Observation Satellite	• Rosetta Spacecraft
• Parker Solar Probe (PSP)	• Restricted program
Nearly 100 flight units built to date.	

Blade Variance Specifications				
Louver Size	**Radiating Area**		**Mass**	
	in²	**cm²**	**oz**	**grams**
20-Blade (2 rows)	248	1,600	45.6	1,290 max
14-Blade (2 rows)	220.8	1,425	29.7	940 max
10-Blade (1 row)	124	800	31.4	890 max
7-Blade (1 row)	110.4	712	20.5	580 max
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.				

Product Specifications		
	U.S.	**SI**
Mechanical		
Qualified Random Vibration	12.6 Grms	
Life Cycles	20,000 cycles	
Thermal		
Thermal Control Band	57 °F to 68 °F	14 °C to 20 °C
Temperature Set Point Range	-4 °F to +122 °F	-20 °C to +50 °C
Effective Emissivity (with radiator emissivity >0.85)	Closed: 0.14 max; Open: 0.74 min	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

PRESSURE CONTROL SYSTEM (PCS)

Sierra Space’s Assembly Units provide a functional, single-panel assembly with flexible controls.

Catalog data sheets for our Assembly Unit technology area include:

Composite Overwrapped Pressure Vessels (COPV)

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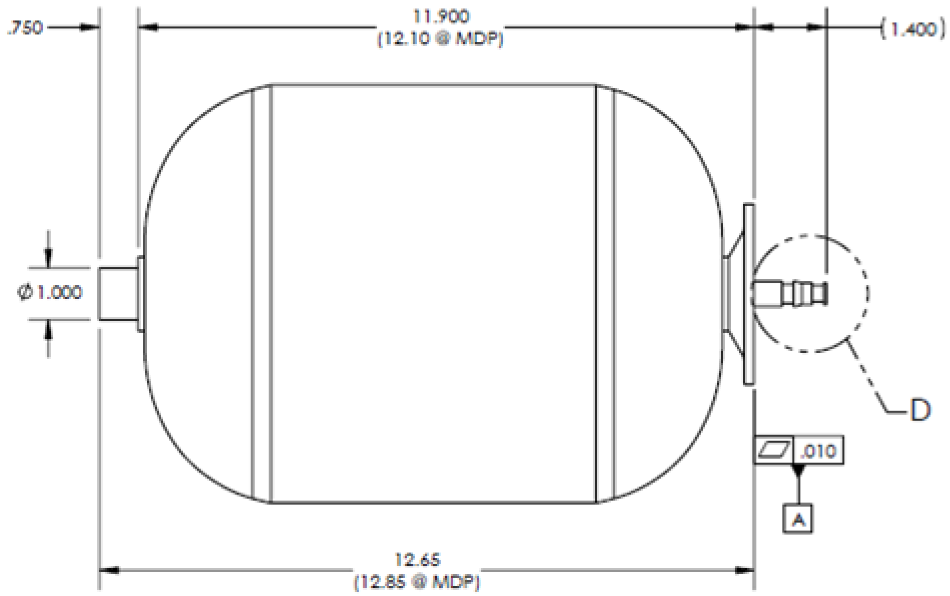
Composite Overwrapped Pressure Vessels (COPV)

Design Description

Sierra Space designed and qualified gaseous oxygen and nitrox Composite Overwrapped Pressure Vessels (COPV). The Inconel lined, carbon fiber overwrapped pressure vessels are designed to store high-pressure oxygen or nitrox safely for gas delivery systems. We developed the COPV with critical, industry partners to provide space flight COPVs that leverage extensive industry heritage. We offer customized designs that can meet customers' needs beyond those listed in the specifications below.

High-Pressure COPV

Dimensions



Note: All dimensions above are in inches

Composite Overwrapped Pressure Vessels (COPV) Features	
• Stretch-formed cylinder heads	• Industry benchmark composite design and analysis tools
• Industry leading Class A welds	• Longstanding working relationship in technology development with NASA
• NASA Special Level Nondestructive Inspection (NDI) certifications	

Applications
• High-pressure gas storage

Product Specifications	
Mechanical	
Storage Capacity	400 in^3, 900 in^3
Maximum Design Pressure (MDP)	5,000 psig
Proof and Burst Factors	Proof: 1.25x MDP, Burst: 2x MDP
Empty Mass	9.1 lbm (400 in^3), 15.4 lbm (900 in^3)
Liner Material	Inconel 718 (Aluminum, Corrosion-Resistant Steel (CRES) available)
Mounting Options	Many. Please inquire.
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

RADIATOR

Sierra Space has extensive experience in spacecraft thermal control. Our portfolio includes thermal louvers that draw from decades of NASA/JPL heritage and are currently supporting several interplanetary spacecraft and heat switches, which for years reliably controlled the main battery temperature on the Mars Exploration Rovers Spirit and Opportunity. Both technologies are considered passive approaches that require no externally supplied power to operate, allowing valuable spacecraft power to be reserved for other needs.

Catalog data sheets for our Thermal Control Systems technology area include:

Miniature Satellite Energy-Regulating Radiator (MiSER)

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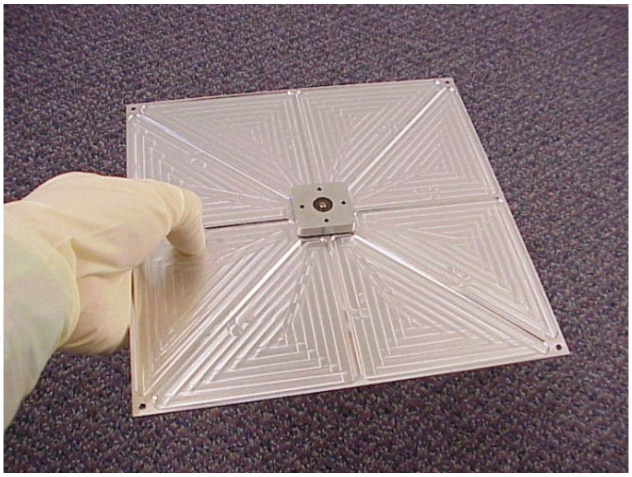
Miniature Satellite Energy-Regulating Radiator (MiSER)

Design Description

Sierra Space developed a Miniature Satellite Energy-Regulating Radiator (MiSER) for small spacecraft thermal control. The design consists of a flat radiator panel integrally mounted on a heat switch. The MiSER is mounted to the exterior of the spacecraft with the integral heat switch coupled to the heat load. The heat switch provides passive thermal control to the internal components of the spacecraft. The design is modular with each switch capable of dissipating 12 W. Single panels can be used to control the temperature of specific components or multiple panels can be used to control the temperature of the entire spacecraft. Custom radiator shapes provide the ability to match unusual geometries.

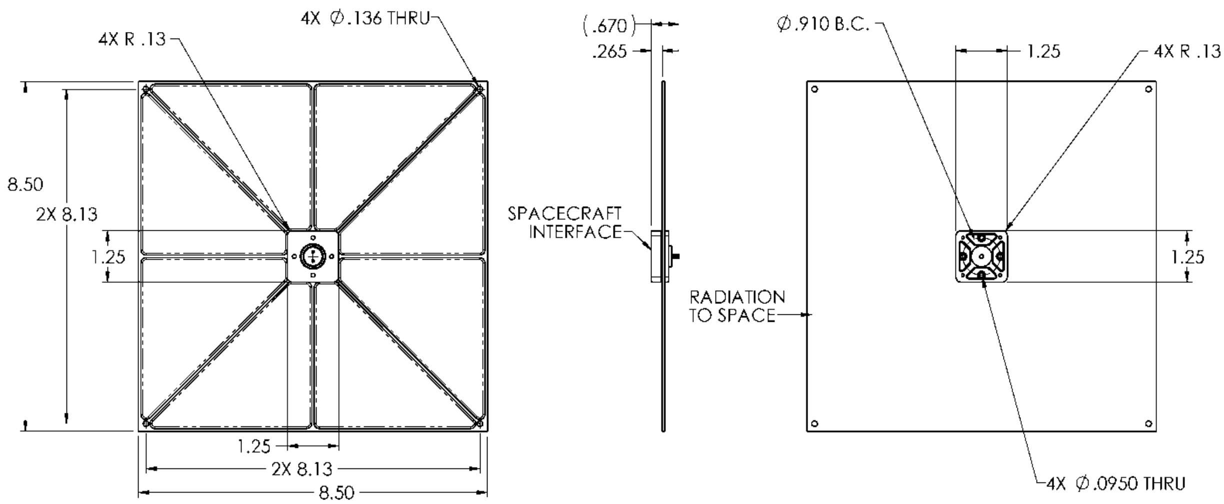


Miniature Satellite Energy-Regulating Radiator (MiSER)

When the temperature of the spacecraft rises above the set-point temperature, the switch conductance increases, allowing the excess heat to be transferred through the switch to the radiator and out to space. The switch conductance decreases when the temperature of the spacecraft drops below the set-point temperature. This insulates the spacecraft from the colder radiator panel and allows it to stay warm using a low-level of standby power.

Miniature Satellite Energy-Regulating Radiator (MiSER) Features	
• Low cost	• Passive operation
• High turndown ratio	• Precise, narrow control band
• Robust construction	• Low mass
• Numerous set points available	• Linear conductance between open/closed valves

Dimensions



Note: All dimensions above are in inches.

Applications	
• Dissipate heat from spacecraft components such as electronics	• Thermally isolate critical areas of spacecraft from cold space environment
• Thermally connect/disconnect a radiator based on Thermal Control System needs	• Switch alone can be used to change conductance of thermal path based on temperature
• Switch radiator combination useful for controlling temperature locally for small heat generating components	

Heritage Programs
• Qualification hardware delivered to customer

Product Specifications		
	U.S.	**SI**
Mechanical		
Heat Switch Dimensions	1.26 in x 1.26 in x. 252 in	32.0 mm x 32.0 mm x 6.4 mm
Radiator Dimensions	8.5 in x 8.5 in x 0.075 in (or to custom requirements)	216 mm x 216 mm x 1.9 mm (or to custom requirements)
Heat Switch Mass	0.705 oz	20 g
Radiator Mass (Aluminum)	4.22 oz	120 g
Life Cycles (Tested)	>100,000	
Operation Time	Depends on heating rate	
Thermal		
Operating Temperatures	-202 °F to +212 °F	-130 °C to +100 °C
Available Set-point Temperatures (Typical; Others Available)	14 °F to 122 °F	-10 °C to +50 °C
Conductance (Total)	Closed: 0.74 BTU/hr-in^2-F Open: 0.0095 BTU/hr-in^2-F	Closed: 607 W/m^2-C Open: 7.8 W/m^2-C
Turndown Ratio	78:1	
Maximum Q (Power)	40.1 BTU/hr	12 W
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

REGULATORS

Single-Stage Gas Regulator

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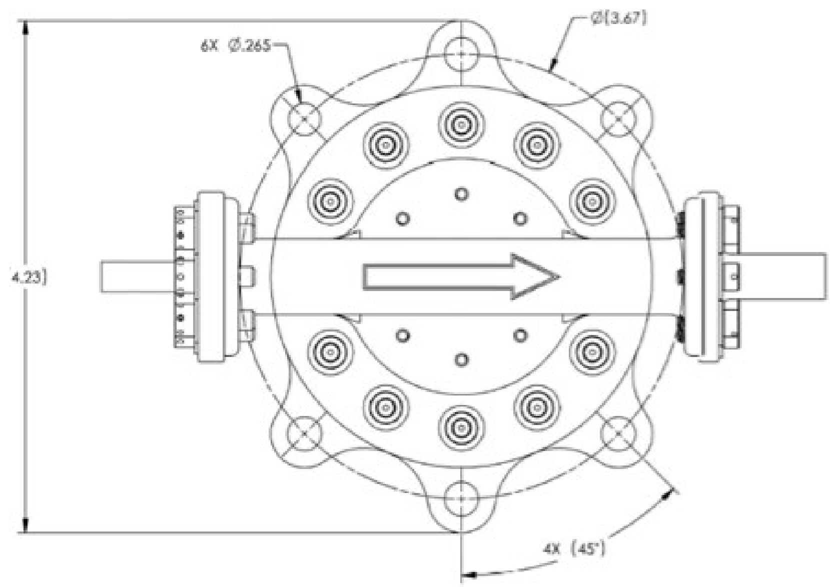
Single-Stage Gas Regulator

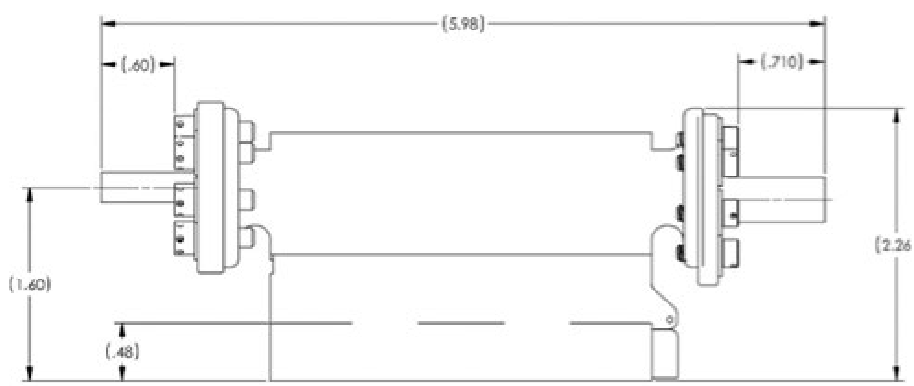
Design Description

Sierra Space collaborated with an industry leading partner to design and flight-certify a single stage, oxygen-rated, pressure regulator. The regulator, in addition to being qualified to the conditions shown in the Product Specifications table, is certified for use with 100% oxygen in accordance with NASA-STD-6001, *Flammability, Offgassing, and Compatibility Requirements and Test Procedures*.

Gas Regulator, shown here with weld tube-stubs, is 100% oxygen compatible.

Dimensions





Note: All dimensions above are in inches.

Single-Stage Gas Regulator Features	
• Inconel construction	• 100% oxygen compatible in accordance with NASA-STD-6001, Flammability, Offgassing, and Compatibility Requirements and Test Procedures
• All external parts welded to eliminate leaks	• Oxygen compatibility analysis and testing available
• Reference cavity is sealed to vacuum	• Four-lobed fastener mounts with weld tube-stubs standard

Applications
• Pressure regulation

Product Specifications		
	U.S.	**SI**
Performance		
Inlet Pressure Range	500 to 4,200 psia	3.4 to 29 MPa
Outlet Regulation Band	70 to 120 psia	0.45 to 0.85 MPa
Flow Rate	=<80 lbm/hr	=<36.3 kg/hr
Mechanical		
Mass	2.3 lbm	5.1 kg
Environmental		
Random Vibration: Qualified to	9.8 Grms	
Shock: Qualified to	5,000 G	
Temperature Range	-115 °F to 120 °F	-80 °C to 49 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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SENSORS

Sierra Space Sensor technology is customizable for a wide range of customer applications and requirements. They are designed to meet high shock and vibration environments, and some designs are available in radiation-qualified lots. Many of these components can be configured for analog or digital output.

Catalog data sheets for our Sensor technology area include:

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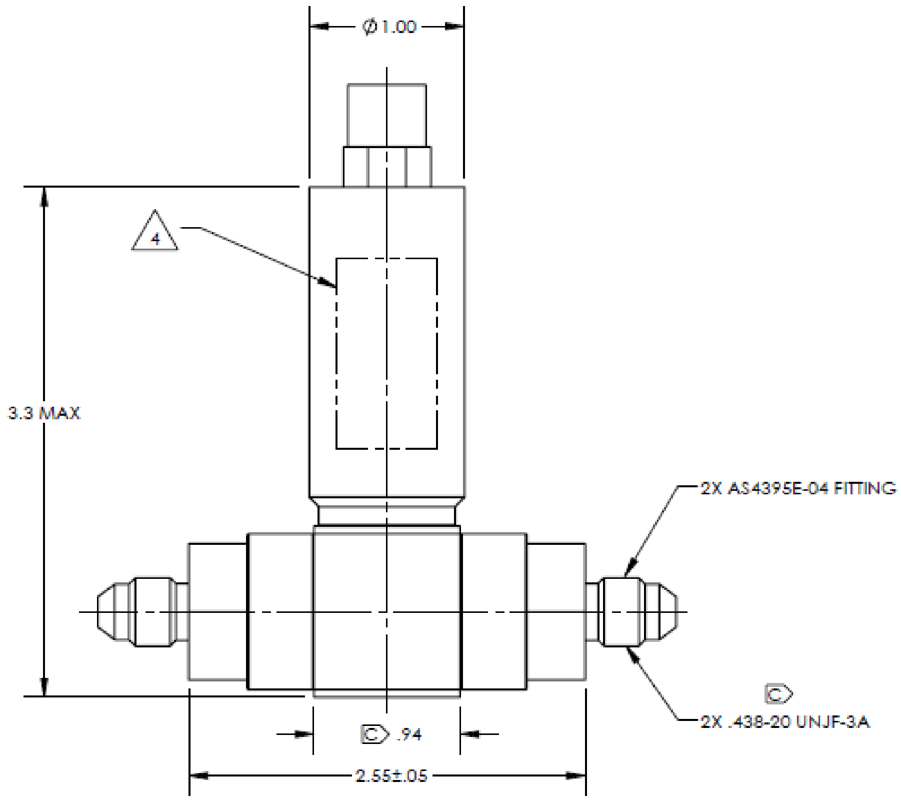
Absolute and Differential Pressure Sensors

Design Description

Sierra Space provides a range of flight-qualified absolute and differential pressure sensors to support current programs. These absolute and differential pressure sensors cover multiple environments and working fluids. The options available across the product line are easily customizable to meet a variety of customer application requirements.

Analog Output, Differential Pressure Sensor

Dimensions



Note: All dimensions above are in inches. Differential pressure unit shown.

Absolute and Differential Pressure Sensors Features	
• Custom pressure ranges: 0-15 ksi (absolute), 0-1 to 0-500 psid (differential pressure)	• Radiation (TID, SEE) qualified lots available
• Designed to meet high shock and vibration environments	

Applications
• Pressure monitoring

Product Specifications		
Mechanical		
Static Pressure Accuracy	±0.05% or ±0.1% full scale output (FSO)	
Process Port	AS4395, AS930, welded stub, custom	
Lightweight	100-250 g	
Electrical		
Connector	Glenair 805 Series, D38999, others	
Output Options	Analog: 0-5 Vdc, 0-10 Vdc, 4-20 mA (isolated or non-isolated) Digital: RS-485	
Circuit Protection	Meets MIL-STD-461 and MIL-STD-462 EMI/RFI (some options may affect ratings)	
Materials of Construction		
316L CRES, 304L CRES, Inconel 625, Monel K500, many more options		
Environmental		
Operating Temperature Range	-65 to +250 °F	-58 to 155 °C
EEE Grade Level	Many available, please inquire	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

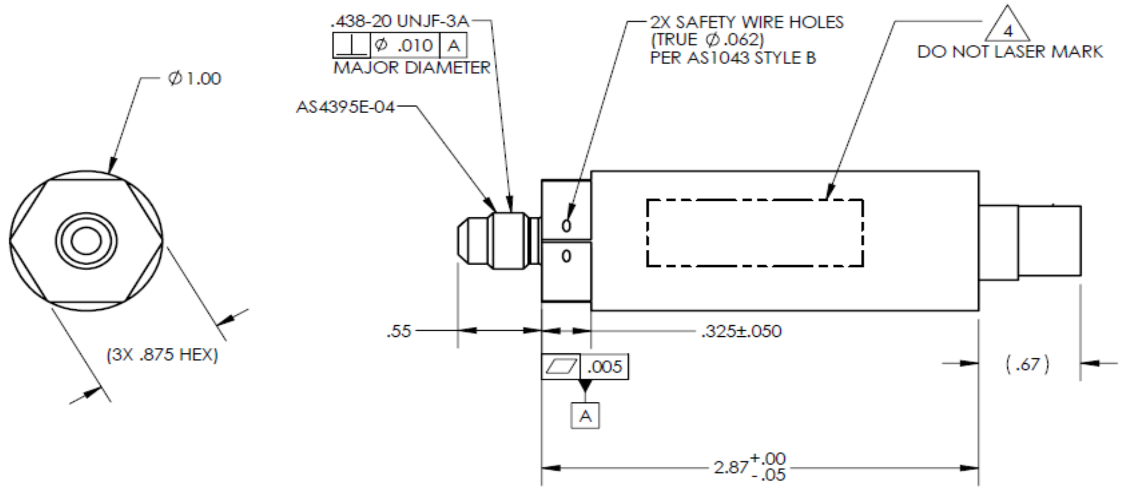
Cabin Pressure Sensor

Design Description

Sierra Space flight-qualified a spacecraft Cabin Pressure Sensor. The sensor provides highly accurate pressure readings with a flight certified materials and electronics. This sensor is compatible with a variety of gases and fluids.

Cabin Pressure Sensor

Dimensions



Note: All dimensions above are in inches

Cabin Pressure Sensor Features	
• Custom pressure ranges: 0-117 kPa, 0-17 psi (custom ranges available)	• Designed to meet high shock and vibration environments
• Temperature Compensation	

Applications	
• Pressure monitoring	

Product Specifications		
	U.S.	**SI**
Performance (Custom Ranges Available)		
Minimum Pressure Measurement Range	0 to 17 psi	0 to 117 kPa
Compensated Temperature Range	0.4 to 159.8 °F	-17 to 71 °C
Zero Error	±0.5% FSO	
Span Error	±0.5% FSO	
Static Accuracy	0.1% FSO	
Total Error = Sum of Zero Error + Span Error + Static Accuracy		
Mechanical		
Mass (maximum)	0.5 lbm	0.22 kg
Housing	316L CRES Bar in accordance with ASTM-249/269	
Finish	Passivate in accordance with AMS 2700, Method 1, Any Recommended Type, Class 1 or Class 2	
Proof Pressure	1.5x Range	
Burst Pressure	2x Range	
Fluid Compatibility	Atmospheric Air	
Electrical		
Electrical Connector	D38999/27YA35PN (many options available)	
Supply Current	50 mA maximum	
Supply Voltage	9 - 32 Vdc	
Input Impedance	>10 MΩ	
Protocol	RS-485/ASCII	
Environmental		
Operational Temperature Range	-27.4 to 159.8 °F	-33 to 71 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

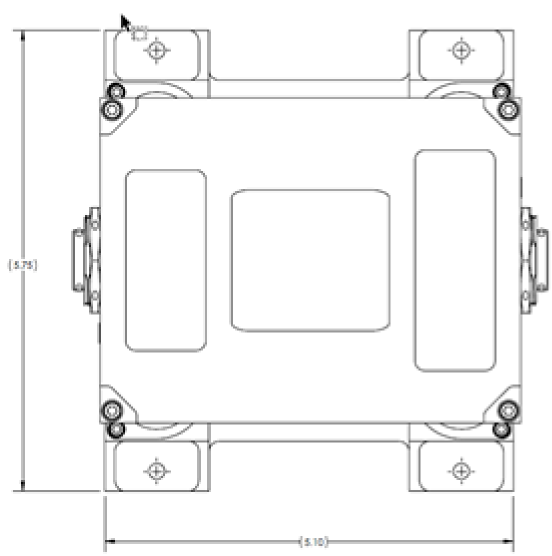
Cabin Smoke Detector

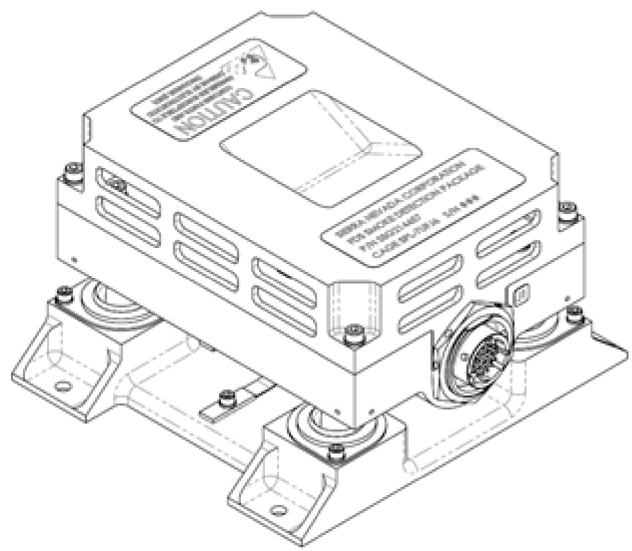
Design Description

Sierra Space collaborated with an industry leader to provide a flight-qualified Cabin Smoke Detector to provide continuous atmospheric measurement of smoke particles. It does this by using photoelectronic technology to deliver stable and accurate measurements and can be supplied with analog or digital signal output.

Smoke Detector undergoing qualification random vibration testing

Dimensions





Note: All dimensions above are in inches.

Cabin Smoke Detector Features	
• Aluminum body construction	• Four mounting feet
• Redundant sensors	• Works in airflow
• Particle profile modification	• Digital serial output
• Currently EEE grade 4+, potential Grade 1	

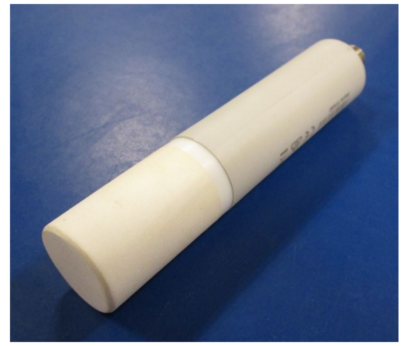
Applications	
• Smoke detection	• Crew safety

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	2.5 lbm	1.1 kg
Electrical		
Maximum Power @ 24 Vdc	<3 W	
Input Voltage Range	18 – 32 Vdc	
Output Options	Analog: Discrete, Digital: Controller Area Network (CAN)	
Environmental		
Vibration: Qualified to	13.8 Grms	
Shock: Qualified to	1,414 G	
Operating Temperature Range	-60 to +167 °F	-50 to +75 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Carbon Dioxide Sensor

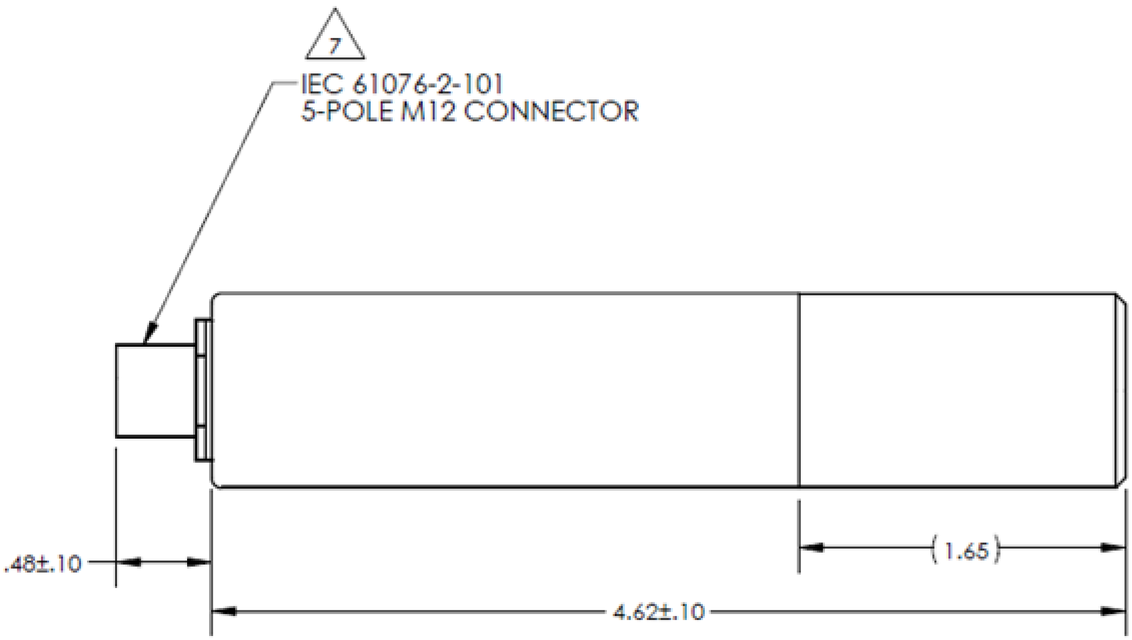
Design Description

Sierra Space provides a flight-qualified Carbon Dioxide Sensor to provide continuous atmospheric measurement of ambient carbon dioxide concentration. The sensor uses non-dispersive infrared (NDIR) technology to deliver stable and accurate measurements and can be supplied with analog or digital signal output.



Carbon Dioxide Sensor

Dimensions



Note: All dimensions above are in inches.

Carbon Dioxide Sensor Features	
• Shock-resistant mount	• Variety of output signal options
• Tested and screened electronics for low Earth orbit (LEO)	• Flight-qualified
• EEE Grade Level 4	• Shock/Vibration isolators are available upon request

Applications
• Continuous measurement of ambient carbon dioxide concentration

Product Specifications		
	U.S.	**SI**
Performance		
Measurement Range	0 – 10,000 ppm CO_2	
Accuracy	0 – 3,000 ppm: ±40 ppm 3,000 - 10,000 ppm: ±2% of reading	
Signal Output Options	Analog: 0 – 5/10 Vdc, 0/4 – 20 mA Digital: RS-485	
Mechanical		
Mass	0.13 lbm	0.58 kg
Electrical		
Maximum Power @ 24 Vdc	<0.5 W	
Input Voltage Range	12 – 30 Vdc	
Environmental		
Operating Temperature Range	-40 to 140 °F	-40 to 60 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

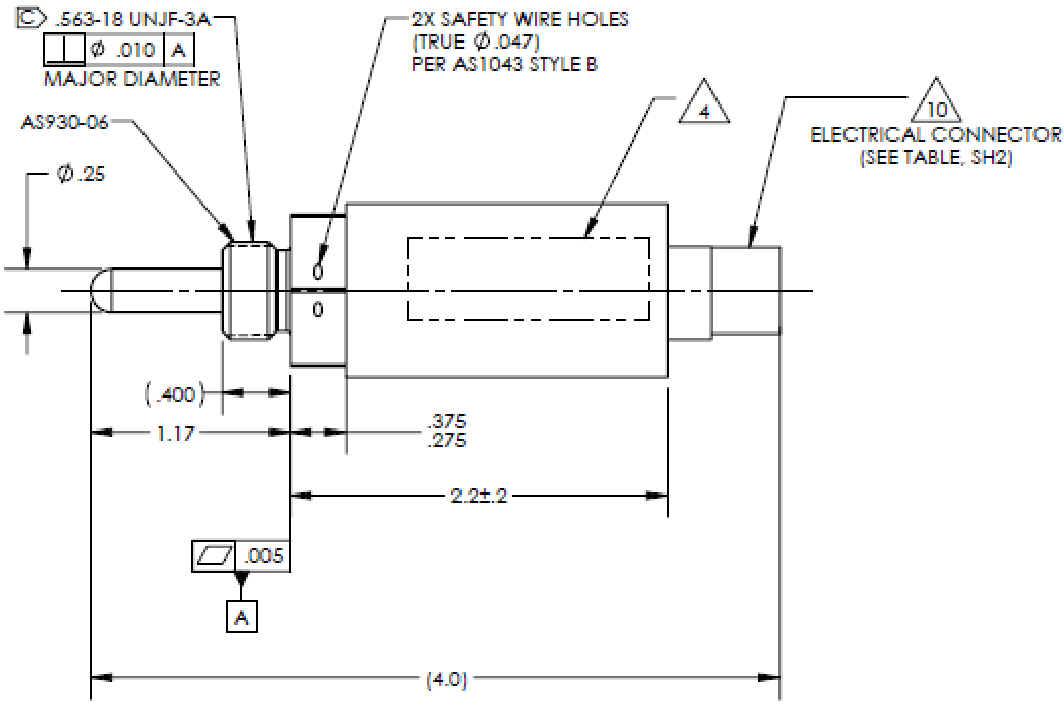
Combined Pressure/Temperature Sensor

Design Description

Sierra Space provides a flight-qualified range of combined pressure and temperature sensors to support current programs. Several unique pressure and temperature sensors are currently in development covering multiple environments and working fluids. The options available across the product line are easily customizable to meet a variety of customer application requirements.

Digital output, combined pressure/temperature sensor

Dimensions



Note: All dimensions above are in inches

Combined Pressure/Temperature Sensor Features	
• Custom pressure ranges: 0-15 ksi (absolute)	• Radiation (TID, SEE) qualified lots available
• EEE Grade Level 2+	• Designed to meet high shock and vibration environments

Applications	
• Pressure monitoring	• Temperature monitoring

Product Specifications		
Mechanical		
Static Pressure Accuracy	±0.05% or ±0.1% full scale output (FSO)	
Temperature Accuracy	Class A in accordance with IEC 60751:2008	
Process Port	AS4395, AS930, custom	
Electrical		
Connector	Glenair 805 Series, D38999, others	
Output Options	Analog: 0-5 Vdc, 0-10 Vdc, 4-20 mA (isolated or non-isolated) Digital: RS-485	
Circuit Protection:	Meets MIL-STD-461 and MIL-DTD-462 EMI/RFI (some options may affect ratings)	
Materials of Construction		
316L CRES, 304L CRES, Inconel 625, Monel K500, many more options		
Environmental		
Operating Temperature Range	-65 to 250 °F	-58 to 155 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

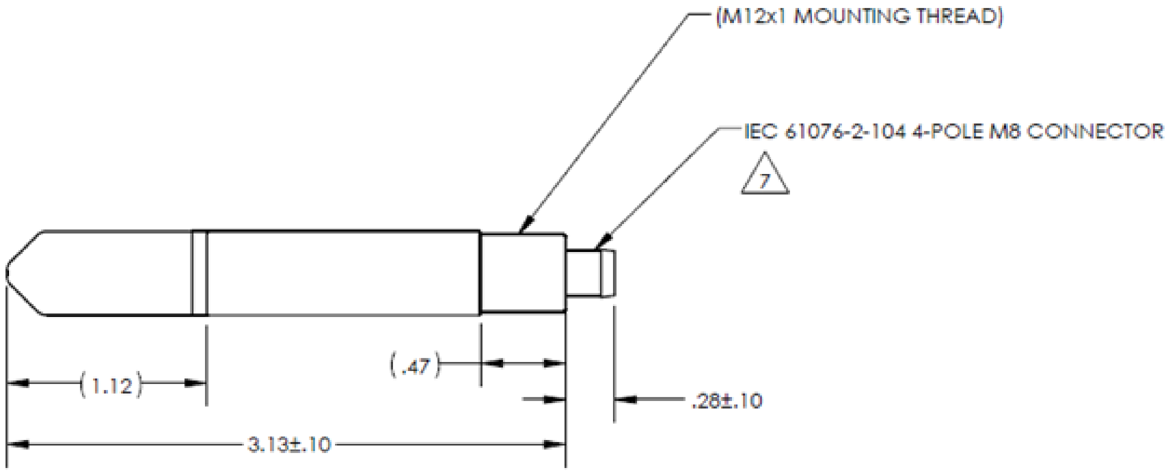
Combination Relative Humidity and Temperature Sensor

Design Description

Sierra Space provides a flight-qualified Combined Relative Humidity and Temperature Sensor to provide continuous atmospheric measurement of ambient conditions. The sensor uses state-of-the-art technology to deliver stable and accurate measurements and can be supplied with analog or digital signal output.

Relative Humidity and Temperature Sensor.

Dimensions



Note: All dimensions above are in inches.

Combination Relative Humidity and Temperature Sensor Features	
• Atmospheric monitoring and measurement	• Relative humidity accuracy: ±2% RH
• Dew point measurement range: -40 °F to +140 °F	• Relative Humidity (RH) Measurement Range: 0-100%
• Temperature Accuracy: IEC 60751 Class F0.1	• Analog output option: 0-2.5 Vdc, 0-5 Vdc, 4-20 mA
• Digital output option: RS-485	

Applications
• Humidity and temperature monitoring

Product Specifications		
	U.S.	**SI**
Performance Characteristics		
Measurement Range	0 – 100% RH	
Accuracy	0 – 90% RH: ±1.5% relative humidity (RH) 90 – 100% RH: ±2.5% RH	
Signal Output Options	Analog: 0 – 2.5, 0 – 5, 4 – 20 mA Digital*:* RS-485	
Heritage	Sierra Space *Dream Chaser*®	
EEE Grade Level	4	
Mechanical		
Mass	0.04 lbm	0.17 kg
Electrical		
Maximum Power @ 24 Vdc	<1.5 W	
Input Voltage Range	5 – 28 Vdc	
Environmental		
Operating Temperature Range	-40 to +140 °F	-40 to +60 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Constituent Sensor Package

Design Description

Sierra Space developed and qualified the Constituent Sensor Package to provide continuous atmospheric measurement of ambient carbon dioxide concentration, oxygen concentration, relative humidity, dew point, and temperature. The gas measurement ranges, and signal output types are customizable, allowing for a package tailored to an application's specific needs.

Constituent Sensor Package

No drawing currently available

Constituent Sensor Package Features	
• Atmospheric monitoring and measurement	• Relative Humidity Accuracy: ±1.5% RH
• Mass: 2.25 kg	• Dew/Frost Point Measurement Range: -40 °F to +140 °F.
• Carbon Dioxide (CO_2) Measurement Range: 0-10,000 ppm CO_2	• Dew/Frost Point Accuracy: ±4 ° F
• CO_2 Accuracy: ±2% of reading	• Temperature Measurement Range: -40 °F to +140 °F.
• Oxygen (O_2) Measurement Range: 0-50% O_2	• Temperature Accuracy: ±1 °F
• O_2 Accuracy: ±0.25% O_2	• Relative Humidity (RH) Measurement Range: 0-100% RH

Applications	
• Atmospheric monitoring	• Atmospheric measurement

Signal Output	
• CO_2 Analog: 0-5/10 Vdc, 0/4-20 mA Digital: RS485	• O_2 Analog: 0-4 Vdc, 4-20 mA
• RH/Dew Point/Temperature Analog: 0-1/2.5/5 Vdc, 4-20 mA Digital: RS485	

Product Specifications			
Default Performance Characteristics			
	Measurement Range	**Accuracy**	**Signal Output**
Carbon Dioxide	0 – 1% CO_2	±2% of reading	0 – 5 Vdc
Oxygen	0 – 50% O_2	±0.1% O_2	
Relative Humidity	0 – 100% RH	±1.5% RH	
Dew Point	-40 to +140 °F	±4 °F	
Temperature	-40 to +140 °F	±1 °F	
EEE Grade Level 4+			
		U.S.	**SI**
Mechanical			
Mass		5.0 lbm	2.25 kg
Footprint		8.0 in X 20.25 in	20 cm x 51 cm
Electrical			
Maximum Power @ 24 Vdc		<7 W	
Input Voltage Range		20 – 28 Vdc	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.			

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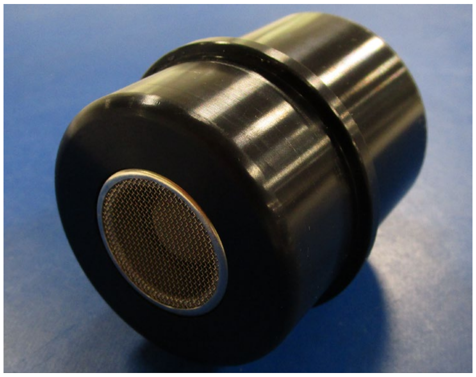
Oxygen Sensor

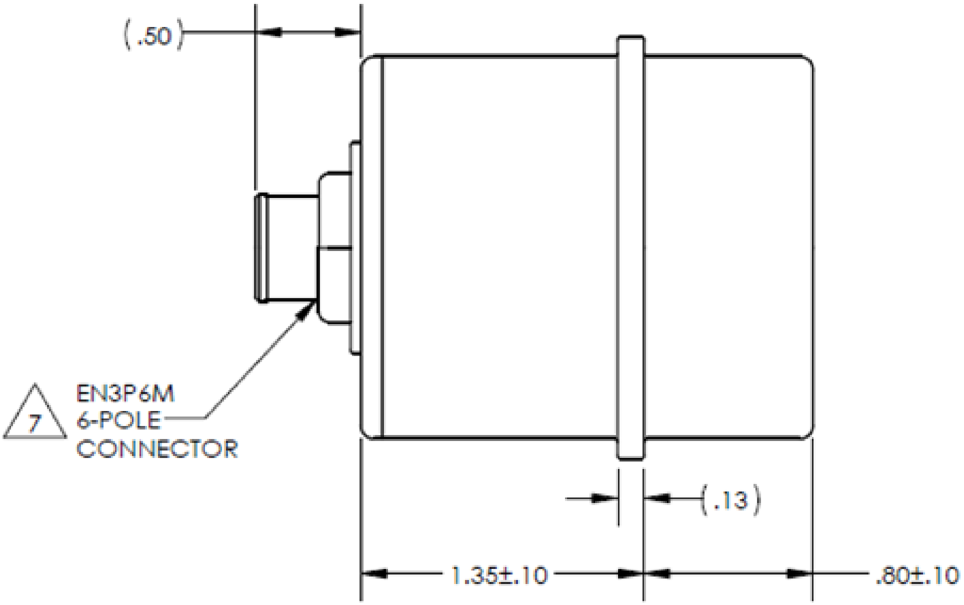
Design Description

Sierra Space provides a flight-qualified Oxygen Sensor to provide continuous atmospheric measurement of ambient oxygen concentration. The sensor uses zirconium oxide technology to deliver stable and accurate measurements and can be supplied with customizable analog outputs.



Oxygen Sensor.

Dimensions



Note: All dimensions above are in inches.

Oxygen Sensor Features	
• Measurement range: 0-50% O_2 (other options available)	• Weight: 0.5 kg
• Accuracy: ±0.25% O_2	• Shock: 1,400 gs
• Analog output options: 0-2.5, 4-20 mA	• Operating temperature range: -40 °F to +140 °F (-40 °C to +60 °C)
• Oxygen monitoring: Continuous ambient oxygen concentration	

Applications
• Continuous measurement of ambient oxygen concentration

Product Specifications		
	U.S.	**SI**
Performance Characteristics		
Measurement Range	0 – 50% O_2 (other options available)	
Accuracy	±0.25% O_2	
Signal Output Options	Analog: 0 – 2.5, 4 – 20 mA	
EEE Grade Level	4	
Mechanical		
Mass	1.0 lbm	0.5 kg
Electrical		
Maximum Power @ 24 Vdc	<3 W	
Input Voltage Range	10 – 28 Vdc	
Environmental		
Operating Temperature Range	-40 to +140 °F	-40 to +60 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

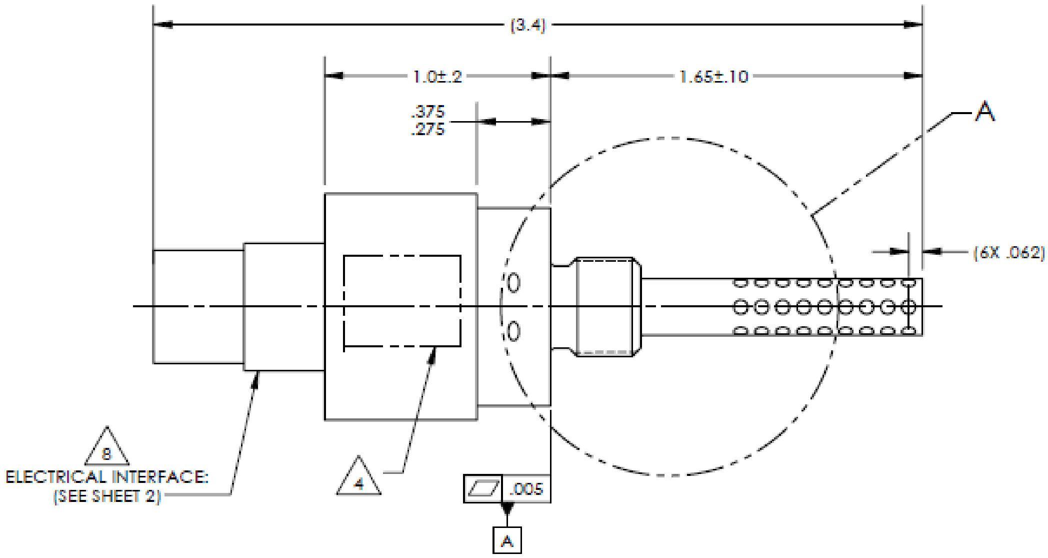
Temperature Sensor

Design Description

Sierra Space provides a range of flight-qualified temperature sensors to support current programs. Several unique temperature sensors are currently in development covering multiple environments and working fluids. The options available across the product line are easily customizable to meet a variety of customer application requirements.

Resistive Temperature Detector (RTD) Sensor

Dimensions



Note: All dimensions above are in inches

Temperature Sensor Features	
• Operating temperature ranges: -65 °F to 250 °F (-58 °C to 155 °C)	• Radiation (TID, SEE) qualified lots available
• Lightweight: 100-200 g	• EEE Grade Level: many available, please inquire
• Designed to meet high shock and vibration environments	• Circuit protection: Meets MIL-STD-461 and MIL-STD-462 EMI/RFI (some options may affect ratings)

Applications
• Temperature monitoring RTD Sensor

Product Specifications	
Mechanical	
Temperature Accuracy	Class A in accordance with IEC 60751:2008
Process Port	AS4395, AS930, custom
Electrical	
Connector	Glenair 805 Series, D38999, others
Output Options	Analog: RTD-multiple resistances available Digital: RS-485
Materials of Construction	
316L CRES, 304L CRES, Inconel 625, Monel K500, many more options	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

VALVES

Sierra Space's fluid control technologies incorporate high-build quality, modularity, and redundancy to fabricate products for a variety of uses. Manufactured to high tolerances, our systems are designed to be lightweight and compact. Many are already flight-qualified or certified, increasing customer confidence. Our fluid controls are also easily scaled to meet size and application requirements.

Catalog data sheets for our Fluid Controls technologies include:

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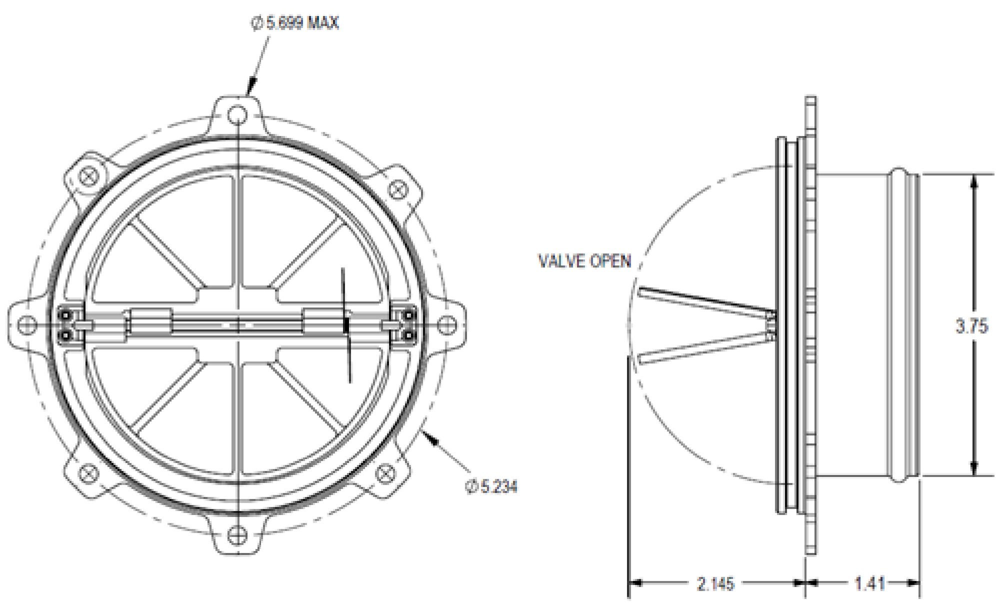
Air Check Valve

Design Description

Sierra Space designed and flight-certified the Air Check Valve for operation in conjunction with spacecraft ventilation systems. The air check valve works by preventing reverse airflow. It is designed for minimal pressure drop and operation in any orientation. The design is scalable/tunable and is offered in other qualified sizes.

Air Check Valve

Dimensions



Note: All dimensions above are in inches.

Air Check Valve Features	
• All-aluminum construction	• Low pressure drop
• Eight-fastener panel mount	• Certified for flight
• Cycle lifetime greater than 1,000 cycles	

Applications	
• Pressure monitoring	• Ventilation monitoring

Product Specifications		
	U.S.	**SI**
Performance		
Flow Rate	130 CFM	3.7 m^3/min
Leakage (Reverse)	0.5 SCFM Air @ 4-12 inH_2O Delta P	
Mechanical		
Mass	0.43 lbm	0.20 kg
Environmental		
Vibration: Qualified to	14 Grms	
Shock: Qualified to	1,414 G	
Operating Temperature Range	-40 to 140 °F	-40 to 60 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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Debris-Tolerant Isolation Valve

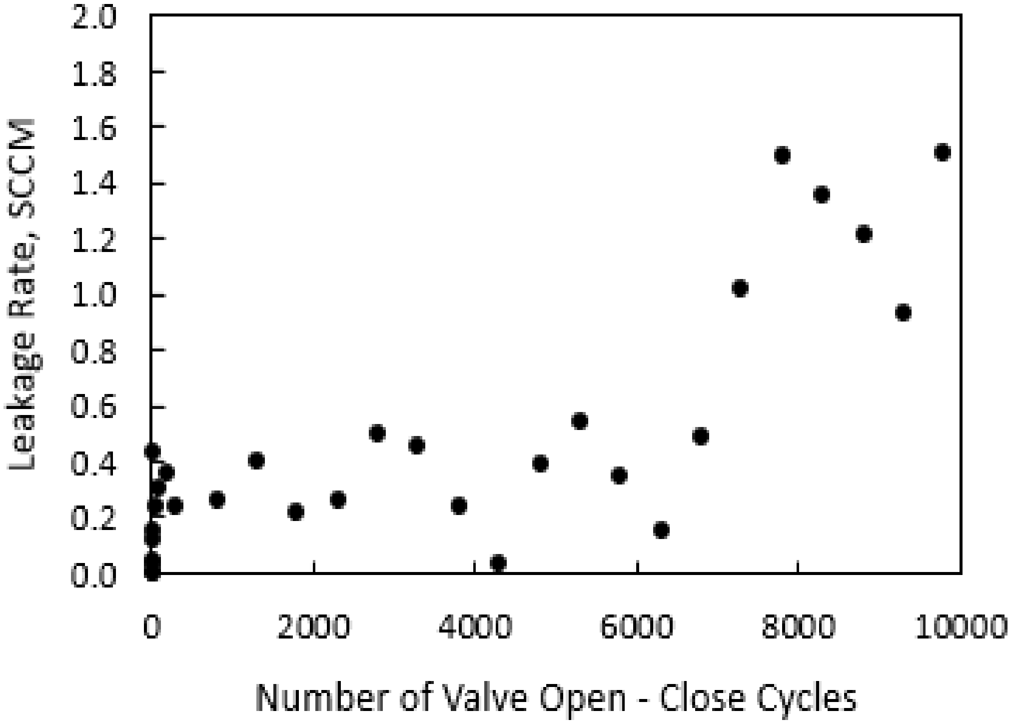
Design Description

Sierra Space developed and demonstrated a patent-pending debris-tolerant valve design capable of withstanding lunar regolith and other debris present on the sealing surface. This design has been demonstrated to survive over 10,000 cycles with lunar regolith simulant directly exposed to the seal at each cycle. Throughout testing, the leakage rate remained less than 2 sccm at 1 atm pressure differential. This valve has been matured to TRL 6 through testing in the relevant thermal vacuum environment.

The design is easily tailorable for different diameters and geometries and can even be adapted for airlock/docking interfaces. The system includes capability to remove bulk debris between sealing cycles, and there is capability to have the seal replaced autonomously for extremely long duration operation.

Debris-Tolerant Isolation Valve offers exceptional leakage and wear resistance over thousands of valve cycles

Leakage Rate Plot



Debris-Tolerant Isolation Valve Features	
• Demonstrated >10,000 cycle durability with flow of GreenSpar 250 lunar highlands regolith simulant through the valve between each cycle	• Design is adaptable for different geometries/sizes
• Unique design features used to minimize wear from abrasive materials without relying on brute-force methods such as hard coatings or exotic materials	• Adaptable to large systems including airlocks

Product Specifications
Performance
<2 sccm leak rate at 1 atm dP demonstrated after 10,000 cycles
Tailorable sizing for all flow rate needs
Environmental
Operating Temperature Range -45 °C to 150 °C (larger ranges can be accommodated upon request)
Vacuum tolerant
Tolerant to GSFC-STD-7000B, Section 2.4.2.5 random vibration profile (alternate vibration profiles available upon request)
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.

Motorized Isolation Valve (MIV)

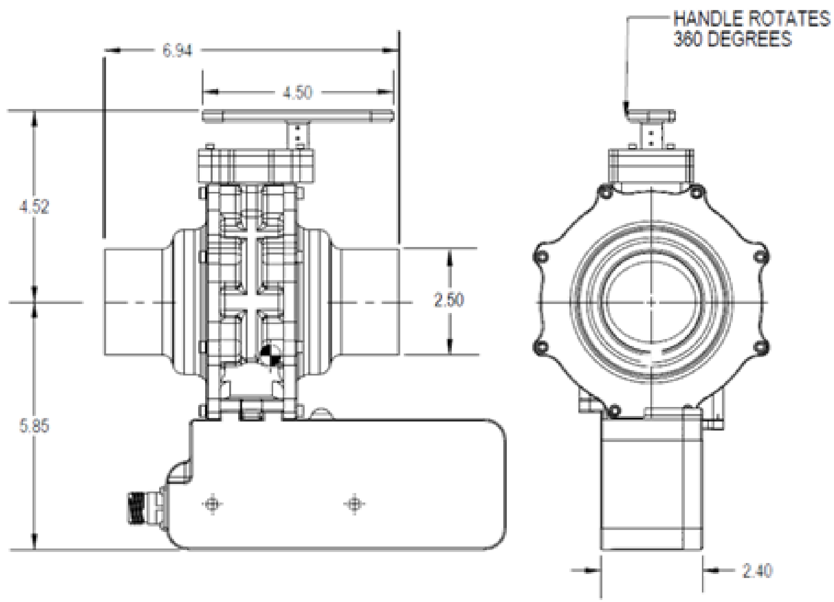
Design Description

Sierra Space designed and flight-qualified a Motorized Isolation Valve (MIV) to complement our ball valve fluid control product line. These MIVs are designed to limit flow resistance in low-pressure applications such as near atmospheric to vacuum conditions. From end-to-end the valve offers a clear path straight through with minimal gaps or intrusions, all designed to offer the lowest levels of pressure drop for a given flow rate.

The valves are actuated via a 3-phase, brushless DC motor with built-in controller. Options include open/close or throttling control via an externally provided analog signal. These valves are built in cleanrooms and are designed to operate within systems that require high levels of cleanliness. The technology used in the MIV is easily scaled to meet a variety of customer size and application requirements. Sierra Space provides multiple versions of this valve. A few example specifications are provided below. Note that most variables, such as actuation time, are dependent on load, power input, and environmental conditions. For applications requiring a smaller size valve, see Dual Motorized Isolation Valve product page.

High Inductance Motor Valve with actuator and manual override

Dimensions



Note: All dimensions above are in inches.

Motorized Isolation Valve (MIV) Features	
• Stainless steel tube ends	• Electronic hard stop
• All wetted materials corrosion-resistant steel (CRES) and PTFE	• High inductance
• 3-phase brushless DC motor	• Position feedback
• Grade 2+ EEE electronics	• Spaceflight-certified

Applications
• Gas/Fluid Isolation and Control

Large Tube – Motorized Isolation Valve – 2.5" Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	8.3 lbm	3.8 kg
Response Time in Vacuum @ 28 Vdc	<7 seconds	
Leakage (Internal @ 14.7 psid)	<0.1 sccm He	
Qualified to Lifetime	500 cycles, but has capability for many more	
Maximum Design Pressure	30 psid	
Electrical		
Maximum Power @ 28 Vdc	5.5 Watts	
Voltage Range	22-37 Vdc	
Environmental		
Vibration: Qualified to	7 Grms	
Shock: Qualified to	3,300 G	
Operating Temperature Range	-11 to 142 °F	-24 to 61 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

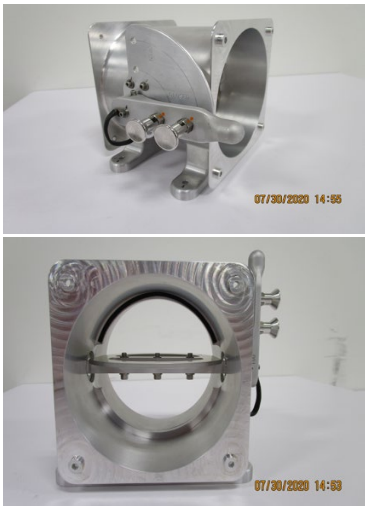
Motorized Isolation Valve – 3.0 in Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	9.9 lbm	4.5 kg
Response Time in Vacuum @ 28 Vdc	<9 seconds	
Leakage (Internal @ 14.7 psid)	<0.1 sccm He	
Qualified to Lifetime	500 cycles, but has capability for many more	
Maximum Design Pressure	30 psid	
Electrical		
Maximum Power @ 28 Vdc	8.5 Watts	
Voltage Range	22-37 Vdc	
Environmental		
Vibration: Qualified to	7 Grms	
Shock: Qualified to	3,300 G	
Operating Temperature Range	-11 to 142 °F	-24 to 61 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Manual Damper Valve

Design Description

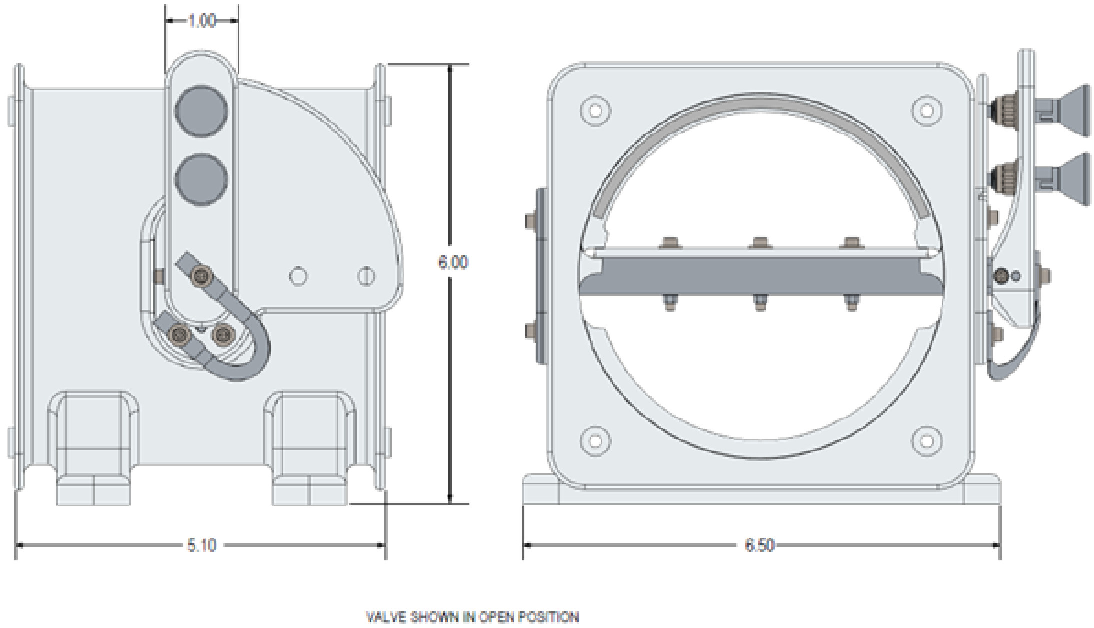
Sierra Space designed and flight-qualified the Manual Damper Valve to complement our environmental systems product line. These manual damper valves are designed to provide gaseous fluid flow dampening to increase pressure drop in the flow path or provide isolation. The valves are manually operated and feature positive locking at full open and full close and can be throttled throughout the entire range. The valves can be mounted via face mounts, flexible duct beaded ends, or welded to adjoining tubing.

The valves are actuated via a rotary handle that rotates 90 degrees against mechanical hard stops. The exact handle type can be modified to fit the application. These valves are built in cleanrooms and are designed to operate within systems that require high levels of cleanliness.



Manual Damper Valve integrated into composite ductwork bypass line.

Dimensions



Note: All dimensions above are in inches

Manual Damper Valve Features	
• Gentle, smooth rotation	• Mechanical hard stop
• 90-degree actuation	• Visual position feedback
• Variety of handle/knobs available	• Positive-lock, two action mechanism

Applications	
• Fluid control	• Gaseous fluid flow dampening

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	2 lbm	0.9 kg
Internal Diameter	4.98 in	126.5 mm
Degrees of Travel	90 deg	
Qualified to Lifetime	500 cycles, but has capability for tens of thousands	
Environmental		
Vibration: Qualified to	9 Grms	
Shock: Qualified to	180 G	
Operating Temperature Range	60 to 102 °F	15 to 39 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Manual Rotary Valve

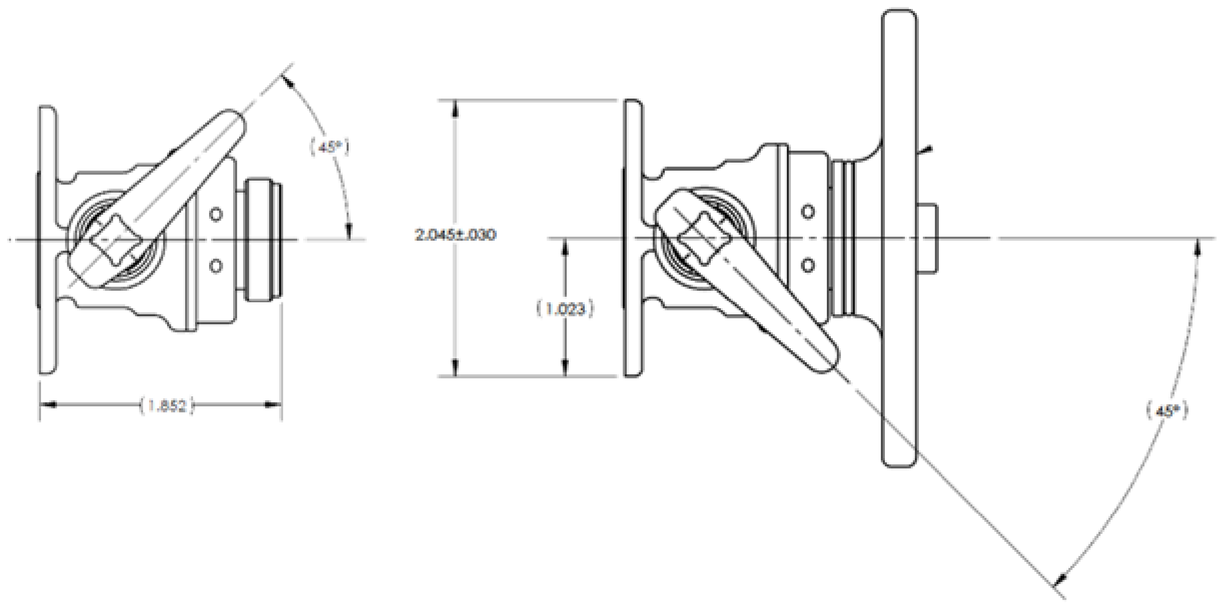
Design Description

Sierra Space designed and flight-qualified a Manual Rotary Valve to complement our ball valve fluid control product line. These manual rotary valves are designed to provide gas isolation. The valves can be mounted via panel mounts or tube clamp and can be mechanically connected or welded to a gas line. On the opposite end, gas is exhausted via a variety of vents or straight lines.

The valves are actuated via a rotary handle. The exact handle type can be modified to fit the application. For added seal redundancy, an easy-to-turn endcap is also standard. These valves are built in cleanrooms and are designed to operate within systems that require high levels of cleanliness.

Manual Rotary Valve with Panel Mount and Cap.

Dimensions



Note: All dimensions above are in inches.

Manual Rotary Valve Features	
• Gentle, smooth rotation	• Mechanical hard stop
• Face-seal or tube end integration	• 90-degree actuation
• 15-5PH Stainless steel construction	• Position feedback
• Variety of handle/knobs available	• Additional seal provided via cap

Applications
• Fluid control

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	1.2 lbm	0.54 kg
Qualified to Lifetime	250 cycles, but capable of thousands of cycles	
Leakage	<1 sccm He	
Operating Pressure	Vacuum - Ambient	
Environmental		
Vibration: Qualified to	16.7 Grms	
Shock: Qualified to	630 G	
Operating Temperature Range	32 to 332 °F	0 to 167 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Motorized Valve Assembly

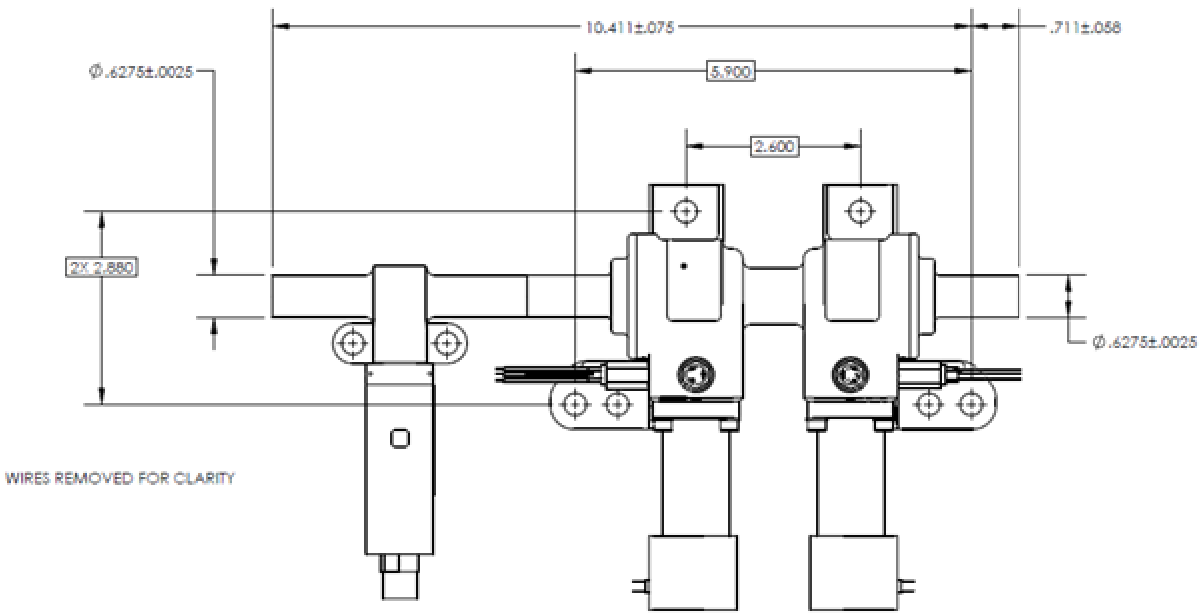
Design Description

Sierra Space designed and flight-qualified the Motorized Isolation Valve Assembly to complement our ball valve fluid control product line. These motorized ball valves are designed to provide isolation capability within a vacuum line, as well as pressure sensing. The full assembly comprises two motorized ball valves in series (for redundancy) and a pressure sensor. Weld tube-stubs are provided for integration into a fluid network.

The valves are controlled and actuated via a remotely positioned controller (not shown in picture below). This assembly is built in cleanrooms and is designed to operate within systems that require high levels of cleanliness. Applications include, but are not limited to, EVA and vacuum isolation.

Development Unit on Random Vibration Shaker Table.

Dimensions



Note: All dimensions above are in inches.

EVA Motorized Isolation Valve Features	
• Dual valves offer system redundancy	• Mechanical hard stop
• Stainless steel tube ends	• All wetted materials corrosion-resistant steel (CRES) and polytetrafluoroethylene (PTFE)
• Can be used for vacuum or pressure	• 3-phase brushless DC motor
• Position feedback	• Grade 2+ EEE electronics
• Spaceflight-certified	•

Applications
• Fluid control

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass (valves, sensor, controller, cables)	21 lbm	TBD kg
Leakage	<0.006 sccm He	
Degrees of Travel	90 deg	
Qualified to Lifetime	1,500 cycles, but has capability for tens of thousands of cycles	
Electrical		
Maximum Power @ 28 Vdc	6 Watts	
Voltage Range	22-37 Vdc	
Sensing Range		
Environmental		
Vibration: Qualified to	23.4 Grms	
Shock: Qualified to	1,500 G	
Operating Temperature Range	40 to 120 °F	4 to 49 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

MV-BY Manual Rotary Bypass Valve

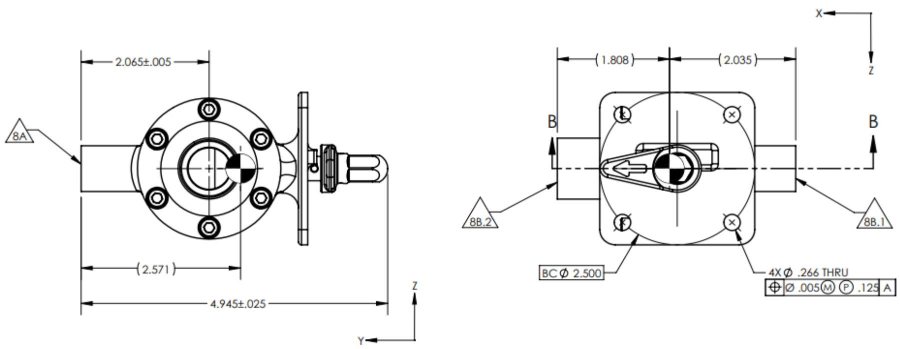
Design Description

Sierra Space designed and flight-qualified a MV-BY Manual Rotary Bypass Valve to complement our ball valve fluid control product line. The Manual Rotary Bypass valve is designed to provide separate and isolated primary and bypass flows. The identification of which of the three ports are used for the primary and bypass line flows can be modified based on customer application needs. The valves can be mounted via panel mounts and can be mechanically connected or welded to a line.

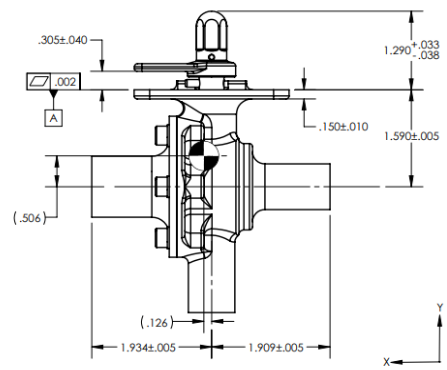
The valves are actuated via a removable rotary handle that rotates 90 degrees against mechanical hard stops. The exact handle type can be modified to fit the application. These valves are built in cleanrooms and are designed to operate within systems that require high levels of cleanliness.

Manual Rotary Valve

Dimensions



FLUID INTERFACE		
PORT	FLOW CONDITION	FITMENT
8A	INLET	Ø .75 ±.003 OD X .035±.0035 WALL INCONEL 718
8B.1	OUTLET, MAIN	Ø .75 ±.003 OD X .035±.0035 WALL INCONEL 718
8B.2	OUTLET, BYPASS	Ø 1.00 ±.003 OD X .028±.0028 WALL INCONEL 718
8C.1	HANDLE POSITION, MAIN FLOW	FLOW PATH, 8A TO 8B.1
8C.2	HANDLE POSITION, BYPASS FLOW	FLOW PATH, 8A TO 8B.2



Note: All dimensions above are in inches.

MV-BY Features	
• Gentle, smooth rotation	• Mechanical hard stop
• Removable handle	• Three ports
• 90-degree actuation	• All wetted materials corrosion-resistant steel (CRES) and polytetrafluoroethylene (PTFE)
• Variety or handle/knobs available	

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Applications
• Fluid control

Product Specifications					
	U.S.		SI		
Performance					
Flowrate vs. Valve Position Configuration 1	**Position**	**Flow-In**	**Primary**	**Bypass**	
	0.5 %	550 lb/hr	100%	0%	
	20 %	550 lb/hr	75%	25%	
	25 %	550 lb/hr	57%	43%	
	70 %	550 lb/hr	45%	55%	
	75 %	550 lb/hr	25%	75%	
	99.5 %	550 lb/hr	0%	100%	
Leakage (Internal @ 80 psid)	1.0 x 10(-4) sccs GHe				
Maximum Design Pressure	150 psid				
Mechanical					
Mass	0.7 lbm		0.3 kg		
Degrees of Travel	90 deg				
Qualified to Lifetime	1,500 cycles, but has capability for tens of thousands				
Environmental					
Vibration: Qualified to	10 Grms				
Shock: Qualified to	1,500 G				
Operating Temperature Range	40 to 120 °F		4 to 49 °C		
Performance					
Flowrate vs. Valve Position Configuration 2	**Position**	**Flow-In**	**Primary**	**Bypass**	
	0%	250 lbm/hr PGW or 900 lbm/hr GFE7200	100%	0%	
	100%	250 lbm/hr PGW or 900 lbm/hr HFE7200	0%	100%	
Internal Leakage:	Liquid Leak-Tight				
External Leakage:	<2.5e-4 sccs GHe @ 190 psid				
Maximum Design Pressure	190 psid				
Mechanical					
Mass	1.8 lbm (maximum, dry)		kg		
Degrees of Travel	180 deg				
Qualified to Lifetime	125 cycles, but capable of many more				
Environmental					
Vibration: Qualified to	43.9 Grms				
Shock: Qualified to	21.2 G (100 Hz) 1,99.7(1,778 Hz) 1,991.7 G (10,000 Hz)				
Operating Temperature Range	-113 °F – 122 °F		-80 to 50 °C		
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.					

Negative Pressure Relief Valve (NPRV)

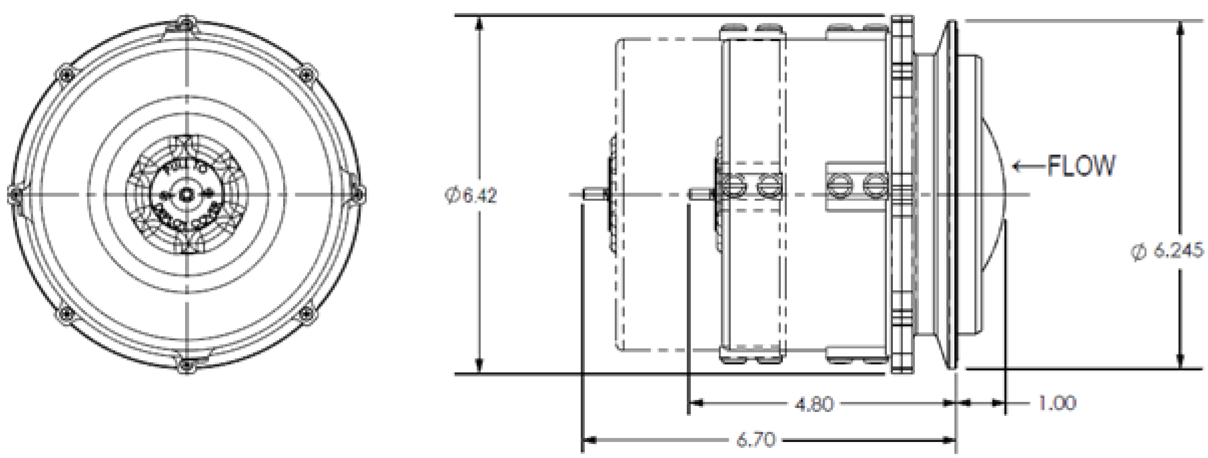
Design Description

Sierra Space flight-qualified a Negative Pressure Relief Valve (NPRV). This relief valve is designed to open at delta pressures below 1 psid and relieve pressure across the hull of a spacecraft via a large diameter relief valve. Once the delta pressure is reduced, the relief valve closes. This relief valve is also designed with a cap that provides a secondary seal during nominal operations. The cap itself is manually resettable.

These valves are built in cleanrooms and are designed to operate within systems that require high levels of cleanliness. These valves have been qualified and certified for space flight.

Negative Pressure Relief Valve (NPRV)

Dimensions



Note: All dimensions above are in inches.

Negative Pressure Relief Valve (NPRV) Features	
• High throughput via large diameter	• V-Band mounted
• Two seals against leakage across valve	• Certified for flight

Applications
• Pressure regulation

Product Specifications		
	U.S.	**SI**
Performance		
Gas Flow Rate (up to)	>1,300 lbm/hr	>590 kg/hr
Leakage (Internal @ 15.4 psid)	0.5 sccm GHe	
Relief Pressure (customizable)	0.4 psid	2.8 kPaD
Mechanical		
Mass	2.0 lbm	0.91 kg
Environmental		
Vibration: Qualified to	7.0 Grms	
Shock: Qualified to	2,500 G	
Operating Temperature Range	40 to 120 °F	4 to 49 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Positive Pressure Relief Valve (PPRV)

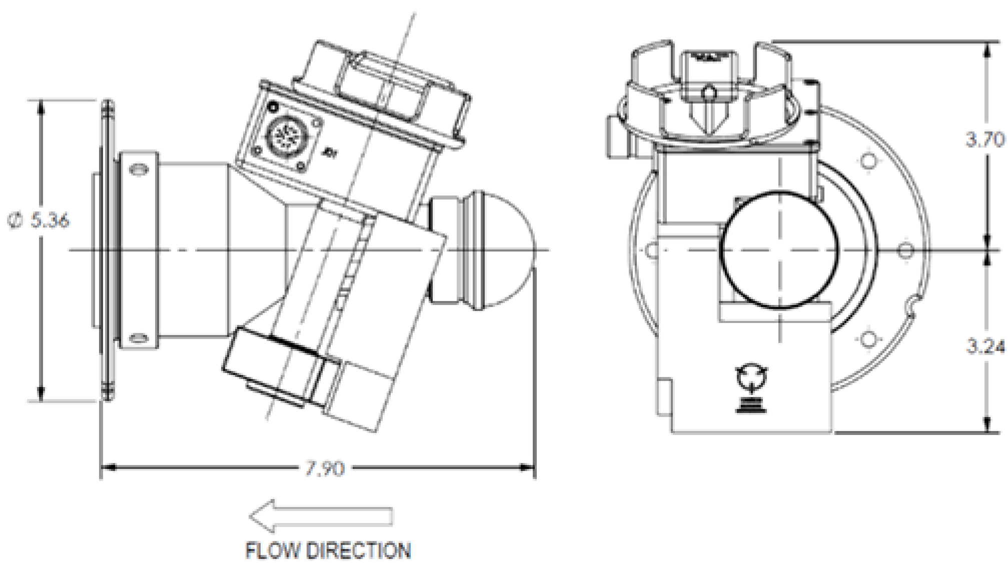
Design Description

Sierra Space flight-qualified a Positive Pressure Relief Valve (PPRV). This relief valve is designed to open at delta pressures just above nominal atmospheric pressure (~15 psid) and relieve pressure across the hull of a spacecraft via a large diameter relief valve. Once the delta pressure is reduced, the relief valve closes. This relief valve is also designed with a motorized isolation valve to provide an added layer of isolation. The isolation valve can be controlled via two 28 Vdc inputs to open and close and can be operated with a manual override.

These valves are built in cleanrooms and are designed to operate within systems that require high levels of cleanliness. These valves have been qualified and certified for space flight.

Positive Pressure Relief Valve

Dimensions



Note: All dimensions above are in inches.

Positive Pressure Relief Valve (PPRV) Features	
• High throughput via large diameter	• Flange mounted
• Motorized valve controlled via two, 28 Vdc inputs	• Certified for flight
• Grade 2+ EEE electronics	

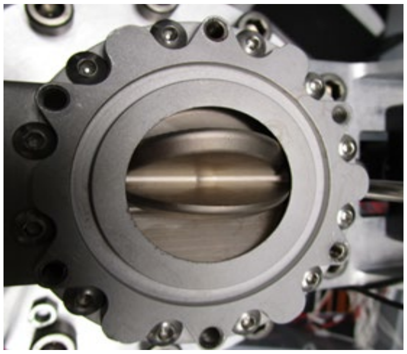
Applications
• Pressure regulation

Product Specifications		
	U.S.	**SI**
Performance		
Gas Flow Rate (up to)	>200 lbm/hr	>90 kg/hr
Leakage (Internal @ 15.2 psid)	0.1 sccm GHe	
Relief Pressure	15.2 psid	1.03 atm
Mechanical		
Mass	3.3 lbm	1.5 kg
Electrical		
Maximum Power	8 Watts @ 37 Vdc	
Input Voltage Range	22-37 Vdc	
Environmental		
Vibration: Qualified to	7.0 Grms	
Shock: Qualified to	3,200 G	
Operating Temperature Range	40 to 120 °F	4 to 49 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Powder Dosing Valve

Design Description

Sierra Space's Powder Dosing Valve starts and stops the flow of powders under harsh environments. This valve was designed specifically for dosing hard abrasive powders, such as lunar regolith but can be used for a wide verity of autonomous material handling operations. The dosing pedals are customizable to achieve different dosing rates depending on the desired application.



Powder Dosing Valve offers precise control for dosing abrasive compounds, such as lunar or Martian regolith handling.

Dimensions

(none in the Excel sheet)

Powder Dosing Valve Features	
• Lightweight	• Simple operation
• Accurate volumetric dosing	• Scalable
• Compact	• Position Feedback

Product Specifications
Performance
Lifecycle (tested) >10,000
Thermal vacuum tested from -45 °C to 150 °C (larger ranges can be accommodated upon request)
Space vacuum tolerant
Tolerant to GSFC-STD-7000B, Section 2.4.2.5 random vibration profile (alternate vibration profiles available upon request)
Tailorable sizing for all flow rate needs
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.

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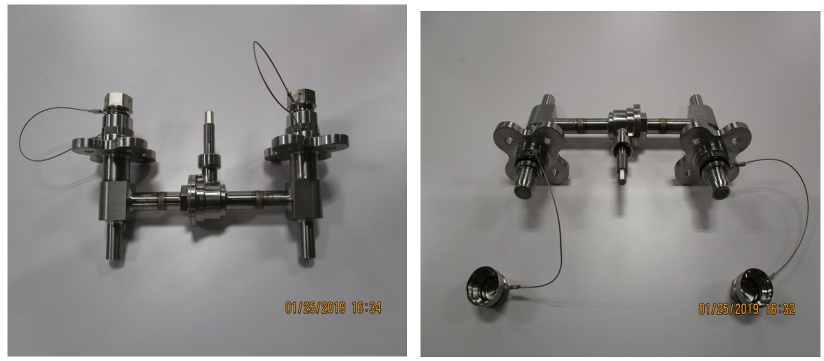
Service Manual Valve

Design Description

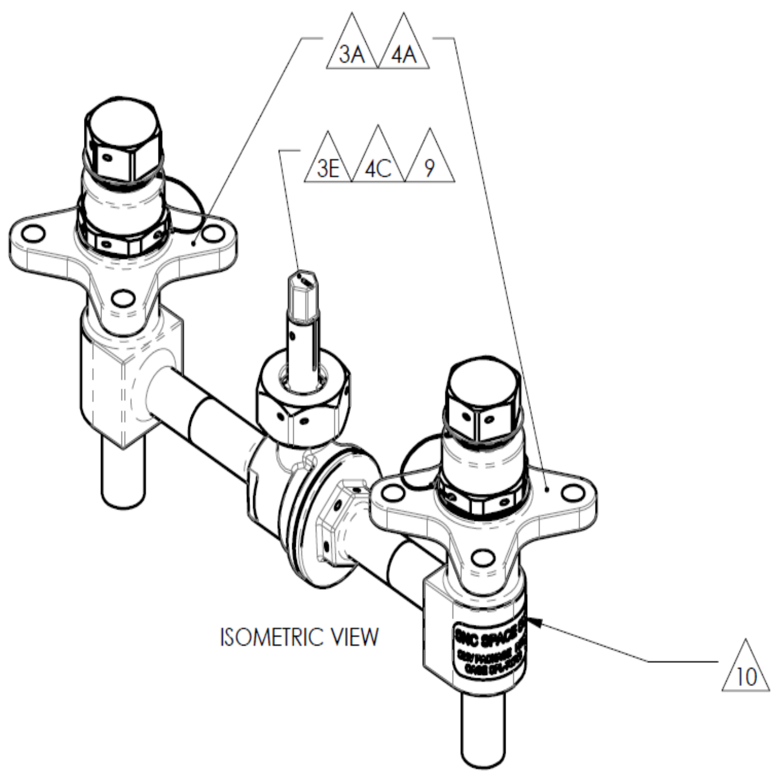
The Service Manual Valve (SMV) is a fight-qualified manually operated ball valve with integral male quick disconnects (QD). The SMV is primarily used for ground-based fill/drain operations for coolant loops and provides an interface for ground support equipment and vehicle coolant loops.

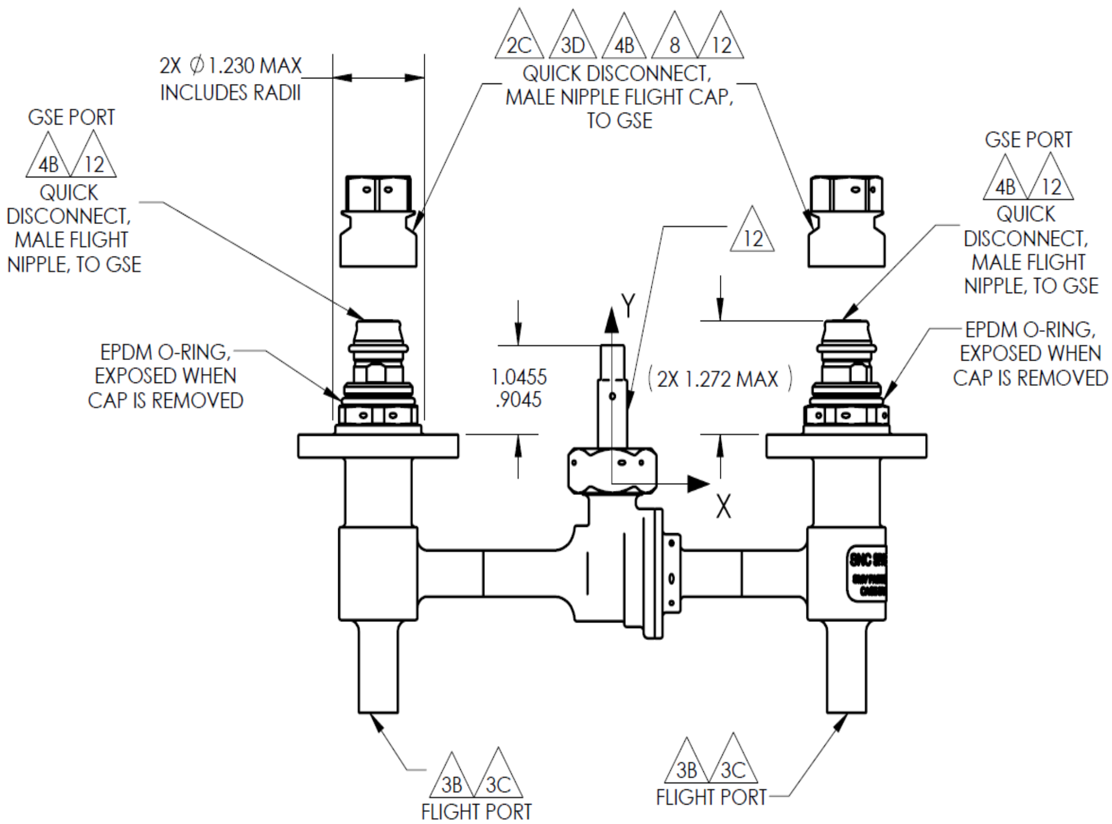


Service Manual Valve

Service Manual Valve Features	
• Manual two-way ball valve	• Two Male QDs with sealing dust caps when not in use
• Scalable	

Dimensions





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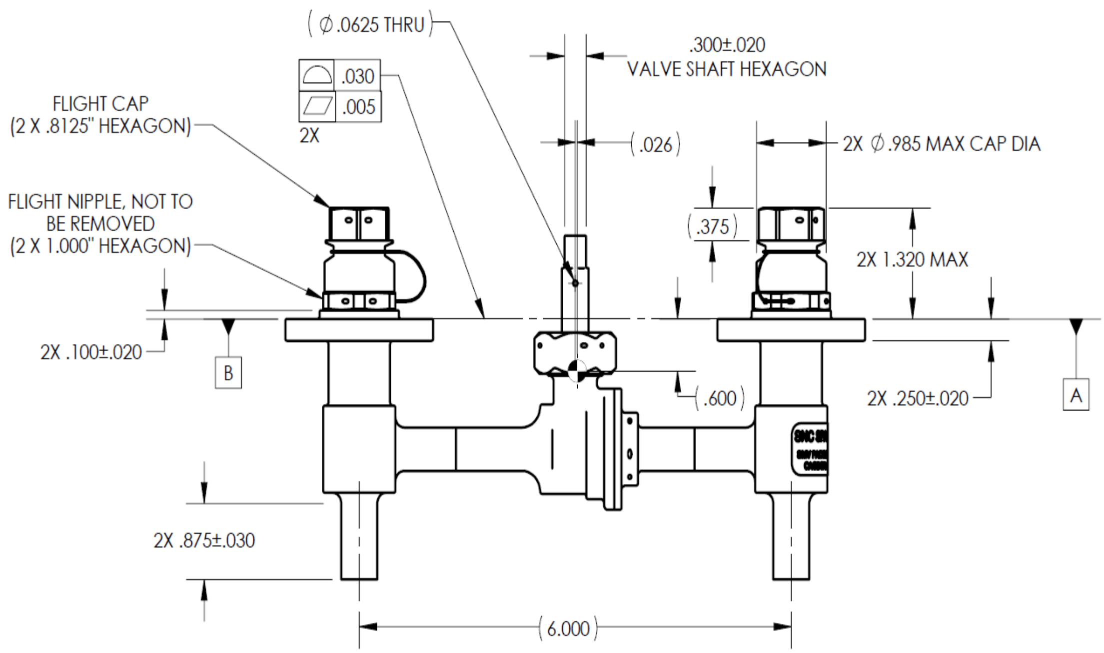

Note: All dimensions above are in inches

Product Specifications		
	U.S.	**SI**
Performance		
Pressure Drop in Open State	<1 psid @ 500 lbm/hr PGW	<6.9 kPad @ 0.063 kg/s PGW
Pressure Drop in Closed State (QDs connected)	<2 psid @ 500 lbm/hr PGW	<13.8 kPad @ 0.063 kg/s PGW
Internal Leakage Rate	<7.9 scc/s GHe when valve in closed position	
External Leakage Rate	<2.8e-4 SCC/S GHe (with caps installed) Zero liquid leakage	
Mechanical		
Mass	<3.3 lbm	<1.5 kg
Maximum Design Pressure	150 psid	1,034.3 kPad
Proof Pressure	225 psid	1,551.4 kPad
Burst Pressure	375 psid	2,585.6 kPad
Environmental		
Vibration: Qualified to	X-Axis: 29.98 Grms, Y-Axis: 18.59 Grms, Z-Axis: 10.18 Grms	
Shock: Qualified to	60 G (100 Hz), 780 G (740 Hz), 780 G (10,000 Hz)	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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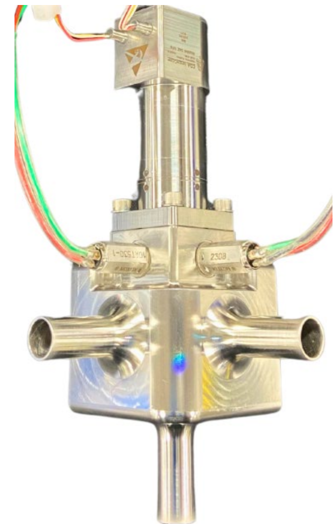
Three-Way Coolant Valve

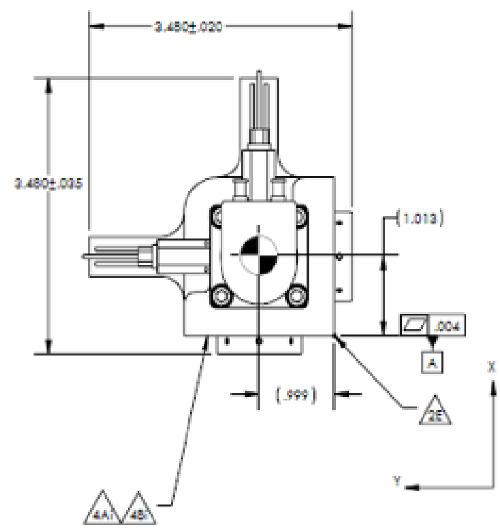
Design Description

Our Temperature Control Valve is a flight-certified unit that integrates a ball valve with an electrical actuator to provide precise proportional fluid control. The ball flow path can be tailored to mission specific flow profiles, whether linear or non-linear. This proportional valve is actuated via a three-phase, brushless DC motor. Valve actuation resolution is less than 0.5 degrees

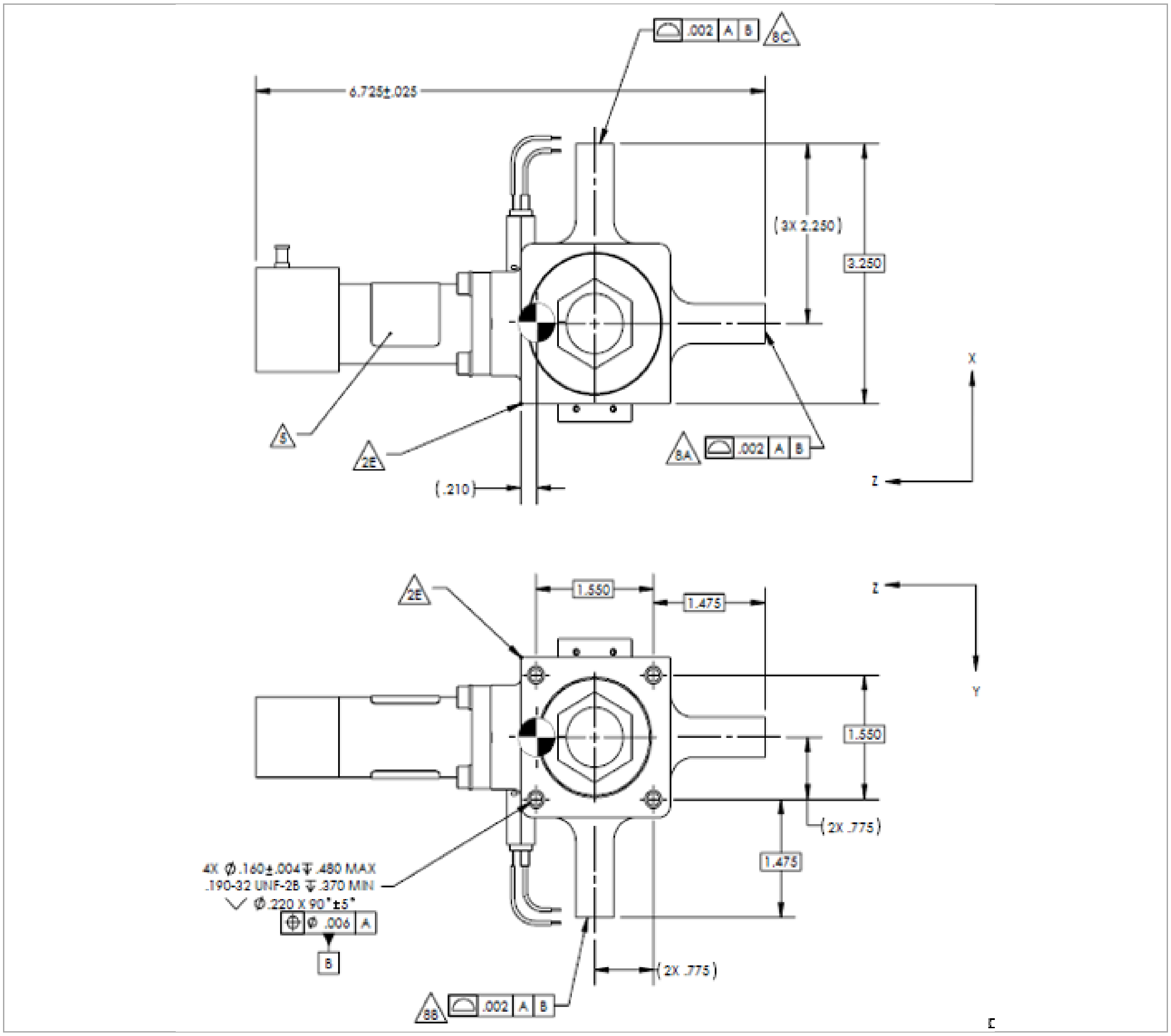


Three-Way Coolant Valve

Dimensions



FLUID INTERFACE		
PORT	FLOW CONDITION	FITMENT
5A	INLET	Ø .50±.003 OD X .028±.0028 WALL INCONEL 625 PER AMS5666
5B 5C	OUTLET	Ø .50±.003 OD X .028±.0028 WALL INCONEL 625 PER AMS5666



Note: All dimensions above are in inches.

Three Way Coolant Valve Features	
• Motorized Coolant Control Valve	• Compatible with a variety of coolants
• Customizable ball geometry and flow profile	• End of Travel Indication
• Scales to meet a variety of flow rates	• EEE components are radiation hard and suitable for deep space

Applications	
• Fluid Control	

Product Specifications		
	U.S.	**SI**
Performance		
Pressure Drop (Primary)	<1 psid @ 500 lbm/hr 50/50 PGW @ 0 deg position Full Open Primary	<6.9 kPad @ 0.063 kg/s 50/50 PGW @ 0 deg position Full Open Primary
Pressure Drop (Bypass)	<1 psid @ 500 lbm/hr 50/50 PGW @ 90 deg position Full Open Bypass	<6.9 kPad @ 0.063 kg/s 50/50 PGW @ 90 deg position Full Open Bypass
Profile between Primary and Bypass conditions are customized per application		
Internal Leakage	<1x10^{-2} scc/s GHe @ MDP; Primary Position	
External Leakage	<1x10^{-5} scc/s GHe @ MDP; Liquid Leak Tight	
Cycle Life	Qualified to 500 cycles where a cycle is closed to open to closed, with capability for many more	
Hardware Life	15 years total • 1 year integration • 4 years shelf • 10 years operational	
Mechanical		
Maximum Design Pressure	150 psid	1,034.3 kPad
Proof Pressure	225 psid	1,551.4 kPad
Burst Pressure	300 psid	2,068.5 kPad
Electrical *(performance at 77 F)*		
Motor Type	3-Phase BLDC	
Excitation	22-32 Vdc	
Maximum Current Draw	0.5 Amps	
Nominal Motor Speed	4 RPM, 3.75 seconds per 90 deg	
Nominal Power	<9 Watts @ 28 Vdc	
Maximum Power	16 Watts @ 32 Vdc	
Hall Effect Device Voltage	5 - 24 Vdc	
Hall Effect Device Signal Level	5 - 24 Vdc	
End of Travel Indicators	SPDT, MIL-PRF-8805 Style Switches, 2 per valve	
Environmental		
Vibration: Qualified to:	X-Axis: 21.5 Grms, Y-Axis: 63.5 Grms, Z-Axis: 30.5 Grms	
Shock: Qualified to:	120 G (100 Hz), 1,560 G (740 Hz), 1,560 G (10,000 Hz)	
Operating Temperature	-29 to 160 °F	-33.9 to 71.1 °C
Non-Operating Temperature	-67 to 257 °F	-55 to 125 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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FLIGHT CONTROL SYSTEMS (FCS) AND THRUST VECTOR CONTROL (TVC) SYSTEMS

Sierra Space's Flight Control Systems (FCS) and Thrust Vector Control (TVC) Systems leverage our extensive experience in space-qualified actuator and electronics design. The Dream Chaser® vehicle's electro-mechanical TVC and FCS is designed in-house to very demanding requirements leveraging spaceflight-proven hardware and engineering methods. Our TVC Systems are designed to meet complete vehicle control requirements with highly scalable actuators and electronics, thus minimizing cost and schedule. In addition to entire TVC systems, our TVC actuators can be used as a cost-effective and reliable replacement for existing TVC system actuators.

Catalog data sheets for our Flight and TVC Systems technology area include:

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Flight Control Systems (FCS) and Thrust Vector Control (TVC) Systems

Design Description

Sierra Space provides electromechanical Flight Control Systems (FCS) and Thrust Vector Control (TVC) Systems designed for spacecraft, launch vehicles, and missile systems. Our control systems use high-performance linear electromechanical actuators and control electronics to provide customers with total system solutions for complex requirements. Our engineering staff and technical heritage in electromechanical mechanisms uniquely position us within the aerospace community to provide these types of system solutions and precision mechanisms.


Electromechanical Thrust Vector Control System (L2)

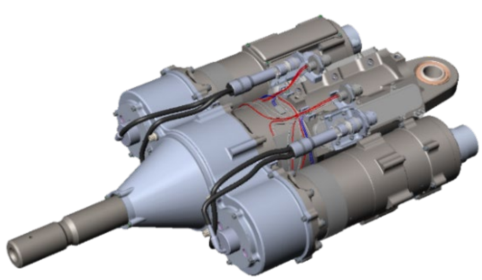
Our electromechanical control systems offer several advantages over hydraulic systems, such as excellent long-term storage, low maintenance, and reduced mass. In addition, our electromechanical design lowers risk of hydraulic fluid leakage and contamination, providing our customers with simple and clean solutions for integration.

Sierra Space is an industry leader in the design and manufacture of numerous precision space mechanisms and complex spacecraft systems and subsystems. As a proven, space-qualified systems integrator, we possess the technological expertise to develop complete systems and ensure customer-specific requirements are achieved.

FCS/TVC Systems Features	
• High-performance systems build on Sierra Space's hardware heritage	• Collaborative and responsive working relationships, resulting in high customer satisfaction
• Complete system solutions with integrated control electronics for precise and reliable performance	• A diverse team of industry experts offering fully engineered solutions
• Aerospace quality materials for mass-optimized design	• Low maintenance, reduced mass, lower risk of leakage

Applications
• Electromechanical flight surface and TVC for spacecraft, launch vehicles, and missiles
• Full electrical and mechanical redundant systems are available for critical spaceflight applications

Dimensions


Dream Chaser® Flight Control Systems (FCS)
Actuator L20: 22 inches


Thrust Vector Control (TVC)
Actuators L11: 18 inches (left) and L2: 14 inches (right)

Note: All dimensions above are in inches.

Heritage Programs
• *Dream Chaser®* Flight Control Systems L20 and L13 (electrically and mechanically redundant)
• TVC System L2 (electrically redundant)

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions (Null Position)	L20: 23.3 in x 11.75 in x 5.5 in L13: 22.6 in x 11.5 in x 5.5 in L11: 18.1 in x 8.1 in x 5.2 in L2: 14.0 in x 5.6 in x 3.3 in	L20: 591.8 mm x 298.5 mm x 139.7 mm L13: 574.0 mm x 292.1 mm x 139.7 mm L11: 459.7 mm x 205.7 mm x 132.1 mm L2: 355.6 mm x 142.2 mm x 83.8 mm
Mass	L20: <52.7 lb L13: <44.4 lb L11: <26.0 lb L2: <14.0 lb	L20: <23.90 kg L13: <20.14 kg L11: <11.79 kg L2: <6.35 kg
Nominal Travel Life	L20: 7,900 in L13: 19,350 in L11: 250 in L2: 5,000 in	L20: 200.66 m L13: 491.5 m L11: 6.35 m L2: 127 m
Nominal Operating Time	L20: 500 minutes L13: 500 minutes L11: 1.35 minutes L2: 150 minutes	N/A
Stall Load	L20: >15,000 lbf dynamic, 19,800 lbf static L13: >10,400 lbf dynamic, 13,600 lbf static L11: >11,650 lbf L2: >2,000 lbf	L20: >66.72 kN dynamic, 88.07 kN static L13: >46.26 kN dynamic, 60.50 kN static L11: >51.8 kN L2: >8.9 kN
Range of Motion	L20: ±2.25 in L13: ±2.25 in L11: ±0.50 in L2: ±0.83 in	L20: ±57.1 mm L13: ±57.1 mm L11: ±12.7 mm L2: ±21.1 mm
No-Load Speed	L20: >7.0 in/s L13: >9.5 in/s L11: >3.8 in/s L2: >3.0 in/s	L20: >177.8 mm/s L13: >241.3 mm/s L11: >96.5 mm/s L2: >76.2 mm/s
Peak Power Point	L20: 5.4 in/s @13,800 lbf L13: 7.5 in/s @9250 lbf L11: 2.6 @ 10,450 in/s @ lbf L2: 2.8 @ 1,500 in/s @ lbf	L20: 137.1 mm/s @ 61.3 kN L13: 190.5 mm/s @ 41.1 kN L11: 66.0 @ 71.1 mm/s @ kN L2: 71.1 @ 6.7 mm/s @ kN
Electrical		
Peak Power Point	L20: 120/120 Vdc/A_{pk} (x2) L13: 120/100 Vdc/A_{pk} (x2) L11: 120/65 Vdc/A_{pk} L2: 120/10 Vdc/A_{pk}	N/A
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

HIGH OUTPUT PARAFFIN (HOP) ACTUATORS AND MECHANISMS

Since 1987, Sierra Space's product line has flown thousands of mechanisms on hundreds of space missions with a legacy of on-orbit operational success. Our very first product, the High Output Paraffin (HOP) Actuator, has become an industry standard for the gentle, low-shock release of critical spacecraft applications such as solar arrays, antennas, and payloads. HOP thermal actuators were developed to provide an alternative to conventional aerospace actuators by directly converting temperature changes to useful mechanical work. When fabricated with internal resistance heating elements, they provide an electric linear motor. For applications in which slower response times are acceptable or preferred, HOP actuators have distinct advantages over conventional approaches that include:

- Resettable: can be cycled >1,000 times
- Flight hardware can be fully verified before flight
- Output force to 4,000 N (900 lb)
- Stroke to 10 cm
- High reliability: one moving part (the actuator rod)
- Can be fabricated magnetically clean
- Gentle smooth stroke
- Low power requirement (5 to 40 W at 28 V)
- Non-explosive: minimal safety concerns
- Weighs less than 30 grams
- Small size

The capability of HOP thermal actuators to convert temperature changes to useful mechanical work also creates a wide variety of aerospace applications in Thermal Control Systems (TCS), and systems that can use mechanical work from temperature changes or heat (solar) input.

Catalog data sheets for our HOP Actuators and Mechanisms product area include:

EH-3525 High Output Paraffin (HOP) Actuator

IH-5055/-10055 High Output Paraffin (HOP) Actuators

PP-35055 Resettable High-Force Pin Puller

PP-5501 Two-Position Latching Actuator

RO-9015 Two-Position Rotary Latching Actuator

SP-5025 High Output Paraffin (HOP) Pin Puller

SP-5025 High Shear High Output Paraffin (HOP) Pin Puller

SP-5085 High Output Paraffin (HOP) Pin Puller

EH-3525 High Output Paraffin (HOP) Actuator

Design Description

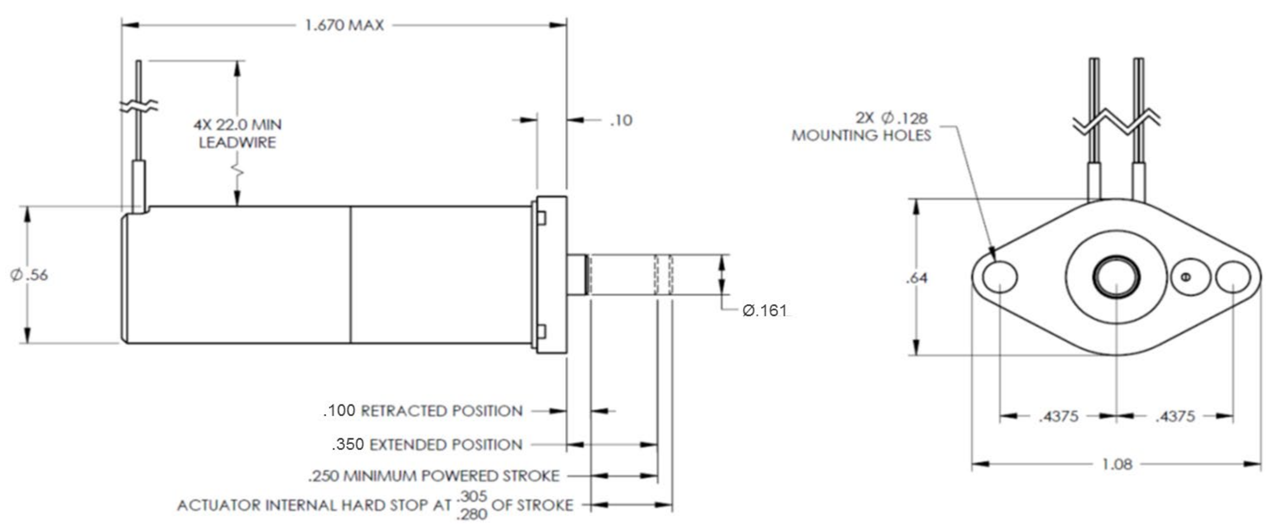
Sierra Space has designed and developed the External Heater (EH) High Output Paraffin (HOP) actuator (linear motor) to complement the IH-5055 series of actuators. These HOP actuators are designed for extreme cleanliness applications and incorporate a welded bellows for a sealed, zero-outgassing prime mover. The EH-3525 uses a redundant external heating element to melt the paraffin charge in the actuator. When melted, the paraffin expands and creates hydrostatic pressure, which is transformed into a gentle, high-force shaft extension. The welded-bellows assembly incorporates an internal return spring and hard stop, which results in a self-resetting actuator.

EH-3525 HOP Actuator. The EH-3525 HOP Actuator incorporates an internal welded bellows, providing a built-in return spring while meeting the most stringent cleanliness requirements.

The extreme cleanliness of the actuators meets the most stringent NASA requirements making them suitable for ultra-clean applications. HOP technology is easily scaled to meet a variety of customer size and application requirements. Sierra Space provides multiple versions of this welded-bellows, seal-type actuator. The overall function time is dependent upon load, power input, and environmental conditions.

EH-3525 HOP Actuator Features	
• Gentle, smooth extension	• Built-in hard stop
• Hermetically sealed	• High force-to-mass ratio
• Stainless steel case	• Self-resetting
• Overpressure safety device	• Nonexplosive
• Fully redundant heaters	• Minimal safety requirements

Dimensions



Note: All dimensions above are in inches.

Applications	
• Linear motor actuator scalable to meet a variety of customer size and application requirements	• Spacecraft environments requiring extreme cleanliness applications

Heritage Programs	
• Stratospheric Aerosol and Gas Experiment (SAGE) III	• Broadcasting Satellite System (BSAT)
• Spitzer Space Telescope	• Defense Meteorological Satellite Program (DMSP)
• Multi-User System for Earth Sensing (MUSES)	• Korean Multi-Purpose Satellite (KOMPSAT)
• Deep Space Program Science Experiment (DSPSE) (Clementine)	• Mars Phoenix Missions – NASA's Mars Exploration Program
• Chandra X-ray Observatory	• Cassini-Huygens (Cassini)
• Earth Observing System (EOS) Terra	• Solar and Heliospheric Observatory (SOHO)

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	1.24 oz	35 grams
Response Time in Air (35-lb load, 28 Vdc)	~200 s @ +75 °F	~200 s @ +24 °C
Full Stroke	0.25 in	0.635 cm
Nominal Output Force	35 lbf	156 N
Load of Overpressure Function	>105 lbf	>467 N
Lifetime (Nominal Load)	500 cycles	
Electrical		
Power	5 W @ 28 V	
Voltage Range	22 Vdc to 34 Vdc	
Wiring/Insulation	4 leads 26 AWG in accordance with Mil-W-22759/33	
Heater Resistance	2 x 157 ±2% Ω	
Thermal		
Operating Temperature Range	-76 °F to +176 °F	-60 °C to +80 °C
Nonoperating Temperature	-184 °F to +176 °F	-120 °C to +80 °C
Nonactuation Temperatures	+176 °F	+80 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

IH-5055/-10055 High Output Paraffin (HOP) Actuators

Design Description

Sierra Space's IH-5055/-10055 High Output Paraffin (HOP) actuators (or linear motors) are electrically powered resettable devices that generate high-force and long-stroke linear motion.

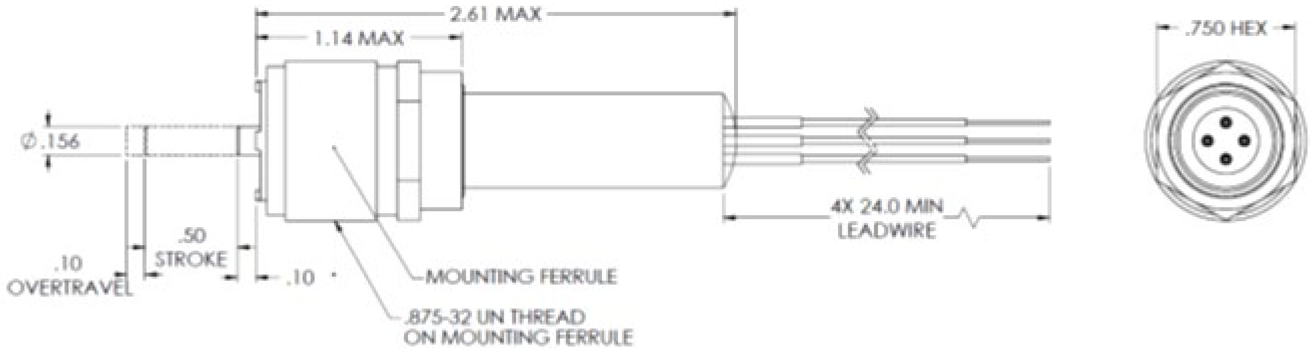
Redundant Internal Heaters (IH) melt a paraffin charge inside the actuator. When melted, the paraffin expands and creates hydrostatic pressure that is transformed into a gentle, high-force shaft extension. A proprietary design incorporating a squeeze boot seals the paraffin and prevents any possibility of material release. Negligible outgassing makes these actuators suitable for most contamination-sensitive applications.

This HOP technology is easily scaled to meet a variety of customer size and application requirements. We provide multiple versions of this squeeze boot seal-type actuator. The overall function time is dependent upon load, power input, and environmental conditions.

IH-5055/-10055 High Output Paraffin (HOP) Actuator. This actuator is shown with a standard thermal insulation-mounting ferrule. The actuator is also available with optional flange mount.

IH-5055/10055 HOP Actuator Features	
• Gentle, smooth extension	• High force-to-mass ratio
• Titanium case	• Easily reset with no disassembly or refurbishment
• Overpressure safety device	• Nonexplosive
• Fully redundant heaters	• Minimal safety requirements
• Ferrule or flange mount available	

Dimensions



Note: All dimensions above are in inches.

Applications	
• Spacecraft launch locks	• Solar array hold down and release
• Release of spacecraft instrument doors and covers	• Used in a broad number of applications as linear motors in spacecraft mechanical systems

Heritage Programs (IH-5055)	
• Global Positioning Satellite (GPS-2F)	• Earth Observing System (EOS)
• Mars Phoenix Lander	• Television Infrared Observation Satellite (TIROS)
• Indostar II	• Thermal Emission Spectrometer (TES)
• Spitzer Space telescope	• Solar Terrestrial Relations Observatory (STEREO)
• Cassini-Huygens (Cassini)	• Solar and Heliospheric Observatory (SOHO)
• Galaxy	• International Telecommunications Satellite Organization (Intelsat)
• SES (Society of European Satellites)	• Koreasat
• MexSat (Mexico's next-generation mobile satellite system)	• Thaicom

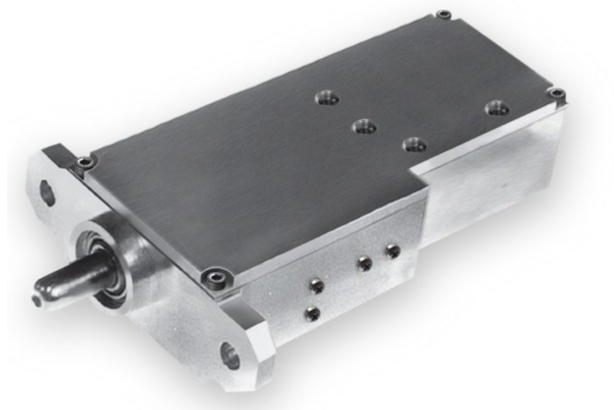
Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	1.76 oz	50 grams
Response Time in Air (50-lb load, 28 Vdc)	~210 s @ +75 °F	~210 s @ +24 °C
Full Stroke	0.55 in	1.40 cm
Nominal Output Force	IH-5055 = 50 lbf, IH-10055 = 100 lbf	444.8 N
Load of Overpressure Function	IH-5055 >100 lbf, IH-10055 >150 lbf	>667 N
Mass	1.76 oz	50 grams
Lifetime	1,000 cycles @ 50 lbf, 100 cycles @ 100 lbf	
Electrical		
Power	10 W @ 28 V	
Voltage Range	22 to 44 Vdc	
Wiring/Insulation	4 leads 26 AWG in accordance with Mil-W-22759/33	
Heater Resistance	2x 78 ±3% Ω	
Thermal		
Operating Temperature Range	-85 °F to +176 °F	-65 °C to +80 °C
Nonoperating Temperature	-319 °F to +176 °F	-195 °C to +80 °C
Nonactuation Temperatures	+176 °F	+80 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

PP-35055 Resettable High-Force Pin Puller

Design Description

Sierra Space's PP-35055 Pin Puller is a remotely resettable mechanism that provides high retraction force. This high-force, ultra-clean pin puller also contains an integral binary latching mechanism. These features provide a high-retraction force, high-shear pin puller that is fully resettable.

When energized, the pin is retracted and then latched in the retracted position. When re-energized, the mechanism unlatches, and the pin extends. Repeated operation alternately extends and retracts the output pin. Appropriate applications include caging of gimbaled instruments, release of high loads and restraint of rotating hardware.

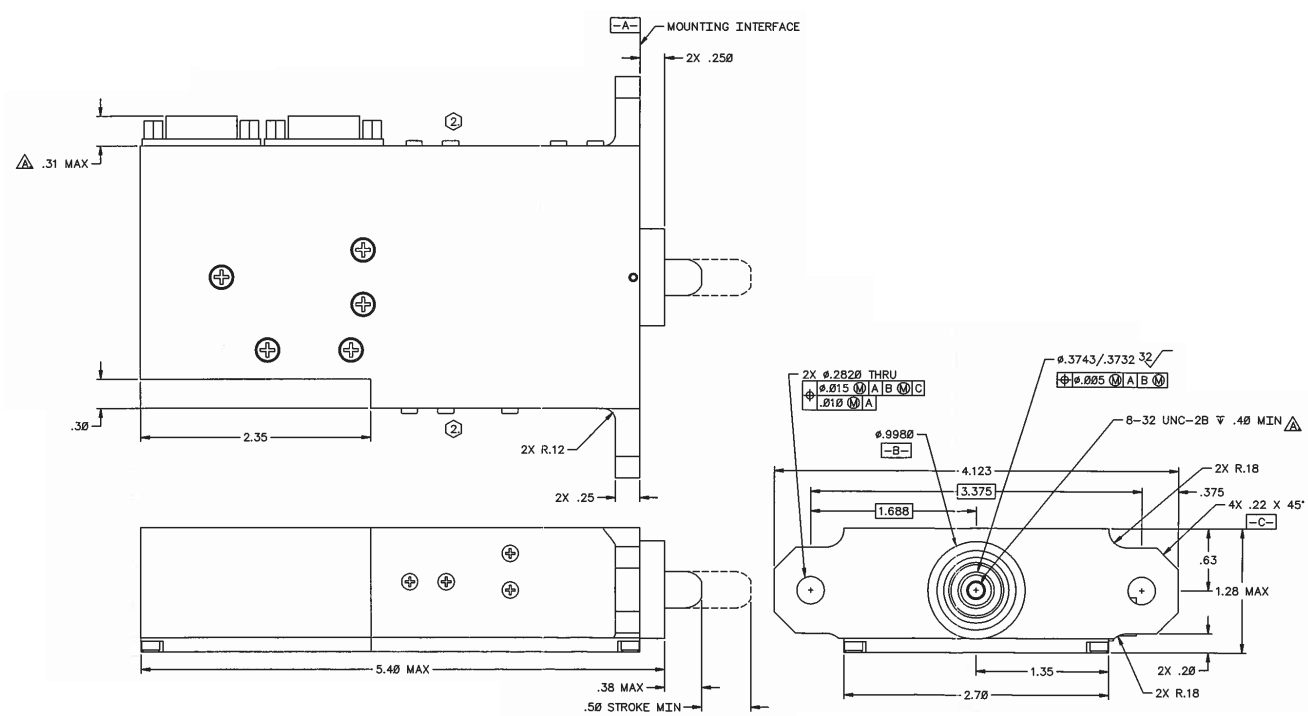


PP-35055 Resettable High-Force Pin Puller

The heart of the PP-35055 is an EH-35055 high force High Output Paraffin (HOP) actuator providing a maximum 350 lbf of retraction force to the output pin. This hermetic bellows-type seal actuator is coupled to a binary latch that toggles the mechanism between the two latched conditions (extended and retracted) when repeatedly operated. Single or redundant limit switches for both extended and retracted conditions provide position telemetry.

PP-35055 Features	
• High-static shear-load capability	• Remotely resettable
• High available retraction force	• Hermetically sealed
• Simple control	• Gentle operation

Dimensions



Note: All dimensions above are in inches.

Applications	
• Mechanism caging and uncaging	• Release of high loads
• Restraint of rotating equipment	• Binary positioning

Heritage Programs	
• International Space Station (Beta Joints)	• Meteosat Second Generation (MSG) Spinning Enhanced Visible and InfraRed Imager (SEVIRI) Instrument
• International Space Station (Solar Experiment)	

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	17.6 oz	500 grams
Response Time	~360 sec. @ 24 °C (75 °F)	
Retraction Force	350 max/250 lbf min	1,557 N max/1,112 N min
Extension Force	3 lbf max	13.3 N min
Shear Load Capability	1,000 lbf static	4,448 N
Lifetime	500+ cycles	
Control	Simple on/off	
Latched Stroke	0.5 in	1.27 cm
Electrical		
Power/Voltage (nominal)	20 W @ 28 V	
Operating Environment	-22 °F to +176 °F	-30 °C to +80 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

PP-5501 Two-Position Latching Actuator

Design Description

Sierra Space's PP-5501 is a remotely resettable mechanism that provides shaft extension and retraction, with zero-power latching in the fully extended and retracted positions. Appropriate applications include caging of mechanisms, instrument cover driving, slow-speed aperture shuttering, and valve opening and closing.

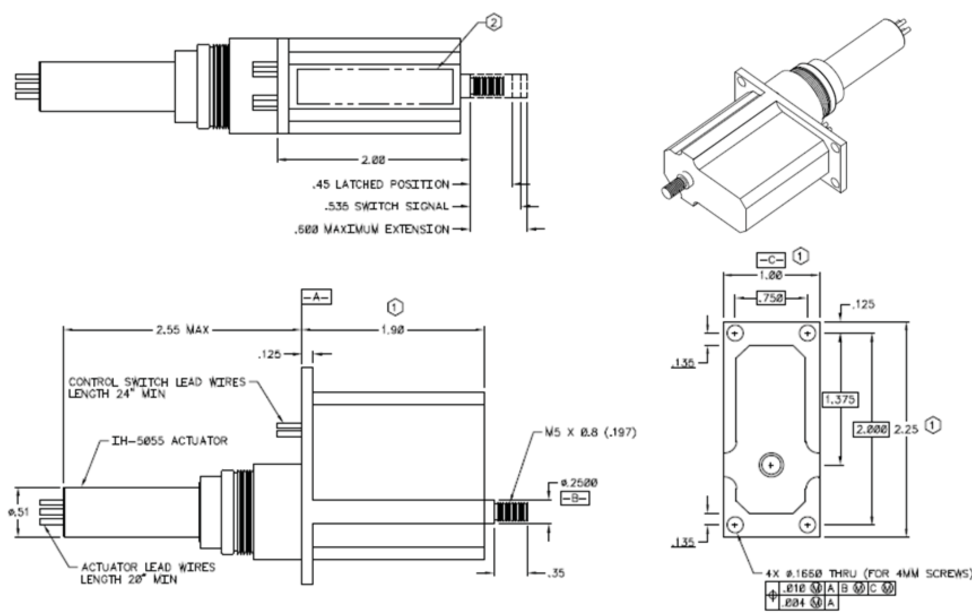
The heart of the PP-5501 is the Sierra Space IH-5055 High Output Paraffin (HOP) actuator. Energizing the actuator drives the output shaft 0.54 inches, at which point the control switches change state, providing a signal to discontinue power. The shaft then retracts and latches at 0.45 inches of extension. The retraction force of the mechanism is supplied by redundant internal bias springs. When energized again, the output shaft extends and unlatches. Power is again interrupted, which allows the output shaft to retract to the original position.

PP-5501 Two-Position Latching Actuator. PP-5501 actuator is a fully resettable, ultra-clean, high-force pin puller.

This cycle can be repeated, as many times as required to alternately extend and retract the output shaft with no power required for maintaining either latched position. Design modifications can be made to increase retraction force or modify stroke length.

PP-5501 Features	
• Gentle extension and retraction	• Remote operation and reset
• Unpowered two-position latching	• Integral redundant control limit switches
• Rotary version available	• Simple control

Dimensions



Note: All dimensions above are in inches. Threaded end optional.

Applications	
• Mechanism caging and uncaging	• Two-position valve operation
• Slow-speed aperture shuttering	• Slow-speed valve opening/closing
• Actuation of instrument cover	• Optical shutter positioning

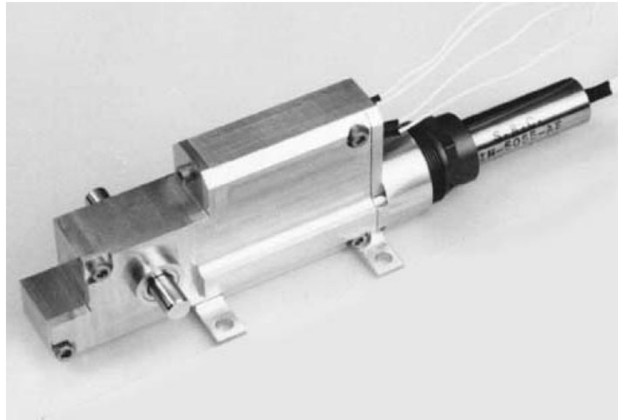
Heritage Programs	
• Clementine spacecraft	• Solar and Heliospheric Observatory (SOHO)
• Geotail spacecraft	

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	6.0 oz	170 grams
Response Time	~200 s from +75 °F	~200 s from +24 °C
Extension Force	50 lbf	222 N
Retraction Force	3 lbf	13.3 N
Maximum Stroke	0.600 in	1.524 cm
Lifetime	1,000 + cycles	
Control	Simple on/off	
Latched Stroke	0.45 in	1.14 cm
Electrical		
Power/Voltage (nominal)	10 W @ 28 V	
Operating Environment	-76 °F to -176 °F	-60 °C to +80 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

RO-9015 Two-Position Rotary Latching Actuator

Design Description

Sierra Space's RO-9015 Two-Position Rotary Latching Actuator provides a high-torque rotational output. Applications for this actuator latch include solar panel deployment, mirror positioning, and multiple operations of covers and doors.

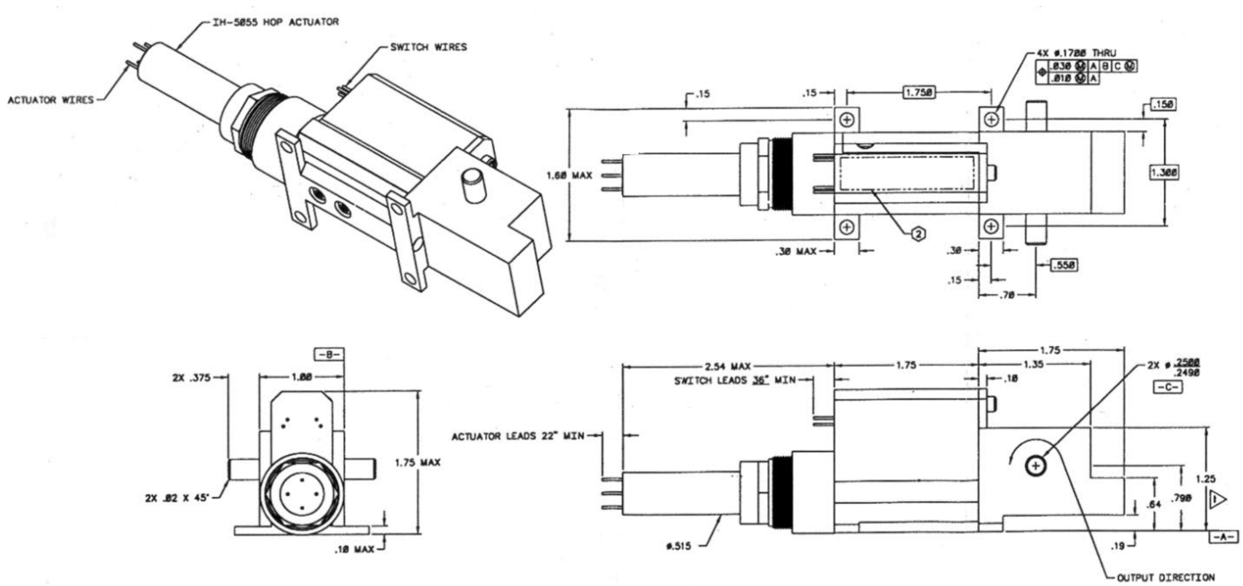


RO-9015 Two-Position Rotary Latching Actuator. Latching actuator provides high-torque rotational output.

This mechanism uses a High Output Paraffin (HOP) force to generate rotational motion in one direction. A return spring drives the mechanism in the opposite direction. Zero-power latching is provided in both fully rotated positions. The RO-9015 features operation torque and latching that is designed for spring-biased components such as instrument covers. Energizing the mechanism initiates heating of the HOP actuator. When the paraffin melting temperature is reached, the output shaft begins to rotate in the drive direction. Drive torque is provided as the shaft rotates through its rotational range. At the end of rotation, the binary latch engages. Limit switches then signal to disconnect power. To reverse the rotation, power is again supplied to the HOP actuator. After a brief warming period, the binary latch disengages. As the actuator cools, the output shaft of the mechanism slowly rotates back to the original position. Repeated operation of the actuator cycles the mechanism between the two latched positions.

RO-9015 Features	
• Remote reset operation	• No power required to hold either latched position
• Smooth rotary motion	• Integral redundant control limit switches
• High torque-to-mass ratio	

Dimensions



Note: All dimensions above are in inches.

Applications	
• Solar panel deployment	• Mirror positioning
• Multiple operations of covers and doors	

Heritage Programs
• Proprietary program–used to open and close an instrument cover

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	7.4 oz	210 grams
Response Time	~210 sec from 24 °C (75 °F)	
Output Torque	15 in-lbf	1.7 Nm
Available Rotation	90 deg to 180 deg	
Lifetime	1,000+ cycles	
Control Requirements	Simple On/Off operation	
Electrical		
Power/Voltage	10 W @ 28 V	
Thermal		
Operating Environment	-148 °F to +176 °F	-100 °C to +80 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

SP-5025 High Output Paraffin (HOP) Pin Puller

Design Description

Sierra Space's Shut-off Pin Puller SP-5025 High Output Paraffin (HOP) actuator is an auto shut-off pin puller. The SP-5025 uses a redundant external heating element to melt the paraffin charge in the actuator. When melted, the paraffin expands and creates hydrostatic pressure that is transformed into a gentle, high-force pin retraction. The SP-5025 includes fully redundant internal circuit interrupts that can discontinue power to the actuator once full retraction has been reached. Alternatively, the circuit interrupts can provide a switch signal to allow the user to power off the actuator, depending upon the chosen wiring configuration.

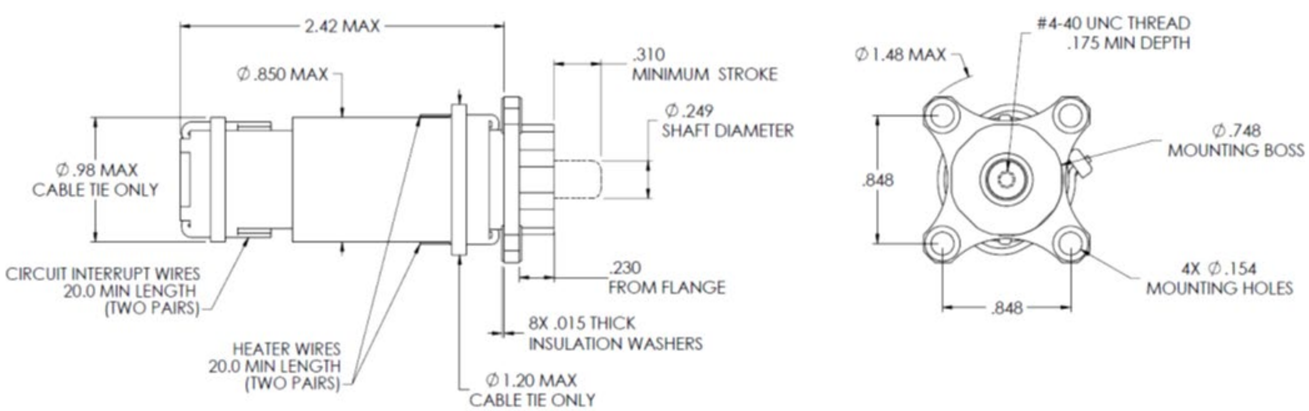
This design reduces overall system cost by simplifying control requirements. The SP-5025 may be powered by a single timed power pulse to one of the fully redundant heater circuits. The dual heaters and dual circuit interrupts can be wired by the user to provide for autonomous or interactive control system designs.

SP-5025 High Output Paraffin (HOP) Actuator

The pin puller is resettable in place using the appropriate reset tool. The overall function time is dependent upon load, power input, and environmental conditions.

SP-5025 HOP Features	
• Integral circuit interrupts	• Resettable without refurbishment
• Simple control system	• Nonexplosive
• Gentle, high-force retraction	• Minimal safety requirements
• Fully redundant heaters	• Includes thermal isolation washers

Dimensions



Note: All dimensions above are in inches.

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Applications	
• Spacecraft launch locks	• Solar array hold down and release
• Release of spacecraft instrument doors and covers	• Used in a broad number of applications as linear motors in spacecraft mechanical systems

Heritage Programs	
• Thermal Emission Spectrometer (TES)	• Cascade SmallSat and Ionospheric Polar Explorer (CASSIOPE)
• Space-Based Infrared System (SBIRS) Highly Elliptical Orbit (HEO)	• Republic of China Satellite-2 (ROCSAT-2) (renamed FORMOSAT-2)
• SBIRS Geosynchronous Earth Orbit (GEO)	• GeoEye 1
• Galaxy Evolution Explorer (GALEX)	• OrbView-3 and -4
• H2 Transfer Vehicle (HTV)	

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	2.82 oz	80.0 g
Response Time in Air (50 lb, 28 Vdc)	~150 s @ +75 °F	~150 s @ +24 °C
Stroke	0.310 in	0.787 cm
Maximum Retraction Force	140 lbf	623 N
Maximum Reset Force Required	15 lbf	66.7 N
Shear Load Capability	350 lbf quasi-static	
Reset Tools Needed	Manual reset tool EP-7032 or Pneumatic tool EP-7056	
Reset Time	<10 min	
Lifetime (nominal load)	500 cycles	
Electrical		
Power	15 W @ 28 V	
Voltage Range	22 Vdc to 34 Vdc	
Heater Resistance	2x 52.3 ±5% Ω	
Wiring/Insulation	8 leads 26 AWG in accordance with Mil-W-22759/33	
Redundancy	Heaters and circuit interrupts	
Thermal		
Operating Temperatures	-85 °F to + 176 °F	-65 °C to +80 °C
Nonoperating Temperatures	-319 °F to +176 °F	-195 °C to +80 °C
Nonactuation Temperatures	+176 °F	+80 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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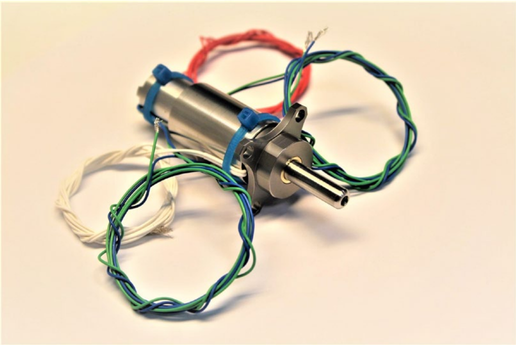
SP-5025 High Shear High Output Paraffin (HOP) Pin Puller

Design Description

Sierra Space's "high-shear" variant of the SP-5025 High Output Paraffin (HOP) actuator is an auto shut-off pin puller with increased shear load capability due to the addition of a higher-strength pin and supplied externally mounted load-bearing bushing (required).



High-Shear SP-5025 High Output Paraffin (HOP) Actuator

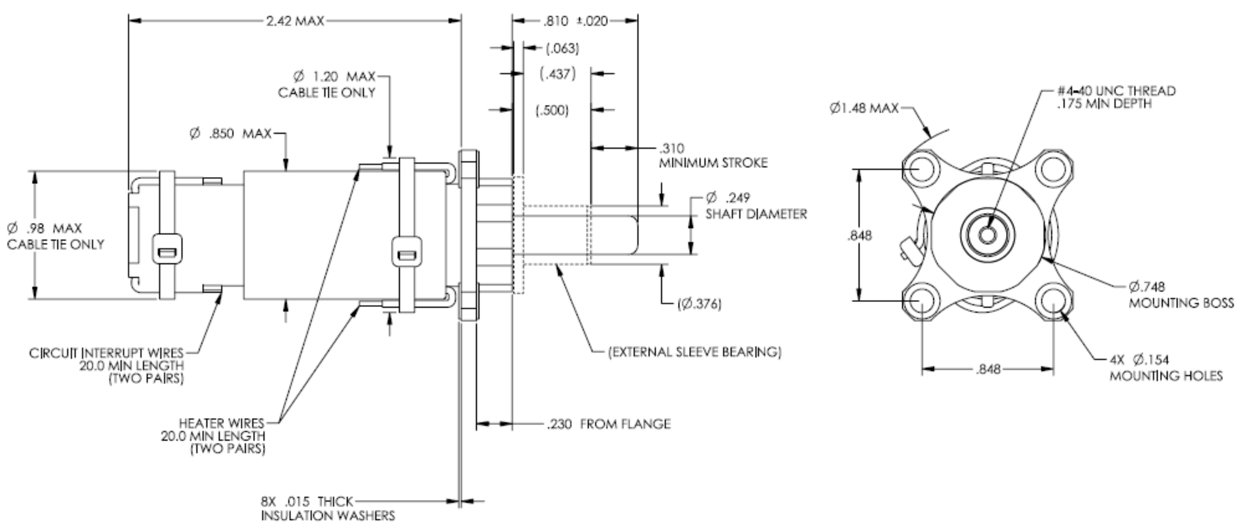
Like the standard SP-5025, the high-shear configuration uses a redundant external heating element to melt the paraffin charge in the actuator. When melted, the paraffin expands and creates hydrostatic pressure that is transformed into a gentle, high-force pin retraction. The High-Shear SP-5025 includes fully redundant internal circuit interrupts that can discontinue power to the actuator once full retraction has been reached. Alternatively, the circuit interrupts can provide a switch signal to allow the user to power off the actuator, depending upon the chosen wiring configuration.

This design reduces overall system cost by simplifying control requirements. The High-Shear SP-5025 may be powered by a single timed-power pulse to one of the fully redundant heater circuits. The dual heaters and dual circuit interrupts can be wired by the user to provide for autonomous or interactive control system designs.

The pin puller is resettable in place using the appropriate reset tool. The overall function time is dependent upon load, power input, and environmental conditions.

High-Shear SP-5025 HOP Pin Puller Features	
• Integral circuit interrupts	• Resettable without refurbishment
• Simple control system	• Nonexplosive
• Gentle, high-force retraction	• Minimal safety requirements
• Fully redundant heaters	• Includes thermal isolation washers
• Increased 1,000 lbf quasi-static shear load rating	• Includes externally mounted sleeve bearing

Dimensions



Note: All dimensions above are in inches

Applications	
• Spacecraft launch locks	• Hold-down and release (e.g., solar panel, cover, etc.)
• Release of spacecraft instrument doors and covers	• Used in a broad number of applications as linear motors in spacecraft mechanical systems

Heritage Programs	
• SBIRS Geosynchronous Earth Orbit (GEO)	• SBIRS High Earth Orbit (HEO)

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass (not including external sleeve bearing)	3.17 oz	90.0 g
Response Time in Air (50 lb, 28 Vdc)	~150 s @ +75 °F	~150 s @ +24 °C
Stroke	0.310 in	0.787 cm
Qualified Retraction Force	140 lbf	623 N
Maximum Retraction Force	100 lbf	445 N
Maximum Reset Force Required	15 lbf	66.7 N
Shear Load Capability (quasi-static)	1,000 lbf	4,448 N
Reset Tools Needed	Manual reset tool EP-7032, Pneumatic tool EP-7056, or Scissors tool 34672	
Reset Time	<10 min	
Lifetime (nominal load)	500 cycles	
Electrical		
Power	15 W @ 28 V	
Voltage Range	22 Vdc to 34 Vdc	
Heater Resistance	2x 52.3 ±5% Ω	
Wiring/Insulation	8 leads 26 AWG in accordance with Mil-W-22759/33	
Redundancy	Heaters and circuit interrupts	
Thermal		
Operating Temperatures	-85 °F to + 176 °F	-65 °C to +80 °C
Nonoperating Temperatures	-319 °F to +176 °F	-195 °C to +80 °C
Nonactuation Temperatures	+176 °F	+80 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

SP-5085 High Output Paraffin (HOP) Pin Puller

Design Description

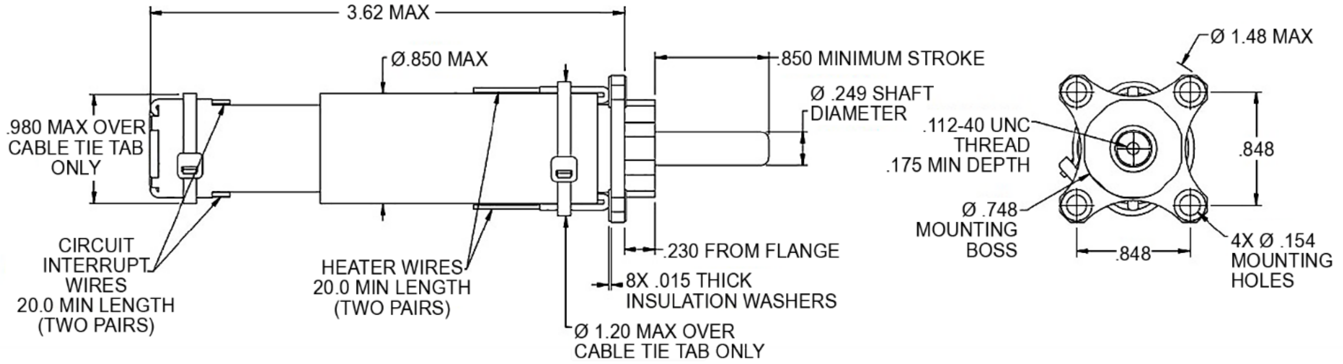
Sierra Space's auto-shut off SP-5085 Pin Puller is a High Output Paraffin (HOP) actuator device, which translates electrical power into a smooth and predictable linear retraction of the output shaft. The SP-5085 HOP automatically disables the power to the redundant heaters upon full retraction eliminating the risk of being over-energized. The unit is non-pyro, field resettable, and capable of hundreds of actuations without refurbishment.

The unit is a high reliability device that has been used in critical applications on many space missions with 100% success. Hundreds of units have been produced over the past 30 years for a wide variety of space applications including instrument cover systems, solar arrays, and other spacecraft subsystems.

SP-5085 High Output Paraffin (HOP) Actuator.

SP-5085 HOP Features	
• Integral circuit interrupts	• Resettable without refurbishment
• Simple control system	• Nonexplosive
• Gentle, high-force retraction	• Minimal safety requirements
• Fully redundant heaters	• Includes thermal isolation washers

Dimensions



Note: All dimensions above are in inches.

Applications	
• Spacecraft launch locks	• Solar array hold down and release
• Release of spacecraft instrument doors and covers	• Used in a broad number of applications such as linear motors in spacecraft mechanical systems

Heritage Programs	
• NASA Docking System	• WorldView
• Visible Infrared Imaging Radiometer Suite (VIIRS)	• Scientific Satellite (SCISAT)
• Restricted Programs	• Atmospheric Chemistry Experiment (ACE)

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	3.70 oz	105.0 g
Response Time in Air (50 lb, 28 Vdc)	~220 s @ +75 °F	~220 s @ +24 °C
Stroke	0.850 in	2.16 cm
Maximum Retraction Force	100 lbf	445 N
Maximum Reset Force Required	15 lbf	66.7 N
Shear Load Capability	120 lbf quasi-static	534 N quasi-static
Reset Tools Needed	Manual reset tool EP-14880 or Pneumatic tool EP-7056	
Reset Time	<10 min	
Lifetime (nominal load)	500 cycles	
Electrical		
Power	25 W @ 28 V	
Voltage Range	21 Vdc to 35 Vdc	
Heater Resistance	2x 31.4 ±5% Ω	
Wiring/Insulation	8 leads 26 AWG in accordance with Mil-W-22759/33	
Redundancy	Heaters and circuit interrupts	
Thermal		
Operating Temperatures	-85 °F to +176 °F	-65 °C to +80 °C
Nonoperating Temperatures	-319 °F to +176 °F	-195 °C to +80 °C
Nonactuation Temperatures	+176 °F	+80 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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INSTRUMENT DOOR AND COVER SYSTEMS

Sierra Space's instrument door and cover systems provide a simple, robust, heritage solution for most spacecraft applications. Sensitive spacecraft instruments can require a wide range of protection from external threats such as dust particles, contaminants, and stray light. Some systems even require a hard space vacuum to be preserved prior to use in space to maintain sensor integrity.

Our instrument doors and covers are turnkey, providing a complete end-to-end solution that can be simply bolted onto the spacecraft instrument aperture interface. Our cover systems are typically comprised of four primary elements: the door and cover structure; the latch mechanism; the seal system, and the hinge system. A more detailed data sheet provides more specific applications and features:

Instrument Door and Cover Systems

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Instrument Door and Cover Systems

Design Description

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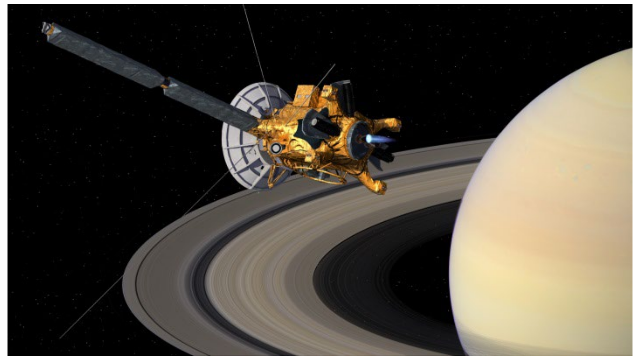


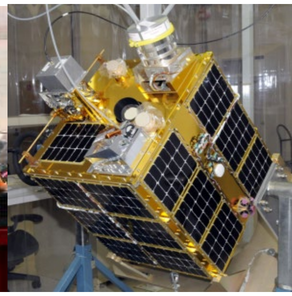
Cover system flown on Cassini. Cover systems span a wide range of programs with flight-proven heritage, providing robust solutions for most spacecraft applications. Credit: NASA

Our instrument doors and covers are turnkey, providing a complete end-to-end solution that can be simply bolted onto the spacecraft instrument aperture interface. Our cover systems are typically comprised of four primary elements: the door and cover structure; the latch mechanism; the seal system, and the hinge system.

Instrument Door and Cover Systems Features	
• Turn-key systems and mechanisms	• Lightweight door structures; variety of seals available
• Redundant latch mechanisms with simple re-set and high reuse	• Experience with a wide range of sizes from 1 inch to >3 feet in diameter
• Thin-film, roll-up covers available for ultra-lightweight needs	• One-time open systems with positive latch out at end of travel, to motorized systems requiring many open-close cycles

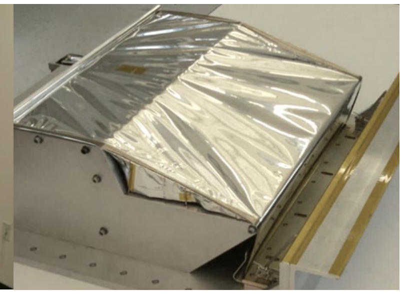
DSCOVR EPIC Camera Door System. This door system was used on NASA's Deep Space Climate Observatory (DSCOVR) Earth Polychromatic Imaging Camera (EPIC) instrument. Credit: Ken Kremer

Swift UVOT - XRT



FASTSAT TTI
(Credit: NASA)

DSCOVR EPIC Camera Door



CrIS Cooler Cover

Heritage Door and Cover Systems. Contributed doors and cover systems to a wide variety of spacecraft programs, including Swift UVOT XRT, FASTSAT TTI, DSCOVR EPIC Camera Door, and CrIS Cooler Cover, as shown above in these examples.

Heritage Cover System Programs	
• Cassini Plasma Spectrometer (CAPS)	• Atmospheric Infrared Sounder (AIRS) Earth Shield
• Swift Ultraviolet/Optical Telescope (UVOT) and X-ray Telescope (XRT)	• Europa Mass Spectrometer for Planetary Exploration (MASPEX)
• Deep Space Climate Observatory (DSCOVR, formerly Triana) Earth Polychromatic Imaging Camera (EPIC)	• Fast, Affordable, Science and Technology Satellite (FASTSAT) Thermospheric Temperature Imager (TTI)
• Clementine	• 2001 Mars In-situ-Propellant-Production Precursor (MIP)
• Earthwatch	• IKONOS (Space Imaging Remote Sensing System)
• Cross-track Infrared Sounder (CrIS) Cooler	• OrbView-3 and -4 (multispectral imagery satellite)
• Government Missions	

Instrument Door and Cover Structure

The door and cover structure consists of lightweight, machined aluminum or composite materials. These structures are available for use on rigid doors, including door paint/tape surface preparations to reflect light and heat away from the instrument, or ultra-lightweight, thin film covers that simply unlatch and roll-up to expose the aperture.

Latch Mechanism

The latch mechanism keeps the door closed during launch and in-space loads. Simple High Output Paraffin (HOP) or Shaped Memory Alloy (SMA) actuators offer ease of use, with hundreds of operation cycles possible with zero latch refurbishment. Single string, electrically redundant and fully mechanically redundant designs are available. We also offer latches than can "re-latch" the door closed for multiple open-close cycle applications, as well as separation nuts for systems requiring a robust pre-load of the door prior to launch.

Seal System

The seal system keeps external environments away from the sensor. We have experience with seals ranging in complexity from simple labyrinth types to keep out stray light, to lightweight foam seals to keep out dust and other particulates, to O-rings with non-stiction features to hold a light differential pressure. We also have experience with a variety of seal approaches (knife-edge seals and others) for holding a hard space vacuum inside the cover.

Hinge System

The hinge system opens the door and exposes the sensor view and features: 1) simple, one-time open spring hinges, with or without dampers; 2) lock-out at end of rotation to preclude bounce back; and 3) motorized hinge-lines and control electronics for multiple open-close cycles.

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LAUNCH ADAPTERS AND SEPARATION SYSTEMS

Sierra Space has supported both U.S. and international launch services for decades with a variety of technologies needed for reliable and gentle deployment of payloads and spacecraft into proper orbit. Devices such as the low-shock Clamp Band Opening Devices (CBOD) are now used to release dozens of primary payloads each year on nearly every major launch vehicle in the world. Other products such as our Fast-Acting Shockless Separation Nuts (FASSN) have become the go-to method for safely restraining and releasing the cargo pallet on every H2 Transfer Vehicle to assist in delivering critical equipment and supplies to the International Space Station (ISS). Our clamp-band separation systems are robust options for high-load, high-stiffness applications. And our non-pyrotechnic Hold Down and Release Mechanisms (HDRM) provide our customers with a field resettable solution, allowing for rapid re-set and re-test, saving significant time and costs. In addition, Sierra Space offers turn-key dispensers and adapters required for carrying spacecraft onward to their mission in space.

Catalog data sheets for our Launch Support Products and Services technology area include:

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Fast-Acting Shockless Separation Nut (FASSN) 30K

Design Description

Sierra Space offers the Fast-Acting Shockless Separation Nut (FASSN) 30K—a space-qualified, low-shock separation nut ideal for restraining and releasing satellite and launch vehicle preloaded structural joints.

Our FASSN 30K offers a revolutionary solution to spacecraft release requirements. This technology developed jointly by Sierra Space and Lockheed Martin offers fast, gentle separation from a device that is fully re-settable without refurbishment. Designed as a drop-in replacement for existing pyrotechnic hardware, the FASSN can easily be incorporated into existing spaceflight configurations.

The FASSN 30K device is shown here with the Extra Vehicular Activity (EVA) bolt retractor.

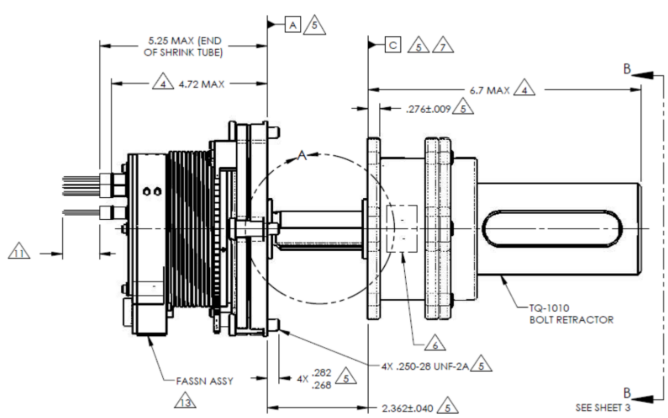
Using a resettable, reusable shape memory alloy (SMA) trigger instead of pyrotechnics for actuation, multiple ground operations are possible without the safety concerns associated with pyros.

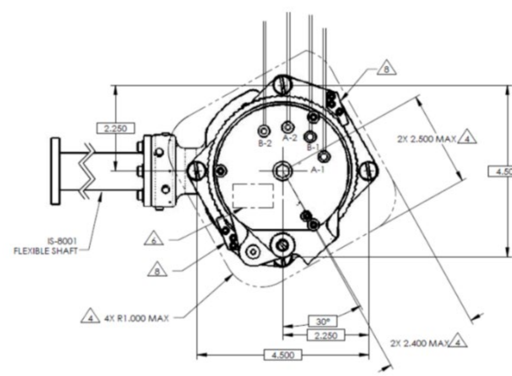
When actuated, a caged flywheel is released. The high-lead threads on the bolt start the flywheel spinning, and the bolt is released in milliseconds. The strain energy of the bolt is converted into rotational energy in the flywheel, resulting in orders of magnitude less shock than a pyro release.

The FASSN is fully resettable using common tools, with no refurbishment or replacement of parts. In addition, it is scalable for most applications. The 1K, 10K, and 30K versions have all successfully flown in space.

Launch Adapters and Separation Systems Features	
• Fully resettable with no refurbishment	• Drop-in replacement for pyro devices
• Orders of magnitude less shock than pyros	• Flight hardware can be repeatedly tested prior to flight
• Release time supports simultaneity needs	• Extravehicular Activity (EVA) back-up release feature available on bolt retractor

Dimensions





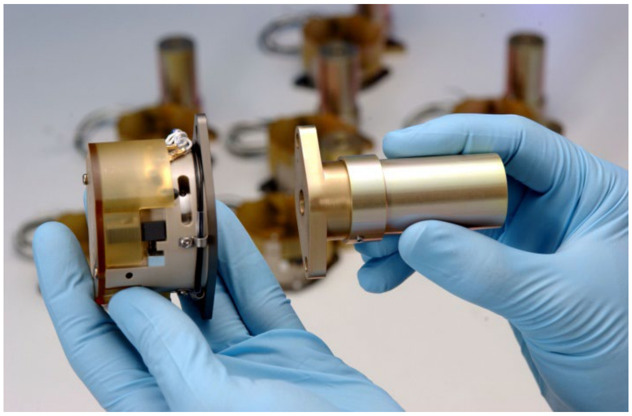
Note: All dimensions above are in inches. Bolt retractor with EVA feature shown.

Applications	
• H2 Transfer Vehicle (HTV) Cargo Pallet Restraint System (30K version)	• Spacecraft Separation (10K version)
• Large Telescope Barrel Cover Release (1K version)	

Heritage Programs	
• H2 Transfer Vehicle (HTV) Cargo Pallet Restraint System (30K version)	• Spacecraft Separation (10K version)
• Large Telescope Barrel Cover Release (1K version)	

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions: Nut: Bolt Retractor:	 5 in x 5 in x 5 in 5-in diameter x 7-in tall	 127 mm x 127 mm x 127 mm 127-mm diameter x 178-mm tall
Mass: Nut: Bolt Retractor (EVA feature):	 6.5 lbm max 4.5 lbm max	 2.9 kg max 2.0 kg max
Preload	10,000 to 30,000 lbf	44.5 to 133.4 kN
Electrical		
Life Cycles	>50 full load releases	
Redundancy	Full electrical	
Release Signal	3.6 A for 75 ms	
Release Time	200 msec max	
Source Shock	<100 gs	
Vibration	16.8 Grms for 2 min per axis	
Reset	Reset tools provided by Sierra Space. Requires access from sides and top of FASSN nut to reset the latch and redundant actuators, and from the top of bolt retractor to insert and then preload the bolt. Super-nut provided for simple pre-load application. Force-sensing bolt ("Strainsert") provided for real-time preload reading.	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Hold Down Release Mechanism (HDRM)



Hold Down Release Mechanism (HDRM).

Design Description

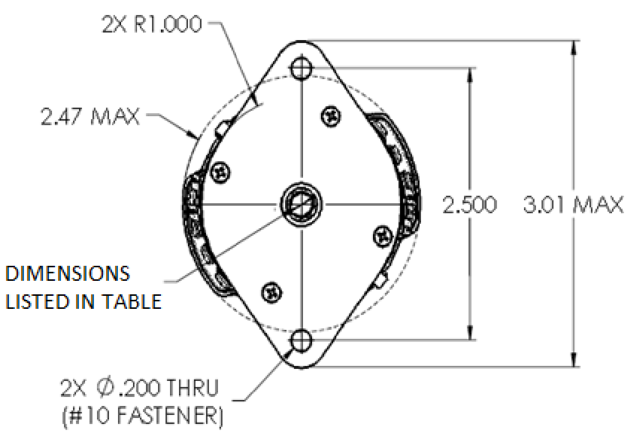
Sierra Space's Hold Down Release Mechanism (HDRM) is a fast-acting separation nut rated to accommodate several working preloads. The HDRM series uses a conventional segmented separation nut with a redundant shape memory alloy (SMA) trigger that responds to a standard pyrotechnic firing pulse. The SMA trigger allows for fast response times with low release shock. Integral circuit interrupts open trigger circuits upon release, simplifying ground operations and flight control requirements. The HDRM resets and is ready for bolt insertion in less than 1 minute with the supplied reset pin.

The HDRM releases a standard UNF (Unified National Fine) high-strength bolt. Our HDRM bolt retractor (offered separately) is a flight-qualified option with a preload measurement using a calibrated load cell and spherical washer set to accommodate angular misalignment. In addition, the bolt retractor features an easily removable cover that facilitates reset.

HDRM Features	
• Uses wide range of initiation pulses	• Millisecond release
• Circuit interrupt feature for simple control	• Low shock
• Eliminates pyrotechnic safety concerns	• Easily reset in place with a simple tool—no refurbishment
• Low mass	• Flight hardware can be repeatedly tested prior to flight
• Redundant, resettable shape memory alloy triggers	• High dynamic load capability

Applications
• Spacecraft-from-launch vehicle separation, solar array hold-down and release, gimbal launch locks and other satellite applications requiring a low-shock, quick release

Dimensions



Note: All dimensions above are in inches.

Heritage Programs	
• Space Test Program Satellite-1 (STPSat-1)	• Communications/Navigation Outage Forecasting System (CNOFS)
• WorldView-1, -2, and -3	• eXperimental Small Satellite 10 (XSS-10)
• Poly Picosatellite Orbital Deployer (P-POD)	• European Space Agency Swarm Satellites for Earth Observation (EO)
• Advanced Extremely High Frequency (AEHF)	• Space Communications and Navigation (SCaN) Testbed
• Cyclone Global Navigation Satellite System (CYGNSS)	• Small Missions for Advanced Research in Technology (SMART-1) • FalconSAT-1
• NanoRacks Kaber Microsat Deployer	• Kestral Eye-2M

Product Specifications				
	U.S.		**SI**	
Mechanical				
Thread	1/4-28 UNF	5/16-24 UNF	No metric equivalent	No metric equivalent
Nominal Working Preload (allows for operating margin and preload uncertainty)	3,400 lbf	4,800 lbf	15,125 N	21,351 N
Maximum Operating Load Capability (higher pre-load versions are currently under development; specifications available upon request)	4,000 lbf maximum	5,300 lbf maximum	17,793 N	23,576 N
Release Bolt Replacement Interval	15 recommended (30 qualified) for NAS1351			
Misalignment Capability	±1.5 deg OR ±0.015-inch lateral		±1.5 deg OR ±0.381 mm lateral	
Mass	9.52 oz max		270 g max	
Life Cycles	>100 full load releases			
Redundancy	Full electrical, partial mechanical			
Operational Margins	>100%			
Source Shock	<400 gs		<400 gs (expected)	
Reliability	>0.9999			
Random Vibration	36 Grms			
Release Time	15 to 200 msec (over operational environment conditions)			
Electrical				
Power Input	Typical: 45 W @ 3.5 A @ 20 °C			
Release Signal Range for Operating Temperatures	Typical: 3.5 A, 35 msec @ 20 °C Range: 2.3 A to 7 A, 15 msec to160 msec			
SMA Resistance (single circuit)	3.9 ±0.1 @ 20 °C Ω			
No-fire Current	0.25 A min			
All-fire Current (200 msec)	2.3 A			
Lead-wire	4x 22 AWG (Mil-W-22759/33)			
Thermal				
Operating Temperatures	-49 °F to +167 °F		-45 °C to +75 °C	
Nonoperating Temperatures	-112 °F to +167 °F		-80 °C to +75 °C	
Reset				
Tools Needed	Ø.1250-inch gauge pin			
Reset for HDRM	<1 minute (ready for bolt insertion)			
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.				

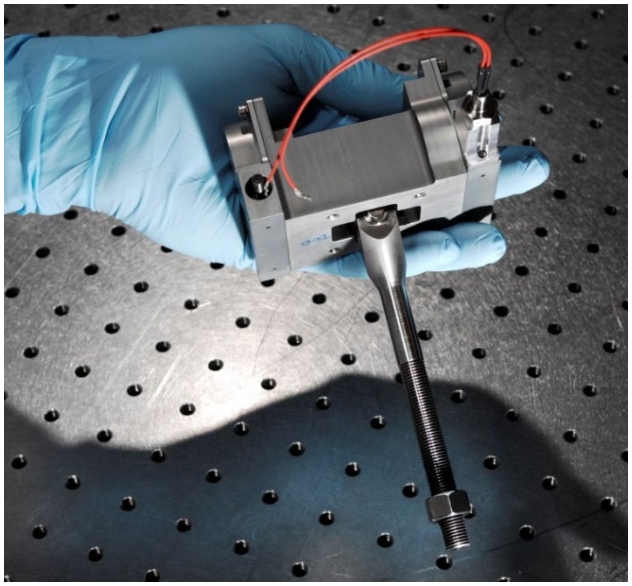
Low Shock Release Mechanism (LSRM) 5K

Design Description

Sierra Space's Low-Shock Release Mechanism (LSRM) 5K is a simple, redundant, and reusable low-shock producing release latch for the hold down and release of preloaded joints. The LSRM uses a conventional toggle bolt that engages a mechanically redundant latch.

The design features a unique gear and flywheel combination that creates low required energy to release a low-source shock upon actuation of the latch and release of the stored strain energy. The LSRM 5K is capable of being released with either low- or high-speed redundant actuators. It can be used as a discrete release latch or used together with multiple latches to release larger interfaces without requiring additional actuators.

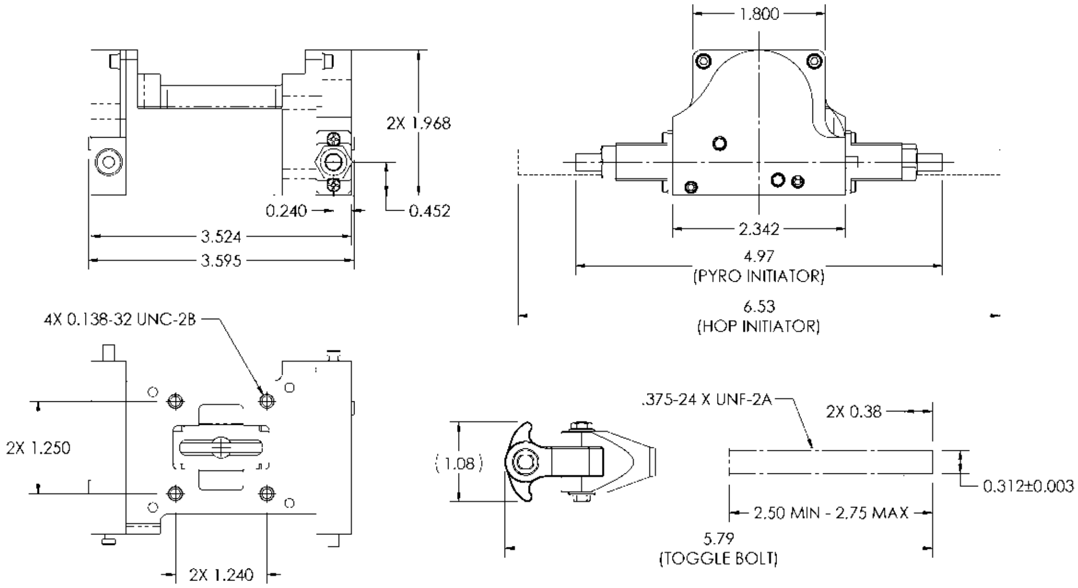
The LSRM 5K (sized for a 5,000-lbf preload) successfully released an important U.S. scientific payload on-orbit in 2014. The LSRM 5K can be scaled up or down to support specific size and preload requirements.



Low Shock Release Mechanism (LSRM) 5k.

LSRM Features	
• Robust and easy to use	• Re-settable *in-situ*
• Mechanically and electrically redundant	• No parts to replace with >100 load and release cycles
• Low-shock release	• Optional bolt catcher features available
• Adaptable for use with fast-acting and slow (very low-shock) actuators (included)	

Dimensions



Note: All dimensions above are in inches.

Applications	
• Spacecraft Hold Down and Release (HDRM) applications	• Smaller launch vehicle staging
• Dispenser/adapter systems	

Heritage Programs
• Drag and Atmospheric Neutral Density Explorer (DANDE)

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	2.6 in x 3.6 in x 2.0 in	66 mm x 91 mm x 51 mm
Mass	1.5 lbm max	0.52 kg max
Preload	5,000 lb	22,241 N
Redundancy	Full mechanical and electrical	
Release Signal	5 A for 100 milliseconds	
Release Time	100 msec max	
Source Shock	100 gs peak between 10 to 5,000 Hz	
Operating Temperature	-65 °F to +160 °F	-54 °C to 71 °C
Shock	Falcon 9 launch loads	
Vibration	Falcon 9 launch loads	
Reset		
Tools Needed	Standard hex and open-end wrenches	
Reset Time	<5 minutes	
Access	Requires access from two sides to reset the latch and redundant actuators, and from the top to insert and then preload the bolt.	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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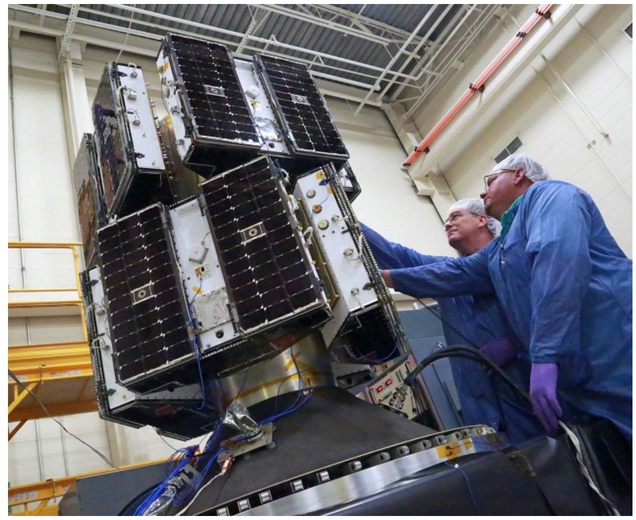
Microsat Deployment Module

Design Description

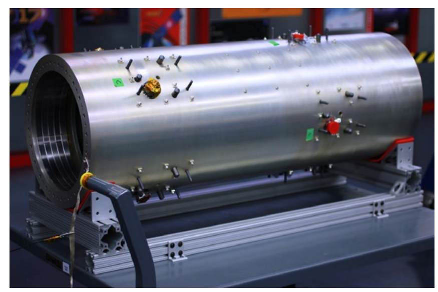
Sierra Space provides highly scalable satellite constellation deployment modules. Providing end-to-end solutions, our systems consist of a fully assembled and tested deployment module structure, hold down and release mechanisms (HDRM) (low-shock and reusable separation nuts), tailorable satellite separation springs, umbilical disconnects, separation indication features, and cabling and harnessing assemblies.



Microsat Deployment Module enables all eight of the CYGNSS microsatellites to be launched simultaneously in pairs. Credit: NASA

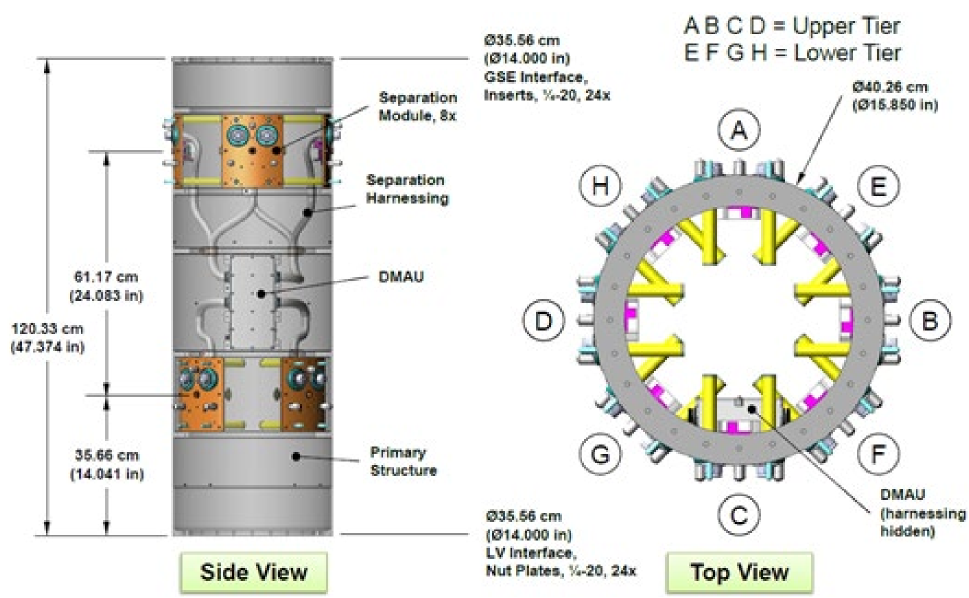
Our deployment modules are available in a wide variety of configurations to meet various mission requirements. With a long and successful heritage, we have provided thousands of systems, subsystems, and components on hundreds of space missions. In 2016, we developed, qualified, and manufactured the deployment module for the CYGNSS mission. This module consists of a central tube structure with discrete separation modules that secure and gently separate the eight CYGNSS microsatellites.

Our experts provided a custom-engineered, design-to-specification solution that enables the entire constellation to be launched simultaneously in pairs. In addition, our heritage, fast-acting and low-shock HDRM product allows for paired sets of satellites to be deployed simultaneously in an extremely soft and clean manner, in contrast to traditional pyrotechnic separation devices that create significant debris and generate high-shock loading into the spacecraft.



CYGNSS Deployment Module.

Dimensions



Note: All dimensions above are in inches. (Note: The origin is at the launch vehicle Interface and on the centerline of the canister. Looking at the Side View above, +X is vertical, +Y is to the left, +Z is out of the page.)

Microsat Deployable Module Features	
• Scalable deployment module based on existing design	• Complete satellite deployment solution
• Enables two satellites to be launched at same time	• Customizable separation rates
• Low-shock, debris-free separation	• Heritage mechanisms
• Heritage minimizes nonrecurring engineering (NRE)	• Options for photos/videos of spacecraft separation
• Integrated deployment module avionics unit (DMAU), cabling/harnessing	

Applications
• Spacecraft launch and separation

Heritage Programs
• Cyclone Global Navigation Satellite System (CYGNSS)

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	18 in x 48 in	46 cm x 121 cm
Deployment Module System Mass	97 lb	44 kg
Maximum Quasi Static Accelerations (worst-case loading from sine burst testing)	11.0 gs (X), 2.53 gs (Y), 5.75 gs (Z).	
Number of Satellites/Mass per Satellite	8 x 29 kg per spacecraft	
Satellite Separation Velocity	0.65 meters per second	
Satellite Tip-off Rate	≤7 deg/s	
Source Shock	<400 gs	
Random Vibe	Based on the CYGNSS random vibration, spectrum was notched to give the following test levels: 2.27 Grms (X), 3.27 Grms (Y), 2.82 Grms (Z)	
Release Time	15 to 155 msec (over operational environment conditions)	
Simultaneity	Deploys two opposing spacecraft simultaneously within 100 ms of each other	
Electrical		
HDRM Power Input (per device)	Typical: 45 W @ 3.5 A @ 20 °C	
HDRM Release Signal Range for Operating Temperatures	Typical: 3.5 A, 35 msec @ 20 °C Range: 2.3 A to 7 A, 15 msec to160 msec	
HDRM Shape Memory Alloy (SMA) Resistance (single circuit)	3.9 ±0.1 Ω @ 20 °C	
HDRM No-fire Current	0.25 A min	
HDRM All-fire Current (200 msec)	2.3 A	
Thermal		
Operating Temperatures	-18 °F to +145 °F	-28 °C to +63 °C
Nonoperating Temperatures	-15 °F to +167 °F	-26 °C to +75 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

QwkSep® 15 Low-Profile Separation System (LPSS)

Design Description

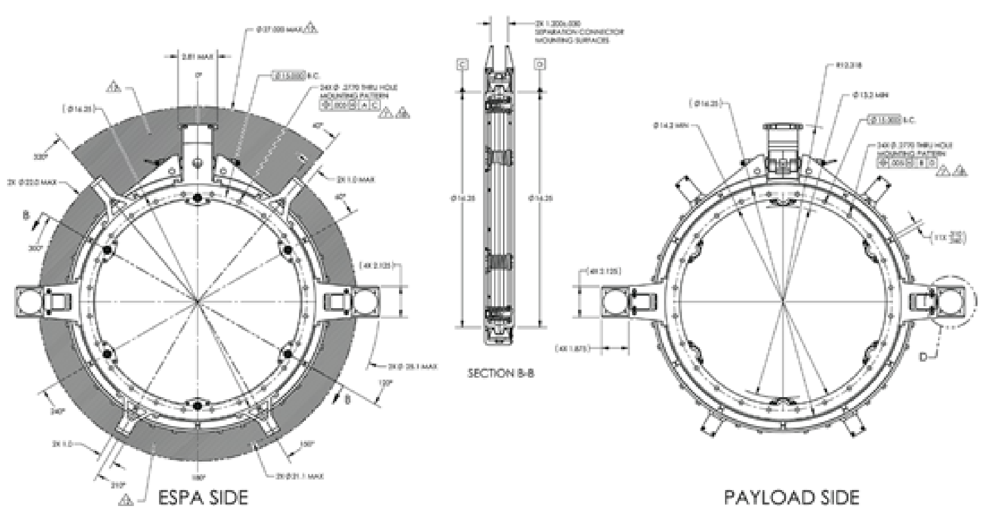
Sierra Space's QwkSep® 15 Low-Profile Separation System (LPSS) provides a low-shock solution to small satellite separation in an extremely low profile. The system is designed for a standard EELV Secondary Payload Adapter (ESPA) with a 15-inch satellite interface launch configuration (orthogonal to thrust axis). The interface rings have integrated adjustable kick off springs, pass-through separation connectors and redundant telemetry indication of positive separation. The system is released with a mini, low-shock Clamp Band Opening Device (CBOD). This design configuration has heritage in more than 100 successful flight releases.

QwkSep® 15 Low-Shock Clamp Band system provides a small satellite separation solution.

The CBOD features redundant circuits driven by a typical pyrotechnic firing pulse. Based on our space-qualified Fast-Acting Shockless Separation Nut (FASSN) technology, the CBOD restrains the band tension bolts with a double helix, flywheel nut. The back drive torque of the high lead, band tension bolts is reacted through the CBOD by the latched flywheel nut. A pyro-compatible pulse releases the flywheel nut, which spins up and ejects the tension bolts. The strain energy in the band is converted to rotational energy in the flywheel nut allowing the two mating halves to separate with extremely low shock.

QwkSep 15 LPSS Features	
• Ultra-high reliability payload separation	• Redundant electrical trigger circuits
• >25% stiffer and >40% more load capability than comparable, alternative solutions	• Uses heritage release technology of CBOD with redundant NASA standard initiator-driven pin puller
• Low-shock operation	• Scalable between 12-inch and 24-inch sizes
• Designed for full ESPA payload weight and ESPA dynamic environments	• Optional nonpyrotechnic mini-CBOD release mechanism available for extremely low-shock release
• Straightforward integration and operation	• No generated debris
• Resettable for multiple ground operations	• Based on extensive clamp band heritage

Dimensions



Note: All dimensions are in inches.

Applications	
• Auxiliary payload separation	• ESPA-compatible integration and operation

Heritage Programs	
• AFRL's University Nanosat Program	• Orbital Express
• Atlas V*	• Delta IV*
• Arianne*	• Sea Launch*
• Proton* (Satellite Program)	• Falcon 9*
**Note: Larger diameter version (primarily 47-inch and 66-inch systems); have more than 100 combined flight releases on these LVs.*	

Product Specifications		
	U.S.	**SI**
Mechanical		
Payload Capability	400 lbm with 20-inch center of gravity (CG) Offset height above ESPA interface	181 kg (508 mm CG height)
Quasi-static Environment	8.5 gs axial and lateral dynamic loading simultaneously	
Random Vibration Environment	Qualified to NASA *General Environmental Verification Specification* (GEVS) levels for large (400+lbm) payloads (5.6 Grms)	
Stiffness Axial: Moment:	2.15E6 lb/in 9.62E7 in•lb/rad	3.76E4 Nm 1.09E7 Nm/rad
Envelope Dimensions	Ø15 BCD x 2.1-inch max stack height	Ø381 BCD x 53.3 mm
Mass, Full System (not including fasteners, harness)	15 lbm max	6.8 kg max
Mass, Flyaway	4.0 lbm max	1.8 kg max
Life (as delivered)	12 full-load release cycles	
Redundancy	Full electrical	
Source Shock	Pyro: 1,000 gs from 1 kHz to 2 kHz near actuator Non-pyro option: 100 gs max from 10 Hz to 10 kHz	
Tip-off Rate	0.5 deg/s max	
Kick-off Rate (separation velocity)	1 ft/s min	0.3 m/s min
Electrical		
Release Signal	Pyro: NASA Standard Initiator (NSI)-firing pulse Non-pyro option: 3.5 amps for 50 ms (typical)	
Separation Telemetry	Redundant loop-back circuits indicate positive separation	
Release Time	50 ms max	
Thermal		
Operating Temperature Range	Pyro: -90 °F to +219 °F Non-pyro option: -85 °F to +167 °F	
Reset		
Refurbishment	Replace standard NSI pin puller trigger	
Special Tools	Sierra Space band loading tool; Sierra Space spring compression tools	
Time Required for Reset	~ 2 hours	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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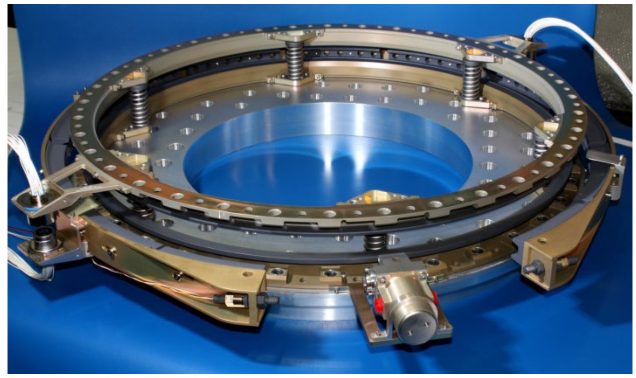
QwkSep® 24 Low-Profile Separation System (LPSS)

Design Description

Sierra Space's QwkSep® 24 Low-Profile Separation System (LPSS) provides a low-shock solution to small satellite separation in an extremely low profile. The system is designed for standard ESPA-Grande (EELV Secondary Payload Adapter) with a 24-inch satellite interface launch configuration (orthogonal to thrust axis). The interface rings have integrated adjustable kick off springs, pass-through separation connectors and redundant telemetry indication of positive separation. The system is released with a mini, low-shock clamp band opening device (CBOD). This design configuration has heritage in more than 100 successful flight releases.

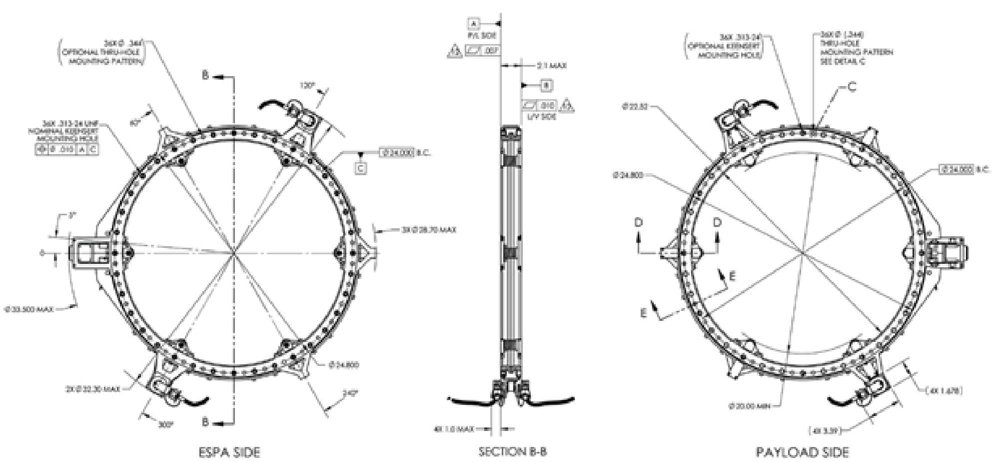


QwkSep® 24 Low-Shock Clamp Band provides a small satellite separation solution.

The CBOD features redundant circuits driven by a typical pyrotechnic firing pulse. Based on our space-qualified Fast-Acting Shockless Separation Nut (FASSN) technology, the CBOD restrains the band tension bolts with a double helix, flywheel nut. The back drive torque of the high lead, band tension bolts is reacted through the CBOD by the latched flywheel nut. A pyro-compatible pulse releases the flywheel nut, which spins up and ejects the tension bolts. The strain energy in the band is converted to rotational energy in the flywheel nut allowing the two mating halves to separate with extremely low shock.

QwkSep® 24 LPSS Features	
• Ultra-high reliability payload separation	• Redundant electrical trigger circuits
• >25% stiffer and >40% more load capability than comparable, alternative solutions	• Uses heritage release technology of CBOD with redundant NASA standard initiator-driven pin puller
• Low-shock operation	• Scalable between 12-inch and 24-inch sizes
• Designed for full ESPA-Grande payload weight and ESPA dynamic environments	• Optional nonpyrotechnic mini-CBOD release mechanism available for extremely low-shock release
• Straightforward integration and operation	• No generated debris
• Resettable for multiple ground operations	• Based on extensive clamp band heritage

Dimensions



Note: All dimensions above are in inches.

Applications	
• Auxiliary payload separation	• ESPA-compatible integration and operation

Heritage Programs	
• AFRL's University Nanosat Program	• Orbital Express
• Atlas V	• Delta IV
• Arianne	• Sea Launch
• Proton (Satellite Program)	• Falcon 9

Product Specifications		
	U.S.	**SI**
Mechanical		
Payload Capability	660 lbm with 20-inch center of gravity (CG) Offset height above EELV Secondary Payload Adapter (ESPA) interface	300 kg (508 mm CG height)
Quasi-static Environment	8.5 gs axial and lateral dynamic loading simultaneously	
Random Vibration Environment	Qualified to NASA *General Environmental Verification Specification (GEVS)* levels for large (400+lbm) payloads (5.6 Grms)	
Stiffness Axial: Moment:	6.23E6 lb/in 4.45E8 lb·in/rad	1.09E3 Nm 5.03E7 Nm/rad
Envelope Dimensions	Ø24 BCD x 2.1-inch max stack height	Ø610 BCD x 53.3 mm
Mass, Full System (not including fasteners, harness)	21 lbm max	9.5 kg max
Mass, Flyaway	5.0 lbm max	2.3 kg max
Life (as delivered)	12 full-load release cycles	
Redundancy	Full electrical	
Source Shock	Pyro: 1,000 gs from 1 kHz to 2 kHz near actuator Non-pyro option: 100 gs max from 10 Hz to 10 kHz	
Tip-off Rate	0.5 deg/s max	
Kick-off Rate (separation velocity)	1 ft/s min	0.3 m/s min
Electrical		
Release Signal	Pyro: NASA Standard Initiator (NSI)-firing pulse Non-pyro option: 3.5 amps for 50 ms (typical)	
Separation Telemetry	Redundant loop-back circuits indicate positive separation	
Release Time	50 ms max	
Thermal		
Operating Temperature Range	Pyro: -90 °F to +219 °F Non-pyro option: -85 °F to +167 °F	Pyro: -68 °C to +104 °C Non-pyro option: -65 °C to +75 °C
Reset		
Refurbishment	Replace standard NSI pin puller trigger	
Special Tools	Sierra Space band loading tool; Sierra Space spring compression tools	
Time Required for Reset	~ 2 hours	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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POINTING SYSTEMS AND MOTION CONTROL

Sierra Space is an industry leader in precision, low disturbance pointing systems for space applications. We have developed several single- and dual-axis pointing systems for deploying and positioning antennae, solar array drives and mechanisms, optical telescopes, and instrument mechanisms. Each axis of the pointing system is typically driven by a precision rotary actuator, which features a redundant stepper motor, strain wave gearset and/or hybrid transmission, with various position telemetry options. The rotary actuator is configurable with multiple options, through holes for cable management, slip rings, twist capsules, radio frequency (RF) rotary joints, telemetry sensors and adjustable hard stops. The biaxial brackets have been designed for minimal orthogonal distortion, high stiffness, and low mass. Our pointing systems are qualified and flight-proven with NASA programs, commercial and military satellites, and the International Space Station (ISS).

Although we specialize in custom-engineered open- and closed-loop solutions, our list of qualified motors, actuators, gimbals, and drive electronics has grown into a substantial portfolio that can support a wide range of applications and sizes with minimal nonrecurring effort required.

Catalog data sheets for our Pointing Systems and Motion Control technology area include:

C14E Incremental Rotary Actuator

C20 Incremental Rotary Actuator

C25 Incremental Rotary Actuator

C50 Incremental Rotary Actuator

CEH25 Compact Incremental Rotary Actuator, 3-Phase

EH25 Bi-Axis Gimbal, 3-Phase

EH25 Incremental Rotary Actuator, 3-Phase

H25 Bi-Axis Gimbal, 4-Phase

Lightweight 2-Axis Mini Gimbal

Size 23 Incremental Rotary Actuator

Size 30 Incremental Rotary Actuator

T25 Incremental Rotary Actuator (RA)

SOLAR ARRAY DRIVES

C14C-40A Twist Capsule Solar Array Drive Assembly (SADA)

C14E-40A Twist Capsule Solar Array Drive Assembly (SADA)

C14E-60A Slip Ring Solar Array Drive Assembly (SADA)

C14-30A Slip Ring Solar Array Drive Assembly (SADA)

C14-110A Slip Ring Solar Array Drive Assembly (SADA)

C25C-70A Twist Capsule Solar Array Drive Assembly (SADA)

C25E-70A Twist Capsule Solar Array Drive Assembly (SADA)

EH25-60A Solar Array Drive Assembly (SADA)

EH50-12.5A Solar Array Drive Assembly (SADA)

BRUSHLESS DC MOTORS

ECLSS Pump Motor

M45L Motor

M45S Motor Brake

GEARED BRUSHLESS DC MOTORS

DM45L Gearmotor

HT32-948 Gearmotor

HT45S-178 Gearmotor with Brake

LT32 Gearmotor

LT45L Gearmotor

LT45S-42 Gearmotor with Brake

ELECTRONIC MOTOR DRIVES

Electronic Control Unit (ECU) – Multi Axis Microstepper with Position Control Over Low-voltage Differential Signaling (LVDS)

Gimbal Control Unit (GCU) – Ultra Smooth Closed-Loop Position Control Unit

Motor Drive Module (MDM) – 2 Axis Microstepper Board with Position Control Over RS-422

Multi-Motion Controller (MMC)

Rotary Drive Electronics (RDE) – 2 Axis Microstepper Position Control Box Over MIL-STD-1553

Simple Stepper Driver (SSD) – Incremental Stepper with Discrete Input Commands

Universal Microstepping Control Driver (UMCD) – Microstepper with Discrete Input Commands

SPECIAL PURPOSE MECHANISMS

eMotor with Integral Brushless DC Electronic Drive

Pivot Platform Mechanism (PPM)

T25 Dual Antenna Pointing System

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MICRO JITTER SYSTEMS

LDC20 Low-Disturbance Gimbal

Low Disturbance Gimbal, 2-Axis, Direct Drive

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LDC20 Low-Disturbance Gimbal

Design Description

Sierra Space has developed an innovative bi-axis gimbal that sets new standards for low-disturbance, open-loop operation when paired with one of our microstepping drives. The gimbal has completed qualification and is available for critical spaceflight applications.

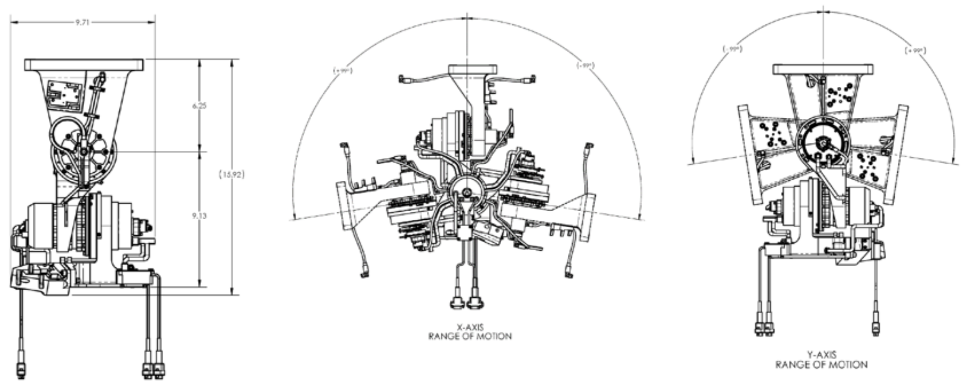
This gimbal features advanced low-disturbance microstepping motors coupled to precision harmonic drives for high-efficiency operation. The actuators can be mounted in rotary isolators that further reduce the transmitted disturbance torque to extremely low levels.

The actuators feature permanent magnet stepper motors with redundant windings that are fully isolated from one another to prevent failure propagation. The unit can be provided in 2- or 3-phase motor configurations. Magnetic modeling and optimization ensure the permanent magnet stepper motor provides smooth motion.

LDC20 Low-Disturbance Torque Gimbal.

Oversized 440C stainless steel ABEC 7 ball bearings support the actuator shafts for maximum stiffness and life. Telemetry is provided by redundant potentiometers that offer a low-cost, low-complexity solution to high-repeatability position measurement. The potentiometers provide absolute position telemetry, with resolution to within a single motor step. The gimbal is capable of ±99-degree rotation about the X- and Y-axis. The gimbal includes an integral launch lock mechanism that supports the gimbal and payload and uses a high output paraffin (HOP) actuator to actuate the mechanism reliably and smoothly. The gimbal structural components and motor housings are fabricated from aluminum alloys for their lightweight and good thermal conduction. Critical actuator components are fabricated from a titanium alloy for added strength. Two radio frequency (RF) channels transition the gimbal from top to bottom through RF rotary joints at the actuators. Electrical power and signals for the Y actuator transition the X-axis through a rotary twist capsule with 24 separate channels and a total power capacity of 15 W. Engineering experts in the industry, who offer their strong customer support for their specific applications, design this system, like all the mechanisms produced by Sierra Space. Contact Sierra Space for additional information.

Dimensions



Note: All dimensions above are in inches.

LDC20 Low-Disturbance Torque Gimbal Features	
• 2- or 3-phase windings	• Redundant telemetry potentiometers or optical encoders
• Movable hard stops	• Available radiation hardened microstepping motor driver
• Bray or Pennzane lubrication	• Available with coax or waveguide rotary joints

Applications	
• Antenna and camera pointing mechanisms	• Robotics applications
• Solar array drives	• Deployment mechanisms

Heritage Programs
• GeoEye

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	18 lbm	8.2 kg
Step Size at 64 Microstep Resolution	0.007 deg	
Output Rotational Rate	8 deg/s	
Powered Holding Torque	120 in-lb	13.6 Nm
Unpowered Holding Torque	3 in-lb	0.34 Nm
Torsional Stiffness	100,000 in-lb/rad	11,300 Nm/rad
Electrical		
Winding Resistance	23 Ω	
Dielectric Strength	500 Vdc	
Insulation Resistance	100 M Ω	
RF		
Insertion Loss	<1.5 dB	
Frequency	8.025 – 8.4 GHz	
Power	<10 W	
Voltage Standing Wave Ratio (VSWR) Ratio	<2.1:1	
Thermal		
Operating Temperatures	-13 °F to 158 °F	-25 °C to +70 °C
Nonoperating Temperatures	-76 °F to 167 °F	-60 °C to +75 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

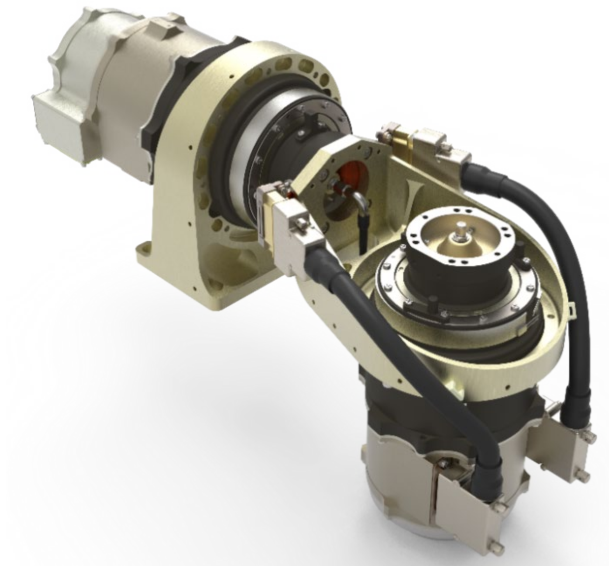
Low Disturbance Gimbal, 2-Axis, Direct Drive

Design Description

Sierra Space has developed an actuator/gimbal architecture specifically designed to minimize disturbance imparted on the spacecraft during highly accurate operation.

The mechanism is comprised of two direct-drive actuators, rotating on perpendicular axes, and connected by an interaxis bracket. The first axis mounts directly to the spacecraft, while the second axis interfaces with the payload.

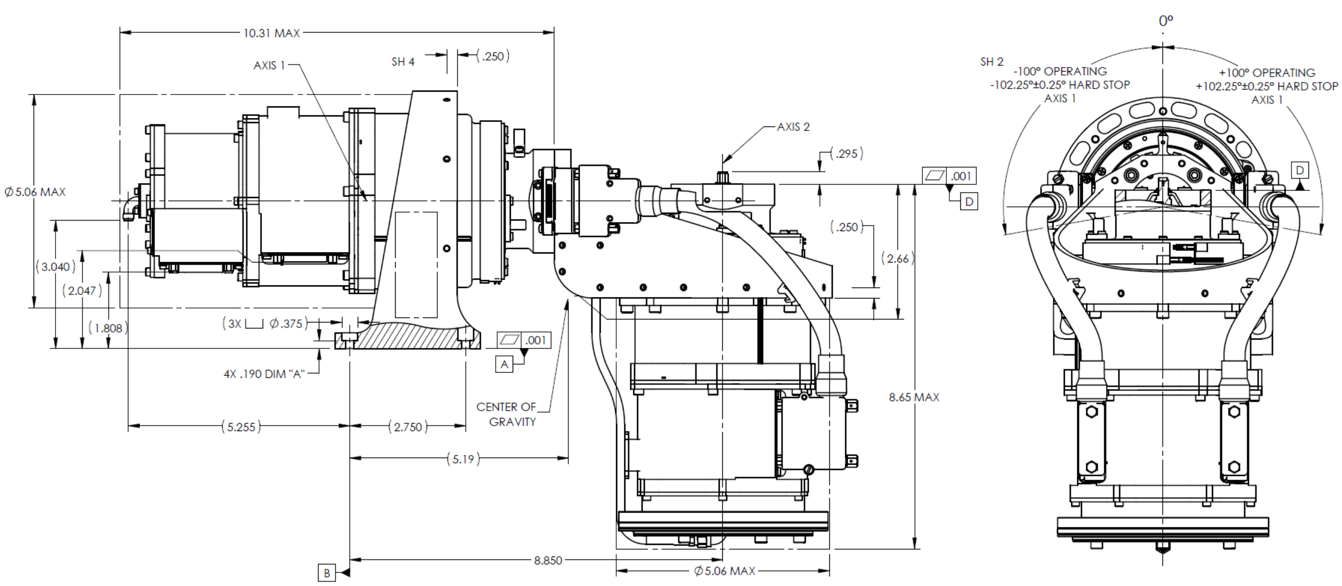
Each actuator is composed of a low cogging, 3-phase brushless permanent magnet synchronous (BPMS) motor, dual speed resolver with integral excitation cable wrap, and radio frequency (RF) signal pass-through. The first axis actuator also includes a twist capsule assembly to provide drive and feedback signal paths to the second axis actuator. All gimbal electrical interfaces except for RF are fully redundant.



Low Disturbance Direct Drive Gimbal.

Gimbal Features	
• 3-phase brushless DC motor operation	• Design optimized for smooth, low disturbance operation
• Fully redundant electrical design	• Qualified for extreme environments
• Near zero cogging torque	• Heaters, temperature sensors, hard stops available
• Highly accurate dual speed resolver telemetry	• Designed for use with low-loss RF pass through

Dimensions



Note: All dimensions above are in inches.

Applications	
• Antenna pointing mechanisms	• Optical systems
• Camera pointing mechanisms	• Robotics applications

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	20.5 lb	9.3 kg
Resolver Accuracy	20 arc-sec (per axis)	
Range of Motion	>±100 deg	
Moment Stiffness, Type	90,000 in-lbf/rad	10,170 Nm/rad
Electrical		
Motor Type	3-phase, brushless, redundant	
Driver Type	Sine/Space Vector	
Voltage, Nominal	28.0 Vdc	
Winding Resistance, L-L	3.3 Ω	
Inductance, L-L	6.5 mH	
Torque Constant, L-L	0.36 Nm/A	
Resolvers (Redundant)	Dual speed 1x/32x high accuracy	
Temperature Sensor Resistance (Redundant)	1,000 Ω @ 25 °C (internal) resistive temperature detectors (RTD) 10 kΩ @ 25 °C (external) thermistor	
Heater Resistance (Redundant)	120 Ω @ 25 °C	
Qualified Thermal Environments		
Operating and Qualified Temperature	-13 °F to +194 °F	-25 °C to +90 °C
Non-Operating Temperature	-76 °F to +212 °F	-60 °C to +100 °C
Random Vibration	14.9 Grms	
Sine Vibration	13.0 G	
Pyrotechnic Shock	860 gs @ 300 Hz	
Life	10.5 years (241M deg)	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

INCREMENTAL MOTION ACTUATION

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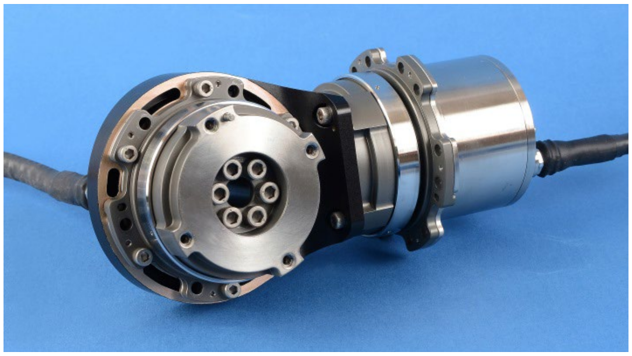
C14 Bi-Axis Gimbal

Design Description



C14 Bi-Axis Gimbal.

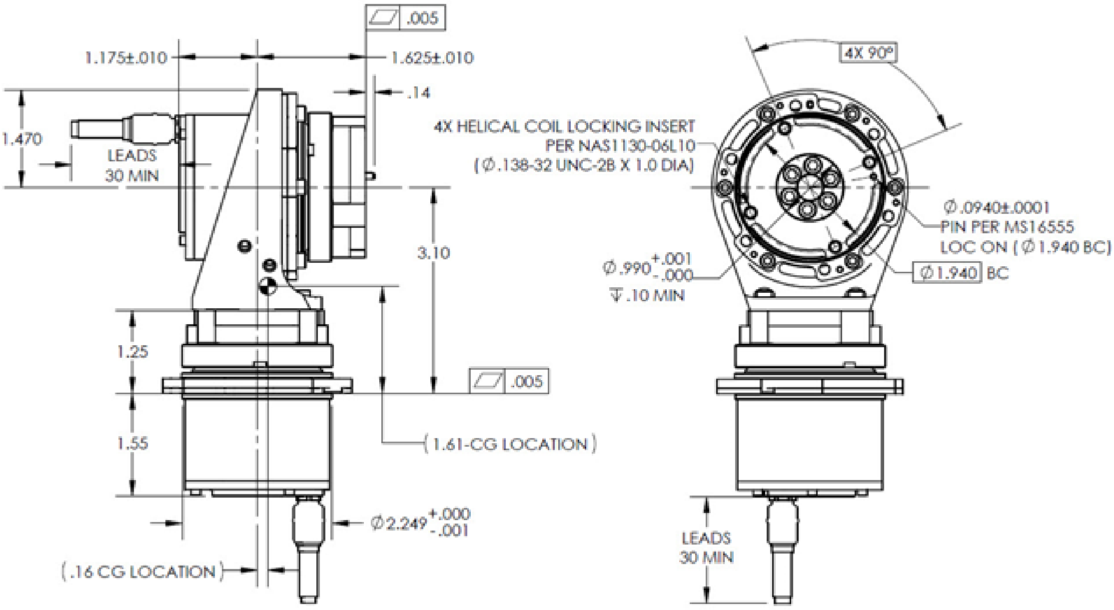
Sierra Space offers a lightweight, bi-axial gimbal, featuring the C14 incremental rotary actuator developed specifically for critical spacecraft pointing applications. Originally developed for antenna pointing mechanisms on communications satellites, the device has also been adapted for solar array drives and is suitable for thruster or instrument pointing.

The actuator uses a 2-phase permanent magnet stepper motor to drive a zero-backlash harmonic drive. An optional 3-phase motor is also available. Magnetic modeling and optimization ensure the permanent magnet stepper motor takes full advantage of the available volume for maximum performance per unit weight. Redundant versions are fully isolated with Nomex-Kapton insulators to prevent failure propagation. High capacity 440C stainless steel ball bearings support the output shaft for maximum stiffness and life. The actuator's titanium construction ensures high strength and consistent performance over a broad temperature range.

A high-stiffness, stainless steel harmonic drive with modified tooth profile and circular spline provides outstanding stiffness and torque capability with extremely low weight. A custom Oldham coupling between the motor assembly and transmission allows for a large through hole that can be used for wire routing, radio frequency (RF) rotary joints, or waveguides. The motor and transmission are designed as freestanding units that allow for modular combinations of motors and transmissions to adapt the assembly easily to a variety of applications.

The gimbal features an aluminum biaxial bracket that has been optimized for low mass and high stiffness. A black anodized, high-emissivity surface finish promotes thermal management, while the low-resistance conversion coating at the mating surfaces ensures electrical bonding throughout the gimbal.

Dimensions



Note: All dimensions above are in inches.

C14 Bi-Axis Gimbal Features	
• Compact design and mass efficient configuration	• Potentiometer for position telemetry
• 2-phase, 3-phase, or 4-phase motor windings	• High stiffness and load capacity in a small package
• Electrical redundancy available	• Internal heaters and thermistor
• Bray or Pennzane lubrication	• Multiple harmonic drive ratios and optional hard stops
Note: Optional: Launch locks, RF coaxial cables, RF joints, and integrated antennas available upon request	

Applications	
• Critical spacecraft pointing applications	• Solar array drive, antenna, thruster, or instrument pointing

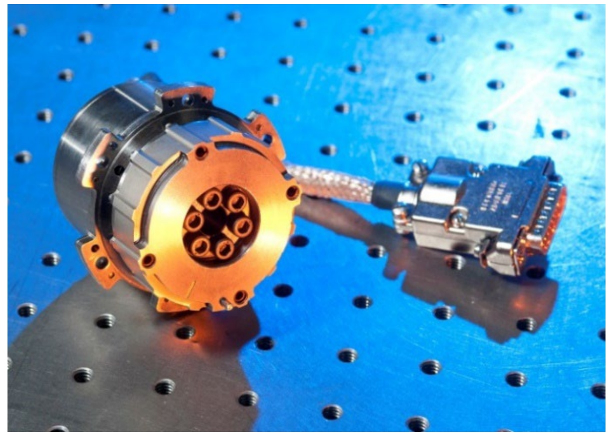
Heritage Programs	
• Eagle (ESPA Augmented Geostationary Laboratory Experiment)	• Geosynchronous Space Situational Awareness Program (GSSAP) 1, 2, 3, and 4
• OrbView-3 and -4 Satellites	• Samaritan Satellite

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	2.7 lbm, excluding cables ~3.25 lb including 33 inches of cabling	1.23 kg, excluding cables ~1.5 kg including 85 cm of cabling
Step Size	0.0625 deg	
Slew Rate	>9 deg/s at no load	
Maximum Output Acceleration	6 deg/s^2	
Output Torque @ 4 deg/s	125 in-lb typical at 77 °F	14 Nm
Maximum Inertial Load	>9 lb-in-s^2	>1 kg-m^2
Unpowered Holding Torque	8 in-lb	0.9 Nm
Actuator Torsional Stiffness	30,000 in-lb/rad	3,390 Nm/rad
Actuator Independent Load Ratings (consult Sierra Space Engineering for Combined Loads)		
Axial Load Capacity (maximum)	1,425 lb	6,338 N
Radial Load Capacity (maximum)	275 lb	1,223 N
Moment Load Capacity (maximum)	800 in-lb	90 Nm
Electrical		
Winding Resistance	57 Ω (nominal, 2-phase)	
Winding Inductance	30 mH typical	
Heater Power	10 W (nominal, each)	
Potentiometer Linearity	0.25% over 350 deg (357 deg total electrical range)	
Qualified Thermal Environment		
Operating Temperatures	-94 °F to 158 °F	-70 °C to 70 °C
Nonoperating Temperatures	-139 °F to 185 °F	-95 °C to 85 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

C14 Incremental Rotary Actuator

Design Description

Sierra Space offers a lightweight, incremental rotary actuator developed specifically for critical spacecraft pointing applications. Originally developed for antenna pointing mechanisms on communications satellites, the device has also been adapted for solar array drives and is suitable for thruster or instrument pointing as well.



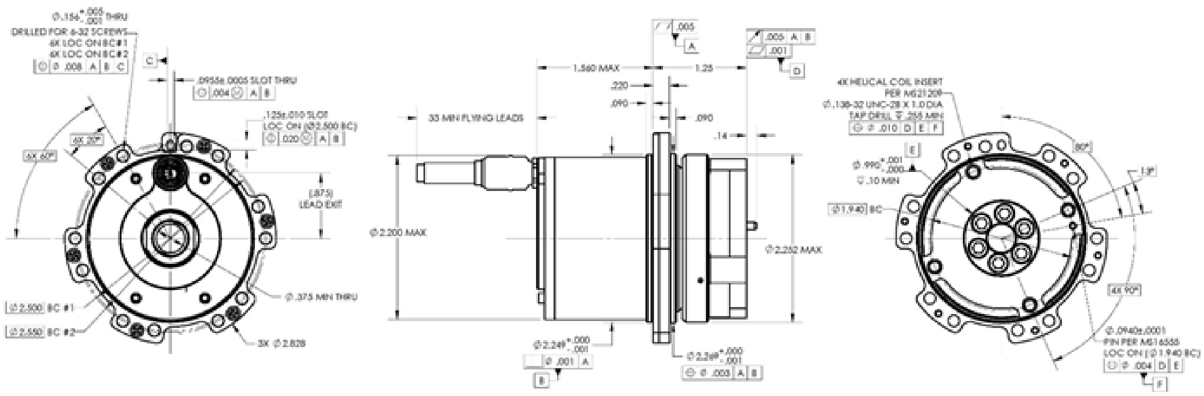
C14 Rotary Actuator.

The actuator uses a 2-phase, permanent magnet stepper motor to drive a zero-backlash harmonic drive. An optional 3-phase motor is also available. Magnetic modeling and optimization ensure the permanent magnet stepper motor takes full advantage of the available volume for maximum performance per unit weight. Redundant versions are fully isolated with Nomex-Kapton insulators to prevent failure propagation. High capacity 440C stainless steel ball bearings support the output shaft for maximum stiffness and life. The actuator's titanium construction ensures high strength and consistent performance over a broad temperature range.

A high-stiffness, stainless steel harmonic drive with modified tooth profile and circular spline, provide outstanding stiffness and torque capability with extremely low weight. A custom Oldham coupling between the motor assembly and transmission allows for a large through-hole that can be used for wire routing, RF rotary joints, or waveguides. The motor and transmission are designed as freestanding units that allow for modular combinations of motors and transmissions to adapt the assembly easily to a variety of applications.

C14 Rotary Actuator Features	
• Compact design, volume, and mass efficient configuration	• Lightweight, all-titanium construction
• High-performance, 2-phase motor windings	• 440C stainless steel harmonic drive/ABEC 7 ball bearings
• 3-phase or 4-phase winding configurations available	• High stiffness and load capacity in a small package
• Potentiometer for position telemetry	• Electrical redundancy available
• Internal heaters and thermistor	• Multiple harmonic ratios and optional hard stops available

Dimensions



Note: All dimensions above are in inches.

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Applications	
• Antenna pointing mechanisms	• Camera pointing mechanisms
• Deployment systems	• Thruster gimbal applications

Heritage Programs	
• OrbView-3 and -4 Satellites	• Geosynchronous Space Situational Awareness Program (GSSAP) 1, 2, 3, and 4
• Samaritan Satellite	

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	1.25 lb	0.57 kg
Step Size	0.0625 deg	
Slew Rate	>9 deg/s @ no load	
Output Torque @ 4 deg/s	125 in-lb typical @ 77 °F	14 Nm typical @ 25 °C
Unpowered Holding Torque	8 in-lb min	0.9 Nm min
Torsional Stiffness	30,000 in-lb/rad	3,390 Nm /rad
Electrical		
Winding Resistance	57 Ω (nominal, two phase)	
Winding Inductance	30 mH typical	
Potentiometer Linearity	0.25% over 350 deg (357 deg total electrical range)	
Independent Load Ratings (Consult Sierra Space Engineering for Combined Loads)		
Axial Load Capacity	1,425 lb	6.3 kN
Radial Load Capacity	275 lb	1.2 kN
Moment Load Capacity	800 in-lb	90 Nm
Qualified Thermal Environment		
Operating Temperatures	-94 °F to +158 °F	-70 °C to +70 °C
Nonoperating Temperatures	-139 °F to +185 °F	-95 °C to +85 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

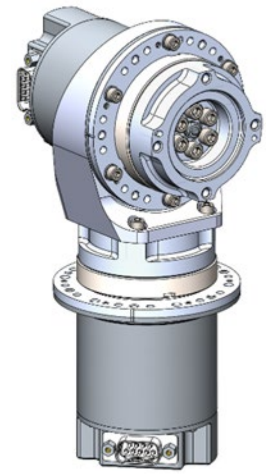
C14E Bi-Axis Gimbal

Design Description

The Bi-Axis Gimbal was developed specifically for spacecraft pointing applications.

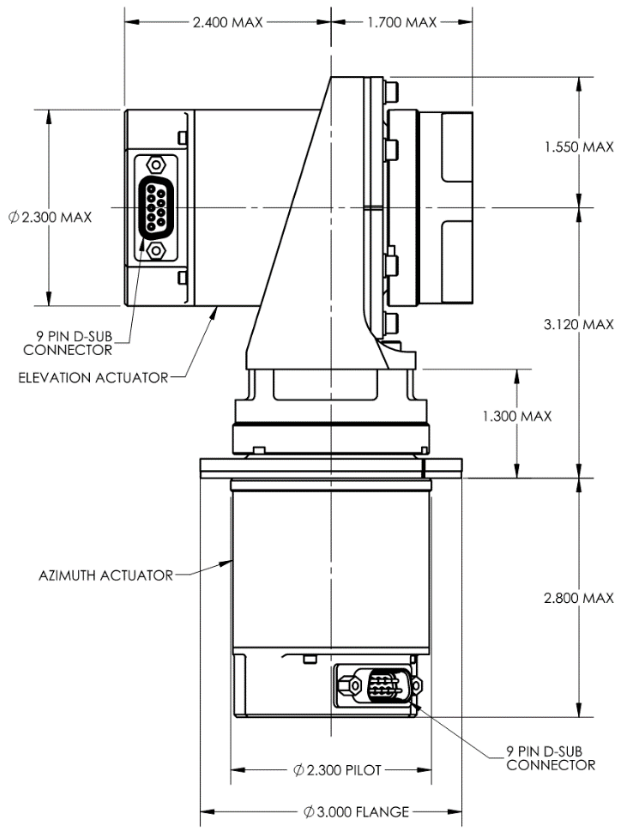
The gimbal is based on the C14E rotary actuator. The actuator contains a permanent magnet stepper motor driving a harmonic drive. The motor and transmission are designed as free-standing units that allow for modular combinations of motor and transmission to easily adapt to a variety of applications.

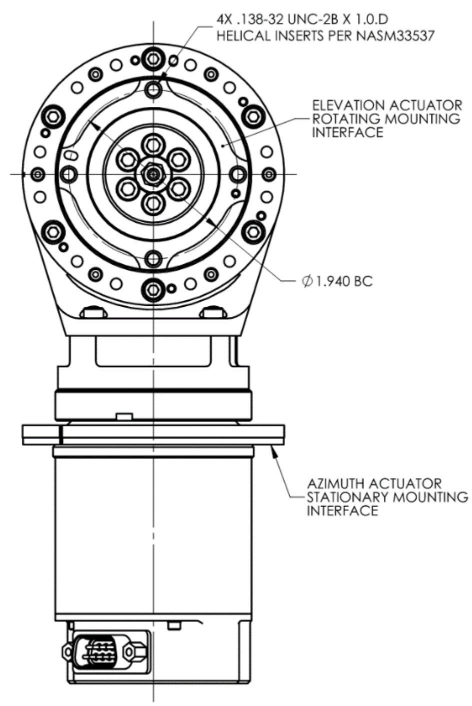
Alternate transmission ratios can be selected to provide output step sizes of 0.10, 0.0625 or 0.05 degrees.



Bi-Axis Gimbal

Dimensions





Note: All dimensions above are in inches.

C14E Bi-Axis Gimbal Features	
• 2-phase motor winding	• Zero backlash harmonic drive
• Potentiometer for position sensing	• High stiffness and load capacity
• 3-phase winding configurations available	• Multiple gear ratios and optional hard stops available

Applications	
• Antenna Pointing Mechanisms	• Thruster Gimbal Mechanisms
• Deployment Systems	• Solar Array Drives
• Camera Pointing Mechanisms	• Instrument Pointing Mechanisms

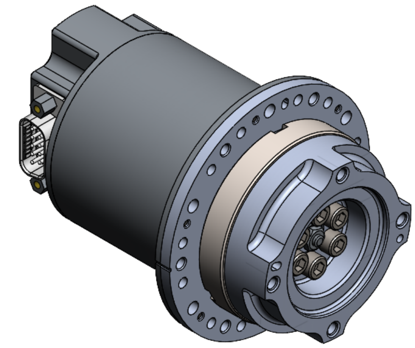
Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	3.8 lbm	1.72 kg
Output Step Size	0.0625 deg	
Slew Rate @ No Load	>9 deg/s	
Output Torque @ 4 deg/s @ Ambient Temperature	125 in-lb	14 Nm
Unpowered Holding Torque (minimum)	8 in-lbf	0.90 Nm
Torsional Stiffness	20,000 in-lbf/rad	2,260 Nm/rad
Electrical		
Winding Resistance (nominal)	57 Ω	
Winding Inductance (typical)	30 mH	
Input Voltage Range	24-32 Vdc	
Position Sensor	Potentiometer	
Actuator Independent Load Ratings (Consult Sierra Space Engineering for Combined Loads)		
Axial	725 lbs	3.2 kN
Radial	725 lbs	3.2 kN
Moment	350 lb-in	39.5 Nm
Thermal		
Operating Temperatures	-22 °F to +149 °F	-30 °C to +65 °C
Non-Operating Temperatures	-40 °F to +167 °F	-40 °C to +75 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

C14E Incremental Rotary Actuator

Design Description

Derived from the successful heritage of the C14 Incremental Rotary Actuator, the C14E, is a lower cost, shorter lead time alternative that is designed for applications targeting a more commercial approach that is willing to accept a commercial-off-the-shelf (COTS) approach to the design verification and acceptance test approach.

The actuator contains a permanent magnet stepper motor driving a strain wave gearset. The motor and transmission are designed as free-standing units that allow for modular combinations of motor and transmission to easily adapt to a variety of applications. Additional design details can be found on the C14 Incremental Rotary Actuator datasheet.

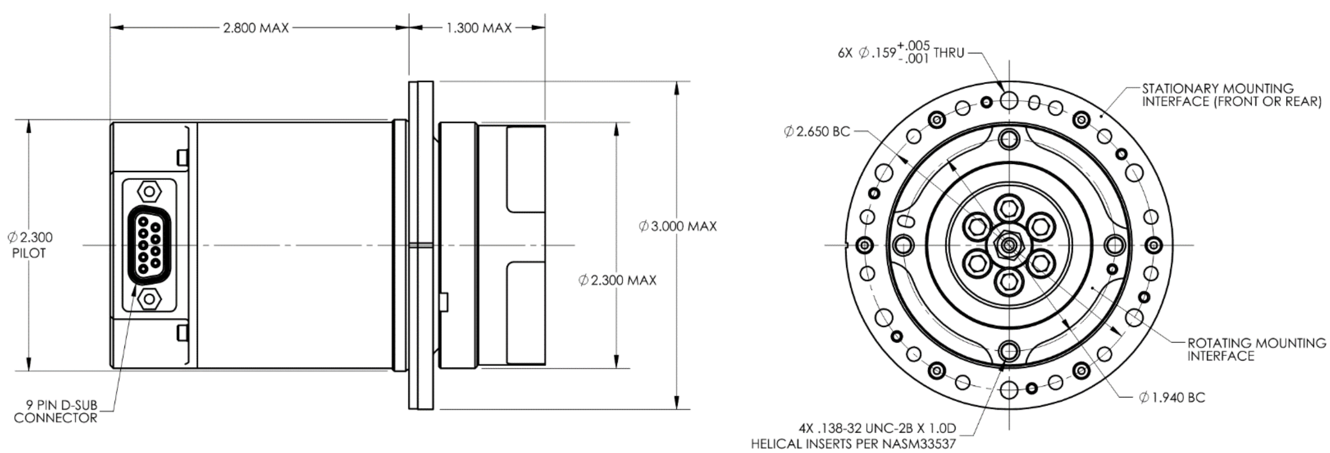


C14E Incremental Rotary Actuator

Alternate transmission ratios can be selected to provide output step sizes of 0.10, 0.0625 or 0.05 degrees.

C14E Incremental Rotary Actuator Features	
• 2-phase motor winding	• Zero backlash strain-wave gearset
• Potentiometer for position sensing	• High stiffness and load capacity
• 3-phase winding configurations available	• Multiple gear ratios and optional hard stops available

Dimensions



Note: All dimensions above are in inches.

Applications	
• Antenna Pointing Mechanisms	• Thruster Gimbal Mechanisms
• Deployment Systems	• Solar Array Drives
• Camera Pointing Mechanisms	• Robotics

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	1.8 lbm	0.82 kg
Output Step Size	0.0625 deg	
Slew Rate @ No Load	>9 deg/s	
Output Torque @ 4 deg/s @ Ambient Temperature	125 in-lb	14 Nm
Unpowered Holding Torque (minimum)	8 in-lbf	0.90 Nm
Torsional Stiffness	20,000 in-lbf/rad	2,260 Nm/rad
Electrical		
Winding Resistance (nominal)	57 Ω	
Winding Inductance (typical)	30 mH	
Input Voltage Range	24-32 Vdc	
Position Sensor	Potentiometer	
Independent Load Ratings (Consult Sierra Space Engineering for Combined Loads)		
Axial	725 lb	3.2 kN
Radial	725 lb	3.2 kN
Moment	350 in-lb	39.5 Nm
Environmental		
Operating Temperatures	-22 °F to +149 °F	-30 °C to +65 °C
Non-Operating Temperatures	-40 °F to +167 °F	-40 °C to +75 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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C20 Incremental Rotary Actuator

Design Description

Sierra Space, in support of Earth observation satellites, has designed, developed, and delivered an Antenna Pointing Mechanism (APM) using the C20 Incremental Rotary Actuators (RA) for its axis drives. The C20 RAs are very low disturbance actuators, ideal for low jitter, high-resolution applications in an open-loop stepper motor-driven system.

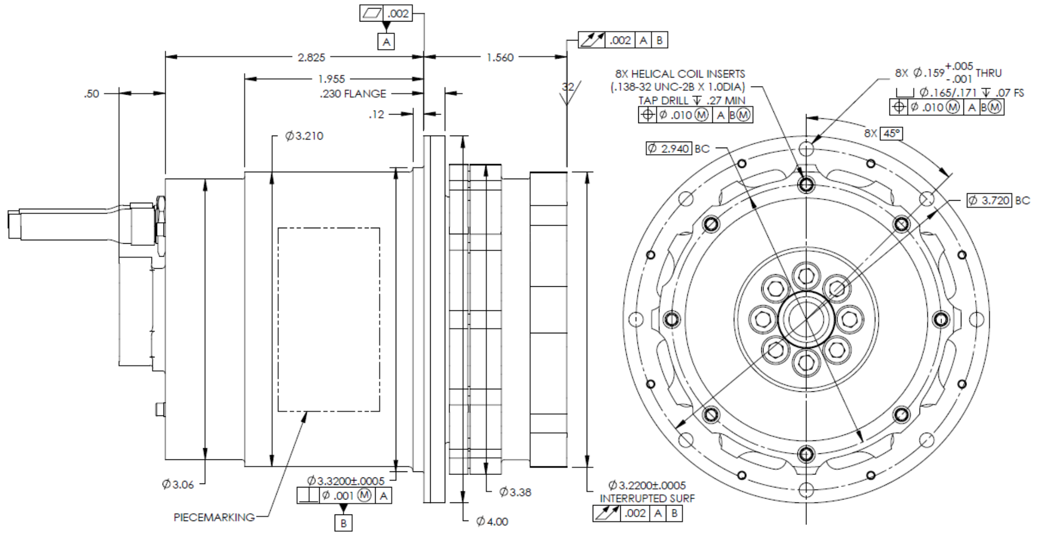
C20 Incremental Rotary Actuator

Our C20 unit is composed of a 3-phase, bipolar, 15-degree stepper motor with redundant windings that are insulated from one another to prevent failure propagation. The motor is directly coupled to a 50:1 harmonic drive gear reducer that features maximum stiffness, strength, and zero backlash. Output position feedback is provided by integral redundant potentiometers with absolute accuracy to ±0.1 percent over electrical travel. A single-channel radio frequency (RF) rotary joint, redundant heaters and thermistors, and internal hard stops complement the actuators' operational features.

A space-qualified twist capsule is available to carry signal and power currents through the actuator, simplifying wiring in the assembly and negating wire stress concentrations caused by actuator or gimbal motion. The RF joints carry RF signals through the actuators' axis of rotation; the RF cabling routes the RF signal through the actuator to the spacecraft antenna.

C20 Incremental Rotary Actuator Features	
• A low-torque disturbance, 3-phase 15-degree stepper motor	• Redundant heaters and thermistors
• Redundant stator windings	• Redundant output position potentiometers
• 50:1 no-backlash, high stiffness, harmonic drive gear set	• RF rotary joint and internal hard stops are available

Dimensions



Note: All dimensions above are in inches.

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Applications	
• Antenna Pointing Mechanisms (APM)	• Gimbals

Heritage Programs
• GeoEye-1

Product Specifications		
	U.S.	**SI**
Mechanical		
Actuator Size (OD x L)	Ø4.0 in x 4.5 in	Ø101.6 mm x 114.3 mm
Actuator Weight	4.1 lb	1.86 kg
Through Hole ID	Ø.375 in	Ø9.5 mm
Step Size	0.3 deg, 0.007 deg with microstepper control	
Electrical		
Motor Type	3-phase, wye-connected, redundant, 15-deg stepper	
Voltage, Nominal	28 Vdc	
Resistance (at Ambient Temperature)	22.6 Ω	
Driver Type	Microstepper with current control	
Potentiometer Resistance	5k Ω ±5%	
Potentiometer Electrical Travel	200-deg min on each resistive track	
Potentiometer Linearity	±0.1% over electrical travel	
Thermal		
Heater Resistance	78 Ω ±2% (each heater)	
Temperature, Operating	-13 °F to +149 °F	-25 °C to +65 °C
Temperature, Survival	-130 °F to 176 °F	-90 °C to +80 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

C25 Incremental Rotary Actuator

Design Description

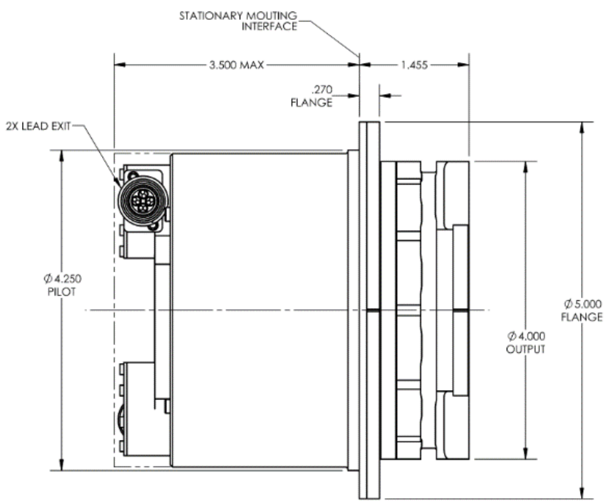
Sierra Space has developed a design for the C25 Incremental Rotary Actuator (RA) to meet the demands for a standard, low-cost, space-rated RA. Used for antenna pointing assemblies or for solar arrays to maintain proper tracking, these C25 RAs meet multiple application requirements with the same design.

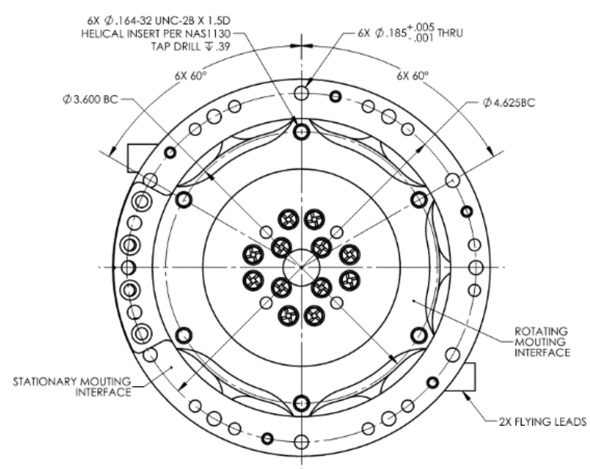
The C25 RA features a 28-Vdc, 3-phase, permanent magnet, 1.5-degree stepper motor with redundant windings that are insulated from one another to prevent failure propagation. The motor has been sized with abundant torque margin, based on magnetic modeling and optimization, which ensures that it provides maximum performance per unit weight.

C25 Incremental Rotary Actuator

The motor is directly coupled to a 160:1 strain wave gearset for maximum stiffness and zero backlash. Motor shaft position is provided by redundant fine optical incremental encoders, while output shaft position telemetry is sensed by redundant coarse optical encoders. The C25 can also be provided with potentiometer position feedback for higher resolution and lower cost, but with limited life and reduced accuracy. The position resolution for a single motor step is 0.009375 degrees and the mechanical position accuracy is better than 0.020 degrees over the full operating range. Oversized 440C stainless-steel ABEC 5 or better ball bearings support the output shaft for maximum stiffness and life. For more severe bending moment/load applications, an enhanced C25 design with strength-optimized cross-sections can be offered. The RA is capable of full 360-degree rotation and adjustable hard stops are available to limit travel to any customer requirement.

Dimensions





Note: All dimensions above are in inches.

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C25 Incremental Rotary Actuator Features	
• Redundant, 3-phase, 1.5-degree stepper motor	• 160:1, zero backlash strain-wave gearset
• Redundant fine and coarse encoders for position sensing	• High stiffness and load capacity
• Multiple gear ratios and optional hard stops available	• 12 mm through hole and rear attachment option

Applications	
• Antenna Pointing Mechanisms	• Single-axis actuator
• Solar Array Drive Assembly (SADA)	• Two-axis gimbal

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	5.4 in x Ø4.8 in	137 mm x Ø121 mm
Mass	4.5 lb	2.0 kg
Gear Ratio	160:1	
Output Resolution	0.009375 deg per motor step, nominal	
Operating Torque, Typical	675 in-lbf	76.3 Nm
Maximum Torque	760 in-lbf	85.9 Nm
Unpowered Holding Torque (minimum)	>250 in-lbf	>28 Nm
Moment Stiffness, Typical	1,200,000 in-lbf/rad	135,582 Nm/rad
Torsional Stiffness, Typical	300,000 in-lbf/rad	33,895 Nm/rad
Lubrication	PFPE lubricant is standard; MAC lubricant can be substituted for longer life but requires -20 °C minimum operating temperature	
Life	15 x 1.5 years attainable, depending on duty cycle	
Electrical		
Motor Type	3-phase, wye-wound, redundant, 1.5-deg stepper	
Voltage, Nominal	28 Vdc	
Resistance	50 Ω	
Power, Nominal	<16 W	
Incremental Encoder Resolution	0.009375 deg	
Encoder Power Consumption	<1 W	
Fine Potentiometer (option)	350-deg electrical travel, 10 kΩ	
Coarse Potentiometer (option)	350-deg electrical travel, 10 kΩ	
Sensor, Temperature (option)	Platinum RTD 2,000 Ω @ 0 °C	
Thermal		
Operating Temperatures	-40 °F to +185 °F	-40 °C to +85 °C
Nonoperating Temperatures	-76 °F to +212 °F	-60 °C to +100 °C
Heater Resistance (option)	98 Ω ±5% (each heater); thermostat controlled	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

C50 Incremental Rotary Actuator

Design Description

Sierra Space has designed and developed a new, robust C50 rotary actuator for spaceflight and satellite applications. Featuring a 6-degree stepper motor, 100:1 C50 harmonic drive gear reducer, motor and output resolvers in a stiff, high-load capacity package, the actuator combines relatively high output slew rates, accuracy, and torque margin.

C50 Incremental Rotary Actuator.

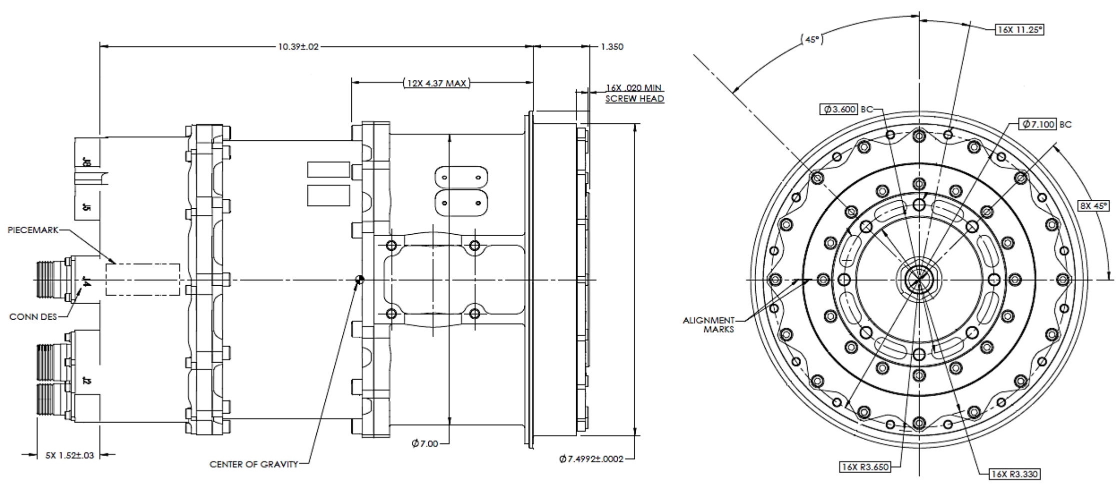
The C50 actuator features a 3-phase, wye connected, 6-degree stepper motor with redundant windings that are fully isolated to prevent failure propagation. The 20-pole motor has minimal cyclic torque for ultra-smooth actuation. A nonredundant incremental motor resolver accurately tracks motor position to ±0.4 degrees for testing feedback or possible commutation.

The 100:1 C50 harmonic drive unit is fabricated from corrosion-resistant stainless steel, which is heat-treated for strength and manufacturability. Its torque rating is 3,328 in-lb at 200 rpm with a torsional stiffness of approximately 1.8 x 10^6 in-lb/rad. Oversized 440C stainless steel ABEC 7 ball bearings in a duplex bearings (DB) configuration support the output shaft for maximum stiffness and life. The space-rated lubricant is Nye oil 2001 with 3 percent PbNp.

The nominal output slew rate is 2.7 degrees/second at a motor pulse rate of 45 pps. Running torque is typically 1,000 in-lb; unpowered holding torque is greater than 250 in-lb. Redundant coarse variable reluctance resolvers provide output telemetry to within ±0.1 degree.

C50 Incremental Rotary Actuator Features	
• 3-phase, redundantly wound, 6-degree stepper motor	• Spaced-rated lubricant: Nye 2001-3 PbNp
• 100:1 C50 harmonic drive reducer	• High torsional and moment output stiffness
• Motor resolver feedback to ±0.4 degrees at motor shaft	• Output resolver telemetry to ±0.1 degree

Dimensions



Note: All dimensions above are in inches.

Applications
• High Torque, Precision Actuation

Heritage Programs
• Restricted program

Product Specifications

	U.S.	SI
Mechanical		
Size (OD x L), including Connector Boss	Ø8.0 in x 13 in	Ø203.2 mm x 330.2 mm
Weight	40.0 lb	18.2 kg
Torsional Stiffness	1,200,000 in-lb/rad, min	135,600 Nm/rad
Qual-level Random Vibration	24.7 Grms (Y axis) ; 20.4 Grms (X-Z axes)	
Electrical		
Motor Type	3-phase, wye-wound, redundant, 6-deg stepper motor	
Voltage (Minimum)	20 Vdc	
Resistance (Room Temperature)	1.7 Ω ±5%	
Output Resolver Input	4 Vrms ±10%, 5 kHz ±10%	
Thermal		
Temperature, Operational	32 °F to 140 °F	0 °C to +60 °C
Temperature, Survival	-24.8 °F to 175.2 °F	-31 °C to +74 °C

Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.

CEH25 Compact Incremental Rotary Actuator, 3-Phase

Design Description

CEH25 Compact Rotary Actuator, 3-phase.

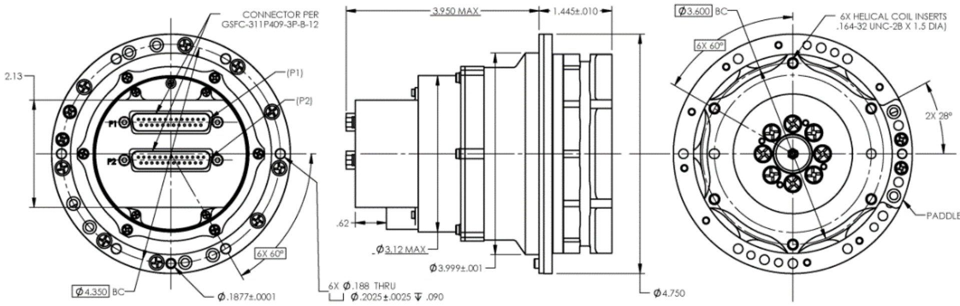
Sierra Space brings a long history of manufacturing space-qualified motors and actuators, both in one-off and multiple unit production runs. The CEH25 Compact Incremental Rotary Actuator, 3-phase, based on a heritage design, which has been in continuous production for several years, uses flight-proven design, assembly, and test heritage. We maintain an inventory of CEH25 long-lead parts in stock.

The CEH25 compact gimbal features an advanced hybrid transmission consisting of a planetary gearbox manufactured to fit completely within a high-stiffness, zero-backlash harmonic drive. The combined transmission provides high internal torque margins throughout the performance range, allowing reduction in the required motor size and resulting in a significantly lighter actuator with exceptional output capability.

The CEH25 rotary actuator (RA) features a lower profile 28 Vdc, 3-phase, permanent magnet, 1.5-degree stepper motor with redundant windings that are insulated from one another to prevent failure propagation. Magnetic modeling and optimization ensure the stepper motor's maximum performance per unit weight. Telemetry is provided by redundant potentiometers that use a Sierra Space proprietary process, yielding previously unattainable potentiometer life in a spaceflight environment. Redundant potentiometers monitor motor and output shaft position with sufficient accuracy to provide absolute position to within a single step over the full operating range. Oversized 440C stainless steel ABEC 7 ball bearings support the output shaft for maximum stiffness and life. The RA's structural components are fabricated from lightweight high-stiffness titanium and high-strength aluminum alloys. Careful selection of materials and precision-machined components ensure consistent performance over a broad temperature range. The RA is capable of full 360-degree rotation with adjustable hard stops.

CEH25 Compact Rotary Actuator Features	
• High stiffness and load capacity	• High-powered and unpowered torque capability
• Fine-pointing resolution, 0.00246 degrees per step	• Long life, qualified for more than 1 million dithering cycles
• 200% minimum torque margin motor design	• Redundant, accurate, potentiometer telemetry
• Internal heaters with temperature sensors and thermostats	• Space-qualified Pennzane or Bray lubricants
• Motor available as 2-, 3-, or 4-phase stepper	• Extreme environmental capability
• Low power consumption	• Full rotation; field-adjustable, hard stop placement

Dimensions



Note: All dimensions are in inches.

Applications	
• Antenna pointing mechanisms	• Deployment mechanisms
• Camera pointing mechanisms	• Solar array drives

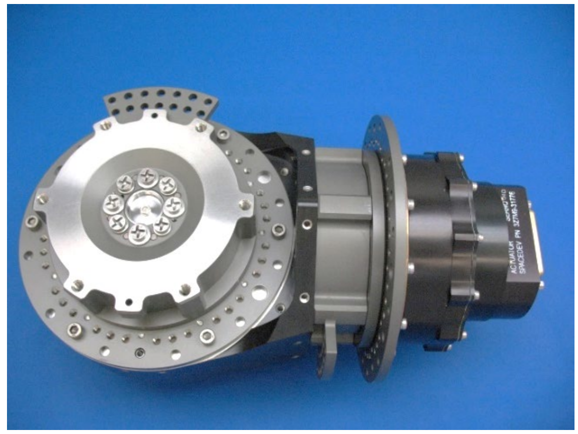
Heritage Programs	
• ViaSat-1 (Oct 2011)	• Asia Broadcast Satellite (ABS-2)
• EchoStar XVI and XVII Satellites (Nov 2012)	• AsiaSat 6 Satellite
• Eutelsat 25B Satellite	• ISDLA-1 (Intesat-30) and -2 (Intesat-31)
• Parker Solar Probe (PSP)	• Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx)

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	5.4 in x Ø4.8 in	137 mm x Ø121 mm
Mass (including potentiometers, heaters, thermostats, and hard stops)	4.5 lb	2.0 kg
Gear Ratio	610:1	
Output Resolution	0.00246 deg	
Operating Torque, Type	300 in-lbf	33.9 Nm
Maximum Torque	2,500 in-lbf	282.5 Nm
Unpowered Holding Torque (minimum)	>600 in-lbf	>67.8 Nm
Moment Stiffness, Type	1,200,000 in-lbf/rad	135,581.8 Nm/rad
Torsional Stiffness, Type	300,000 in-lbf/rad	33,895.5 Nm/rad
Lubrication	Brayco 815Z and Braycote 600EF	
Unpowered Holding Torque	>250 in-lb	>28 Nm
Life	15 x 1.5 years (>29 million motor steps)	
Electrical		
Motor Type	3-phase, wye-wound, redundant, 1.5-deg stepper	
Voltage, Nominal	28 Vdc	
Resistance	20 Ω	
Power, Nominal	8.3 W	
Fine Potentiometer (redundant)	350-deg electrical travel, 10 kΩ	
Coarse Potentiometer (redundant)	350-deg electrical travel, 10 kΩ	
Sensor, Temperature	Platinum RTD 2,000 Ω @ 0 °C	
Thermal		
Operating Temperatures	-40 °F to +185 °F	-40 °C to +85 °C
Nonoperating Temperatures	-76 °F to +212 °F	-60 °C to +100 °C
Heater Resistance	98 Ω ±5% (each heater); thermostat controlled	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

EH25 Bi-Axis Gimbal, 3-Phase

Design Description

Sierra Space has developed an Enhanced Hybrid (EH25) Bi-Axis Gimbal that has improved stiffness and torque capability closely modeled after our standard H25 gimbal. The EH25 gimbal features very fine pointing resolution, position telemetry precise to within a single step, infinitely adjustable hard stops, internal heaters and temperature sensors, and extremely long-life capability.



EH25 Bi-Axis Antenna Gimbal, 3-phase.

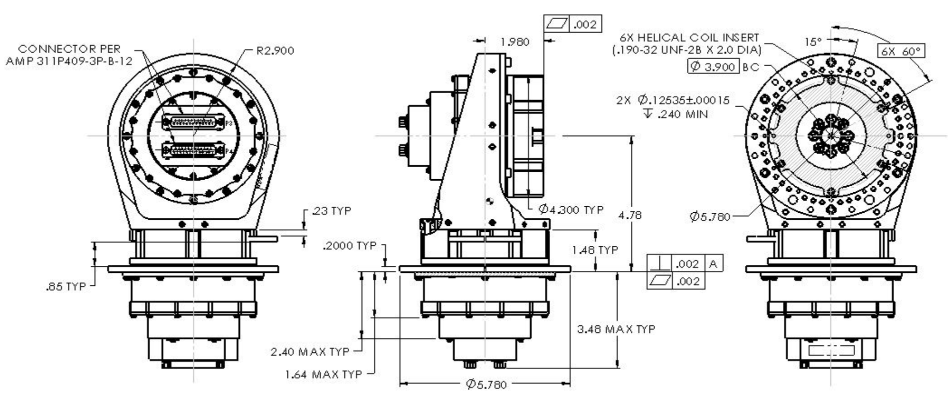
The gimbal actuator features an innovative hybrid transmission consisting of a planetary gearbox designed to fit completely within a high stiffness, zero backlash harmonic drive. The combined transmission provides high internal torque margins throughout the operational range and enables enhanced performance.

Telemetry is provided by redundant potentiometers that use a Sierra Space proprietary process, yielding previously unattainable potentiometer life in a spaceflight environment. Redundant potentiometers monitor motor and output shaft position with sufficient accuracy to resolve position within a single step over the full operating range.

We fabricate the gimbal structural components from lightweight high stiffness titanium and high strength aluminum alloys. Careful selection of materials and use of precision-machined components ensure consistent performance over a broad temperature range. Oversized 440C stainless steel ABEC 7 ball bearings support the output shaft for maximum stiffness and life. The gimbal actuators are capable of full 360-degree rotation and adjustable hard stops are available to limit gimbal travel to any customer requirement.

EH25 Bi-Axis Gimbal Features	
• High stiffness and load capacity	• High-powered and unpowered torque capability
• Fine-pointing resolution, 0.0025 degrees per step	• Long life, qualified for more than 1 million dithering cycles
• 200% minimum torque margin motor design	• Redundant, accurate, potentiometer telemetry
• Internal heaters with temperature sensors	• Space-qualified Pennzane lubricant
• Motor available as 2-, 3-, or 4-phase stepper	• Extreme environmental capability
• Low power consumption	• Full rotation; field-adjustable, hard stop placement

Dimensions



Note: All dimensions above are in inches.

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Applications	
• Antenna Pointing Mechanisms (APM) with very fine pointing resolution	• Gimbals

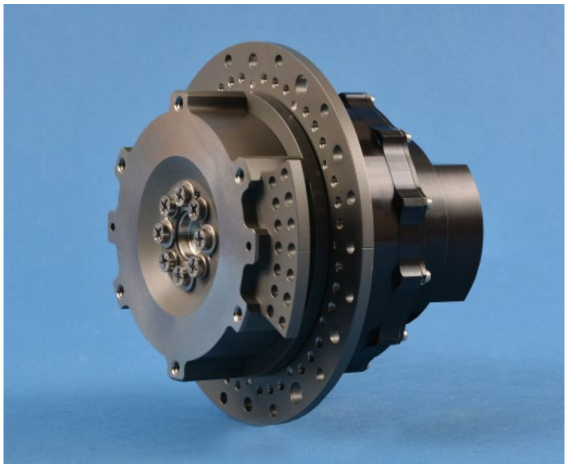
Heritage Programs	
• ViaSat-1 (Oct 2011)	• Asia Broadcast Satellite (ABS-2) Geostationary Communications Satellite
• EchoStar XVI and XVII Satellites (Nov 2012)	• AsiaSat-6
• Eutelsat 25B Satellite	• International Telecommunications Satellite (Intelsat) ISDLA-1 and -2
• T14 (formerly DirecTV-14) Commercial Communications Satellite	• National Broadband Network (NBN) Company NBN Co 1A and 1B
• Thor-7 Commercial Geostationary Communications Satellite	• Star One C4 Communications Satellite

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	11.2 in x Ø5.8 in	284.5 mm x Ø147 mm
Mass (excluding stops)	12.8 lb	5.8 kg
Unpowered Holding Torque	>400 in•lb	>45 Nm
Torsional Stiffness of 2-axis Gimbal	150,000 in-lb/rad, min	17,000 Nm/rad, min
Load Inertia	2,655 lbf-in-sec^2	300 kg-m^2
Gear Ratio	610:1	
Output Resolution (step)	<0.0025 deg	
Life	15 x 1.5 years (tested >29 million motor steps)	
Electrical		
Motor Type	3-phase, wye wound, redundant, 1.5- stepper motor	
Voltage, Nominal	28 Vdc	
Resistance	117 Ω	
Power, Nominal	6.7 W	
Fine Potentiometer (redundant)	350-deg electrical travel, 10 kΩ	
Coarse Potentiometer (redundant)	160-deg electrical travel, 8 kΩ	
Sensor, Temperature	Platinum RTD, 2,000 Ω @ 0 °C	
Thermal Qualifications		
Operating Temperatures	-13 °F to +221 °F	-25 °C to +105 °C
Nonoperating Temperatures	-76 °F to +239 °F	-60 °C to +115 °C
Heater Resistance	98 Ω ±5% (each heater)	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

EH25 Incremental Rotary Actuator, 3-Phase

Design Description

Sierra Space brings a long history of manufacturing space-qualified motors and actuators, both in one-off and multiple unit production runs. The Enhanced Hybrid (EH25) Incremental Rotary Actuator (RA), in continuous production for several years, uses flight-proven design, assembly, and test heritage. We maintain an inventory of EH25 long-lead parts in stock.

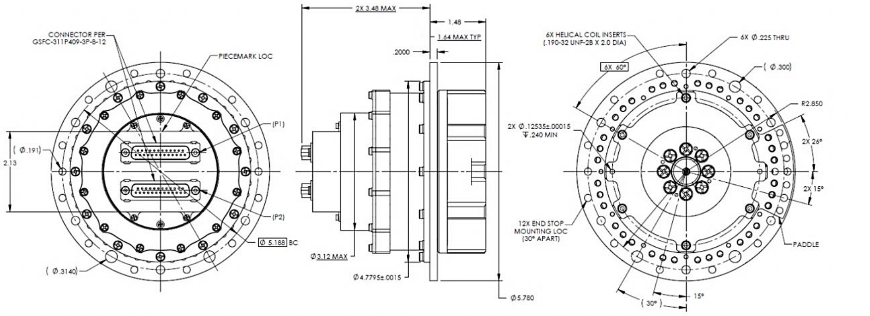

EH25 Incremental Rotary Actuator.

The EH25 Incremental Gimbal RA features an advanced hybrid transmission, consisting of a planetary gearbox manufactured to fit completely within a high-stiffness, zero-backlash harmonic drive. The combined transmission provides high internal torque margins throughout the performance range, allowing reduction in the required motor size and resulting in a significantly lighter actuator with exceptional output capability.

The RA features a 28 Vdc, 3-phase, permanent magnet, 1.5-degree stepper motor with redundant windings that are insulated from one another to prevent failure propagation. Magnetic modeling and optimization ensure the stepper motor's maximum performance per unit weight. Telemetry is provided by redundant potentiometers that use a Sierra Space proprietary process, yielding previously unattainable potentiometer life in a spaceflight environment. Redundant potentiometers monitor motor and output shaft position with sufficient accuracy to provide absolute position to within a single step over the full operating range. Oversized 440C stainless steel ABEC 7 ball bearings support the output shaft for maximum stiffness and life. The RA's structural components are fabricated from lightweight high-stiffness titanium and high-strength aluminum alloys. Careful selection of materials and precision-machined components ensure consistent performance over a broad temperature range. The RA is capable of full 360-degree rotation and adjustable hard stops are available to limit travel to any customer requirement.

EH-25 Incremental Rotary Actuator Features	
• High stiffness and load capacity	• High-powered and unpowered torque capability
• Fine-pointing resolution from 0.0025 degrees to 0.0082 degrees per step	• Long life, qualified for more than 1 million dithering cycles
• 200% minimum torque margin motor design	• Redundant, accurate, potentiometer telemetry
• Internal heaters with temperature sensors	• Space-qualified Bray or Pennzane lubricants
• Motor available as 2-, 3-, or 4-phase stepper	• Extreme environmental capability
• Low power consumption	• Full rotation; field-adjustable, hard stop placement

Dimensions



Note: All dimensions are in inches.

Applications	
• Antenna Pointing Mechanisms	• Deployment Mechanisms
• Camera Pointing Mechanisms	• Robotics Applications
• Solar Array Drives	

Heritage Programs	
• ViaSat-1 (Oct 2011)	• Asia Broadcast Satellite (ABS-2) Geostationary Communications Satellite
• EchoStar XVI and XVII Satellites (Nov 2012)	• AsiaSat-6
• Eutelsat 25B Satellite	• ISDLA-1 (Intesat-30) and -2 (Intesat-31)
• T14 (formerly DirecTV-14) Commercial Communications Satellite	• National Broadband Network (NBN) Company NBN Co 1A and 1B
• Thor-7 Commercial Geostationary Communications Satellite	• Star One C4 Communications Satellite
• Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS REx)	

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	5.0 in x Ø5.8 in	126 mm x Ø147 mm
Mass	5.8 lb	2.6 kg
Unpowered Holding Torque	>400 in-lb	>45 Nm
Gear Ratio	610:1	
Output Resolution	0.0025 deg (or 0.0082 deg) per step	
Life	15 x 1.5 years (>29 million motor steps)	
Electrical		
Motor Type	3-phase, wye-wound, redundant, 1.5-deg stepper (or 5-deg stepper)	
Voltage, Nominal	28 Vdc	
Resistance	70 Ω – 117 Ω	
Power, Nominal	6.7 W – 10 W	
Fine Potentiometer (redundant)	350-deg electrical travel, 10 kΩ	
Coarse Potentiometer (redundant)	160-deg electrical travel, 8 kΩ (or 350-deg electrical travel, 10 kΩ)	
Sensor, Temperature	Platinum RTD 2,000 Ω @ 0 °C	
Thermal		
Operating Temperatures	-31 °F to +221 °F	-35 °C to +105 °C
Nonoperating Temperatures	-76 °F to +239 °F	-60 °C to +115 °C
Heater Resistance	98 Ω ±5% (each heater)	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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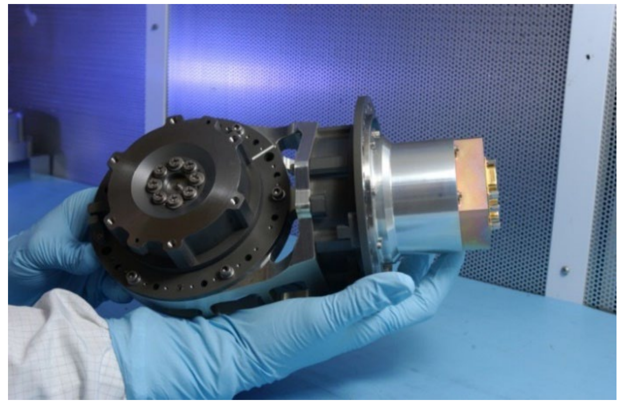
H25 Bi-Axis Gimbal, 4-Phase

Design Description

Sierra Space's H25 Bi-Axis Gimbal features very fine pointing resolution, position telemetry precise to within a single step, adjustable hard stops, and extremely long-life capability.

The gimbal actuator features a state-of-the-art hybrid transmission consisting of a planetary gearbox that is designed to fit completely within a high stiffness, zero backlash harmonic drive. The combined transmission provides high internal torque margins throughout the operational range and enables optimal performance.

Telemetry is provided by redundant potentiometers that have been treated using a Sierra Space proprietary process, yielding previously unattainable potentiometer life in a spaceflight environment. Redundant potentiometers monitor motor and output shaft position with sufficient accuracy to resolve position within a single step over the full operating range.

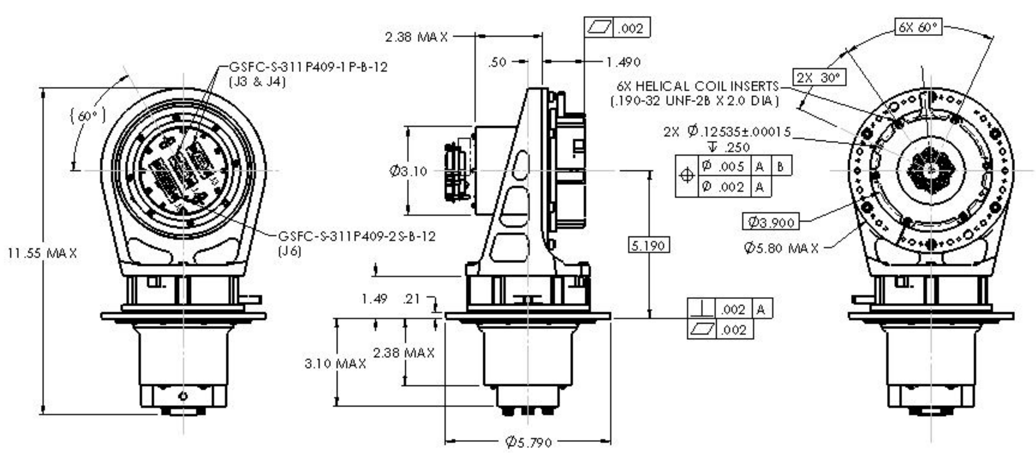


H25 Bi-Axis Antenna Gimbal, 4-Phase.

The gimbal structural components are fabricated from lightweight high stiffness titanium and high strength aluminum alloys. Careful selection of materials and precision-machined components ensure consistent performance over a broad temperature range. Oversized 440C stainless steel ABEC 7 ball bearings support the output shaft for maximum stiffness and life. The gimbal actuators are capable of full 360-degrees rotation and adjustable hard stops are available to limit gimbal travel to any customer requirement.

H25 Bi-Axis Antenna Gimbal Features	
• High stiffness and load capacity	• Long life, qualified for more than 1 million dithering cycles
• Fine pointing resolution, 0.003 degrees per step	• Redundant, accurate, potentiometer telemetry
• 200% minimum torque margin motor design	• Space-qualified Pennzane lubricant
• Motor available as 2- or 4-phase stepper	• Extreme environmental capability
• Low power consumption	• Full rotation, removable hard stops
• High powered and unpowered torque capability	

Dimensions



Note: All dimensions above are in inches

Applications	
• Antenna Pointing Mechanisms (APM) for very fine pointing resolution	• Deployment Mechanisms
• Camera Pointing Mechanisms	• Robotics Applications
• Solar Array Drives	

Heritage Programs	
• CLIO Satellite	• Mobile User Objective System (MUOS-1–5)
• Vietnam Satellite (VINASAT-1 and -2)	• Americom Communications Satellite (AMC-14)
• EchoStar X Geostationary Communications Satellite	• PAN (Palladium at Night) USA-207
• Broadcasting Satellite System (BSAT-3C)	• Jabiru Satellite Program
• Geostationary Operational Environmental Satellite R-Series (GOES-R)	• Japanese Communications Satellites (JCSAT-9 through -12)
• Space-Based Infrared System (SBIRS) Geosynchronous Earth Orbit (GEO)	

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	11.6 in x Ø5.8 in	295 x Ø147 mm
Mass (excluding Stops)	10.7 lb	4.9 kg
Unpowered Holding Torque	>650 in•lb	>70 Nm
Torsional Stiffness of 2-axis Gimbal	100,000 in•lb/rad, min	11,300 Nm/rad, min
Load Inertia	266,000 lbf-in-sec^2	30,000 kg-m^2
Gear Ratio	1246.75:1	
Output Resolution (Step)	0.003 deg	
Life	15 x 1.5 years, 55,000 cycles, 775,000 motor revs	
Electrical		
Motor Type	4-phase, wye wound, redundant, 3.75-deg stepper	
Voltage, Nominal	70 Vdc	
Resistance	323 Ω	
Power, Nominal	15 W	
Fine Potentiometer (redundant)	350-deg electrical travel, 10 kΩ	
Coarse Potentiometer (redundant)	350-deg electrical travel, 10 kΩ	
Environmental Qualification		
Operating Temperatures	-13 °F to +207 °F	-25 °C to +97 °C
Nonoperating Temperatures	-47 °F to +212 °F	-44 °C to +100 °C
Random Vibration	27 Grms	
Sine Vibration	20 G	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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Lightweight 2-Axis Mini Gimbal

Design Description

Sierra Space's Lightweight 2-Axis Mini Gimbal is a simple X/Y gimbal designed for spacecraft requiring a small, fast-moving antenna or other payload. The interface brackets and cable wrap spools are removable, providing excellent adaptability to many applications requiring a small gimbal with moderate pointing accuracy for 1- or 2-axis motion.

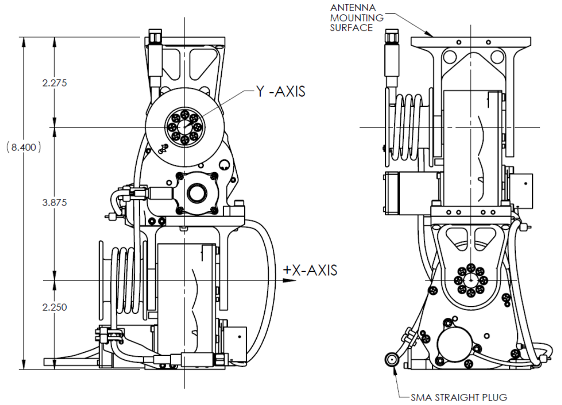
Each of the two axes uses identical actuators that can be used individually for a single-axis gimbal or coupled together with interface brackets to operate as a 2-axis gimbal. Each actuator is outfitted with a nonredundant, 3-phase stepper motor, heater, temperature sensor, and potentiometer output position feedback.

The gimbal shown has a short interface bracket connecting it to the upper axis while the upper actuator bracket has an extended length to position the antenna higher above the deck. A high-flex coaxial cable with shape memory alloy (SMA) connectors is provided for antenna connections. The interface brackets and cable spools shown were sized to allow ±90 degrees of rotation on each axis with continuous position telemetry and without self-interference.

Lightweight 2-Axis Mini Gimbal.

Lightweight 2-Axis Mini Gimbal Features	
• As little as 7.75-inches tall (8.4-inches tall as shown) when fully upright	• Potentiometer accurate to ±0.5 degrees, continuous over ±90 degrees
• Maximum output speed 9 deg/s	• Actuator capable of continuous rotation
• Output Cardinal Step Size 0.3 degrees	• ±90-degree rotation on each axis, hard-stop limited
• Gimbal mass of 3.5 lb as shown	• Minimum output torque 20 in-lb from -30 °C to +100 °C
• Actuator mass of 1.3 lb without connectors or brackets	• Tested life of 60 k cycles
• 22–34 Vdc nominal voltage range	

Dimensions



Note: All dimensions above are in inches.

Applications
• Spacecraft requiring a small, fast-moving antenna for moderate pointing accuracy; adaptable to many applications

Heritage Programs
• Flight Unit Delivered to Customer

Product Specifications—Single Actuator

	U.S.	SI
Mechanical		
Mass (without Brackets or Connectors)	1.3 lb	0.59 kg
Step Size	0.3 deg ±15%	
Output Torque	20–45 in-lb	2.25 to 5.08 Nm
Unpowered Holding Torque	60 in-oz min	424 mNm min
Torsional Stiffness	4,500 in-lb/rad nominal	508 Nm/rad nominal
Electrical		
Voltage Range	22 to 34 Vdc	
Motor	3-phase	
Winding Resistance	52 Ω nominal (L-2L)	
Winding Inductance	13 mH nominal (L-2L)	
Potentiometer Resistance	1,000 ±10% Ω	
Thermal		
Operating Temperature	-22 °F to 212 °F	-30 °C to 100 °C
Nonoperating Temperature	-49 °F to 239 °F	-45 °C to 115 °C
Heater Resistance, Single or Dual Configuration	112 Ω or 224 Ω	112 Ω or 224 Ω
Heater power, 28 V	7 W or 3.5 W	7 W or 3.5 W
Thermistor, S-310-P18	10,000 Ω @ 77 °F	10,000 Ω @ 25 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Product Specifications—Biax Gimbal with Coax Cable Spools

	U.S.	SI
Mechanical		
Mass	3.5 lb	1.58 kg
Rotational Stiffness, X axis (Lower Axis)	3,800 in-lb/rad nominal	430 Nm/rad nominal
Rotational Stiffness, Y axis (Upper Axis)	4,425 in-lb/rad nominal	500 Nm/rad nominal
Electrical		
Connectors, Motors	Connector: Positronic PN: SDD15M00200G Backshell: Glenair PN: 550T100M1R8B	
Connector, Heaters, and Telemetry	Connector: Positronic PN: SDD26M00200G Backshell: Glenair PN: 550T100M2R8B	
Coax Cable Connectors	MIL-C-39012 and MIL-STD-348	
Thermal		
Operating Temperature	-22 °F to 212 °F	-30 °C to 100 °C
Nonoperating Temperature	-49 °F to 239 °F	-45 °C to 115 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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Size 23 Incremental Rotary Actuator

Design Description

Sierra Space has designed, developed, and delivered an incremental actuator configured around a Size 23 hybrid stepper motor and a 10:1 planetary gearhead, providing output step resolution of 0.18 degrees per motor step. The Size 23 Rotary Actuator was originally developed and qualified for a solar array drive application but is useful for any open-loop stepper motor driven system that needs fine incremental motion but can tolerate a small amount of backlash.

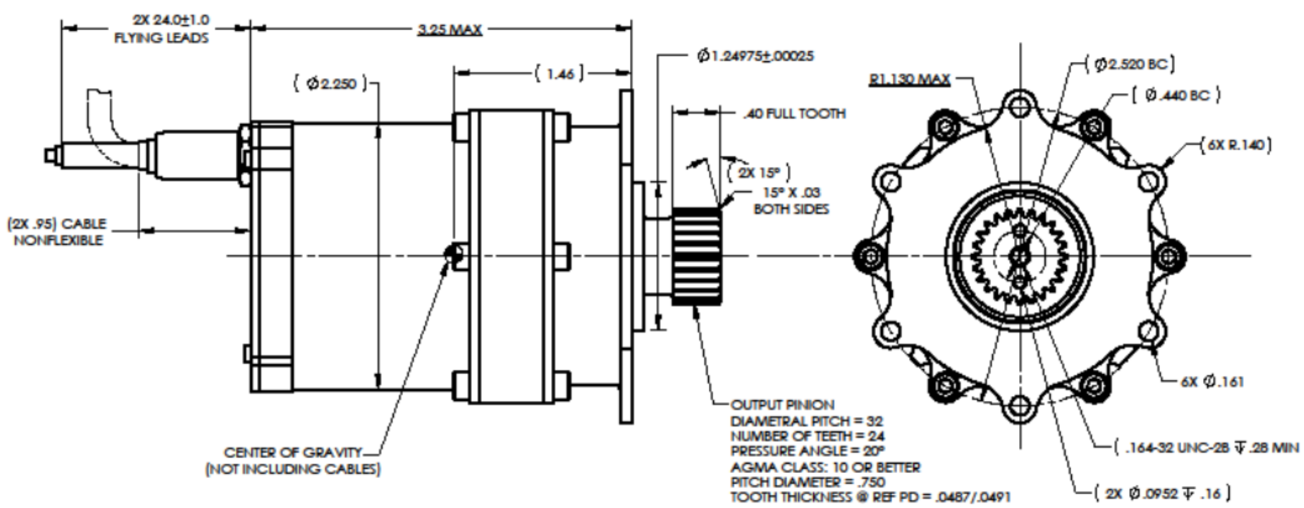
Size 23 Incremental Rotary Actuator.

Our Size 23 actuator is composed of a 2-phase, bipolar, 1.8-degree hybrid stepper motor with redundant windings that are insulated from one another to prevent failure propagation. The motor is directly coupled to a 10:1 planetary gear reducer, which features high strength and low backlash. The motor can be provided without the planetary stage and has a detachable shaft so that it can be mated to a different transmission or used as a direct drive motor. The output shaft can be provided with a spur gear, splined interface, or other configuration. The redundant motor leads exit through the rear of the motor in two locations and are continuously shielded from the housing to the ends of the cables

Our Size 23 actuator is composed of a 2-phase, bipolar, 1.8-degree hybrid stepper motor with redundant windings that are insulated from one another to prevent failure propagation. The motor is directly coupled to a 10:1 planetary gear reducer, which features high strength and low backlash. The motor can be provided without the planetary stage and has a detachable shaft so that it can be mated to a different transmission or used as a direct drive motor. The output shaft can be provided with a spur gear, splined interface, or other configuration. The redundant motor leads exit through the rear of the motor in two locations and are continuously shielded from the housing to the ends of the cables.

Size 23 Incremental Rotary Actuator Features	
• High torque density, 2-phase, 1.8-degree hybrid stepper motor	• Removable transmission assembly
• Redundant stator windings	• Replaceable motor shaft extension
• 10:1 low-backlash, high strength planetary gear set	• Fully shielded flying lead cabling

Dimensions

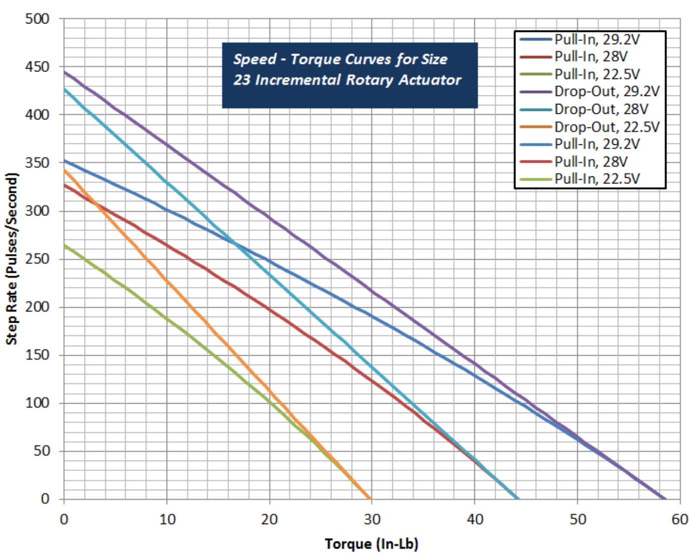


Note: All dimensions above are in inches.

Applications	
• Solar array drives	• Antenna gimbals

Heritage Programs
• Qualified but not yet flown for a solar array drive assembly (SADA) application

Product Specifications		
	U.S.	**SI**
Mechanical		
Actuator Size (OD x L)	Ø2.8 in x 4.5 in	Ø71.1 mm x 114.3 mm
Actuator Mass	2.0 lb	0.9 kg
Motor Mass	1.3 lb	0.6 kg
Output Torque (Maximum)	58.0 in-lb	6.6 Nm
Step Size	0.18 deg with gearhead, 1.8 deg without gearing	
Backlash	0.2 in typical, 0.4 in max	
Electrical		
Motor Type	2-phase, bipolar, redundant, 1.8-deg stepper	
Voltage, Nominal	28 Vdc	
Resistance (at Ambient Temperature)	120 Ω	
Driver Type	2-phase, bipolar (or 4-phase unipolar with reduced torque)	
Qualified Environments		
Random Vibration	10.5 Grms; 180 s/axis	
Sine Vibration	13.0 G; 2 octaves/min/axis	
Pyrotechnic Shock	1,865 gs; 3 events/axis	
Temperature, Operating	-4 °F to +176 °F	-20 °C to +80 °C
Temperature, Survival	-40 °F to 185 °F	-40 °C to +85 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

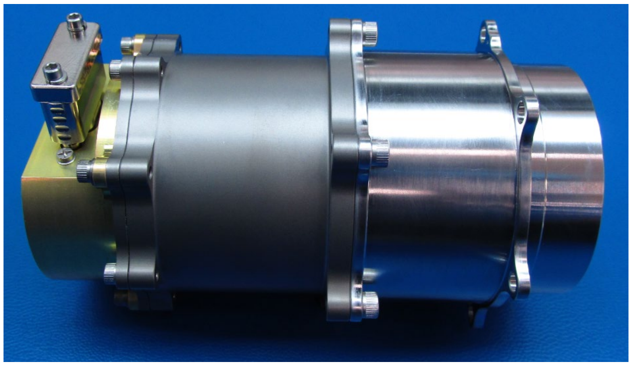


Size 30 Incremental Rotary Actuator

Design Description

The Size 30 Incremental Rotary Actuator was developed specifically for use in custom mechanism designs requiring moderate torque and simplified operation by leveraging open-loop control or separate external feedback for operation.

The actuator contains a 2-phase bi-polar stepper motor coupled to a three-stage planetary gear train. The motor and transmission are designed as separable units to allow for custom gear ratios and output configuration that adapt to a variety of applications.

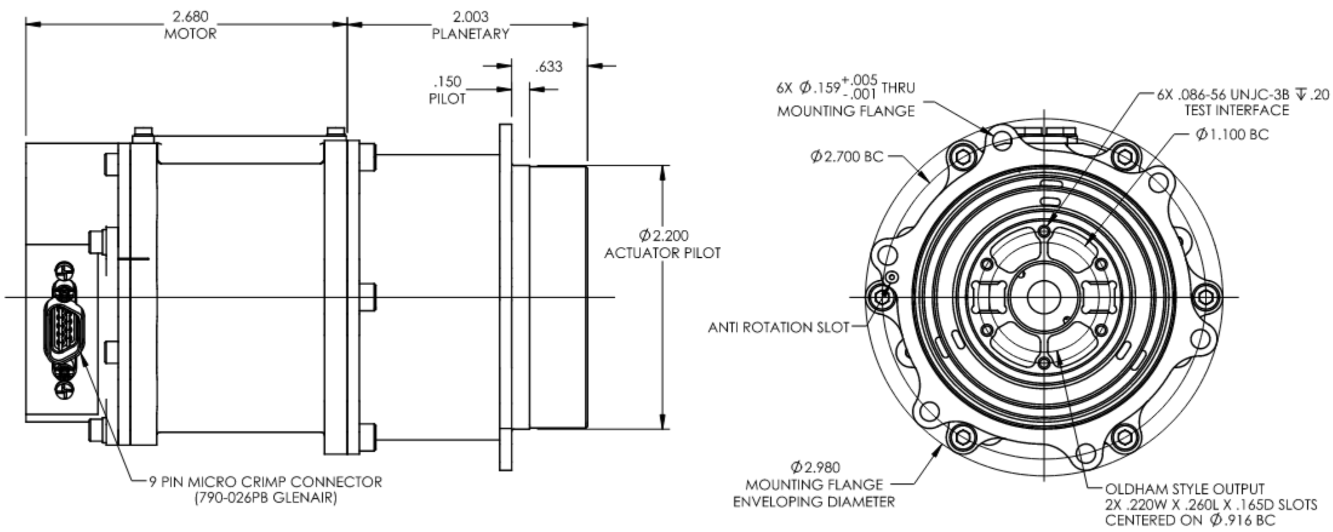


Size 30 Incremental Rotary Actuator

Integrate platinum resistance thermometer allows for temperature monitoring directly at the motor.

Size 30 Incremental Rotary Actuator Features	
• 2-phase bi-polar motor winding	• Customizable gear ratio and output configuration
• Integrated platinum resistance thermometer (PRT)	• Moderate-to-high stiffness and load capacity
• Simplified control	• Oldham style output

Dimensions



Note: All dimensions above are in inches.

SIERRA SPACE

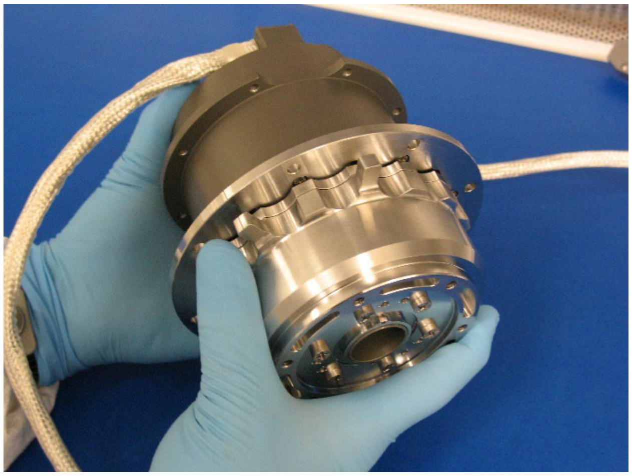
Applications	
• Antenna/Camera Pointing Mechanisms (APM)	• Thruster Gimbal Mechanisms
• Deployment Systems	• Solar Array Drives
• Custom Mechanisms	• Robotics

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	2.7 lbm	1.23 Kg
Ratio	42.8 : 1	
Output Step Size	0.042 deg	
Output Slew Rate @ No Load	>10 deg/s	
Output Torque @ 250 Hz and Nominal Voltage (Ambient Temperature)	180 in-lb	20.3 Nm
Unpowered Holding Torque (Minimum)	10 in-lbf	1.1 Nm
Electrical		
Winding Resistance (Nominal)	27.7 Ω	
Winding Inductance (Typical)	50 mH	
Input Voltage Range	26 - 34 Vdc	
Position Sensor	N/A – Design for open-loop commanding, or external feedback	
Thermal		
Operating Temperature	-22 °F to +150 °F	-30 °C to +65 °C
Nonoperating Temperature	-67 °F to +167 °F	-55 °C to +75 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

T25 Incremental Rotary Actuator (RA)

Design Description

Sierra Space has designed and manufactured the T25 Incremental Rotary Actuator (RA) to meet the demands for a standard, low-cost, space-rated RA. Used for antenna pointing assemblies or for solar arrays to maintain proper tracking, these T25 RAs meet multiple application requirements with the same design.

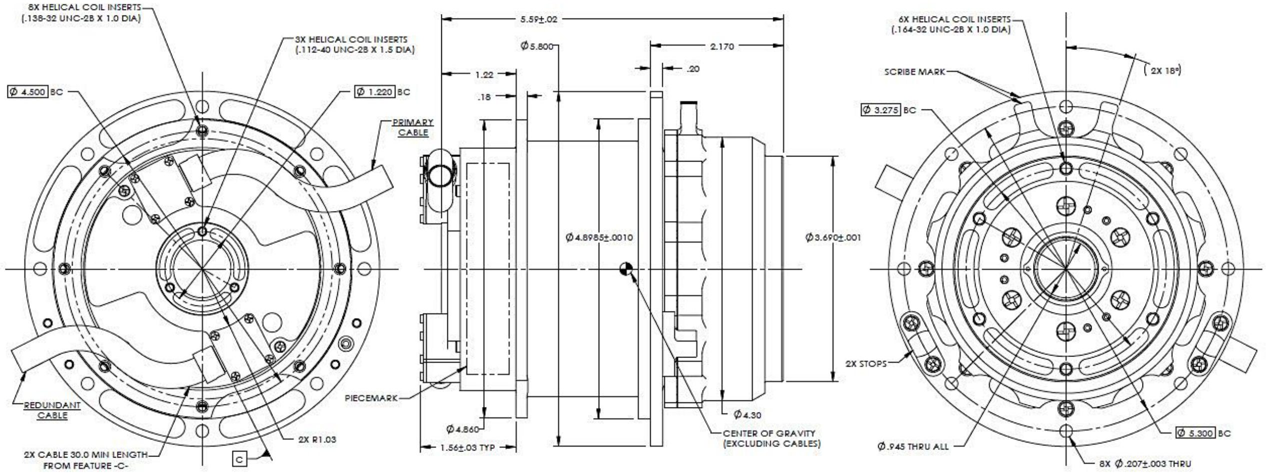


T25 Incremental Rotary Actuator Global Precipitation Measurement (GPM) High Gain Antenna System (HGAS)

The T25 RA features a 24-Vdc, 3-phase, permanent magnet, 1.5-degree stepper motor with redundant windings that are insulated from one another to prevent failure propagation. The motor has been sized with abundant torque margin, based on magnetic modeling and optimization, which ensures that it provides maximum performance per unit weight.

The motor is directly coupled to a 200:1 T-Cup harmonic drive gearbox for maximum stiffness and zero backlash. The high gear ratio provides high internal torque margins throughout the performance range and allows for a significant reduction in the required motor size. Thus, the T25 RA is a significantly lighter actuator with exceptional output capability. Motor position is provided by a fine optical incremental encoder, while position telemetry is sensed by redundant coarse encoders attached to the output. The position accuracy is within a single motor step (0.0075 degrees) over the full operating range. Oversized 440C stainless-steel ABEC 7 ball bearings support the output shaft for maximum stiffness and life. For more severe bending moment/load applications, an enhanced T25 design with strength-optimized cross-sections is also offered and qualified. Sierra Space fabricates the RA’s structural components from lightweight high stiffness titanium and high-strength aluminum alloys. Careful selection of materials and precision-machined components ensures consistent performance over a broad temperature range. The RA is capable of full 360-degree rotation and adjustable hard stops are available to limit travel to any customer requirement. A center through hole with an inside diameter (ID) of 0.9 inches comes standard with the T25 RA. The center hole is designed for use with a radio frequency (RF) rotary joint, cabling, or other access from spacecraft to mechanism.

Dimensions



Note: All dimensions above are in inches.

T25 Incremental Rotary Actuator (RA) Features	
• 1.5-degree stepper motor with redundant windings	• Oversized output bearings for enhanced stiffness
• 200:1 T-cup harmonic drive unit	• Full 360-degree output rotation
• Telemetry provided by coarse encoders (redundant)	• Center hole for RF joint or cabling (Ø.9 inches)

Applications	
• High Gain Antenna System (HGAS)	• Single-axis Actuator
• Gimbal	• Solar Array Drive Assembly (SADA)

Heritage Programs	
• Solar Dynamics Observatory (SDO)	• Global Precipitation Measurement (GPM)
• Space Communications and Navigation (SCaN), aka, Communications, Navigation, and Networking	• Lunar Reconnaissance Orbiter (LRO)
• Communications, Navigation, and Networking re-Configurable Testbed (CoNNeCT)	

Product Specifications		
	U.S.	**SI**
Mechanical		
Actuator Size (OD x L)	Ø5.8 in x 6 in	Ø147.3 x 152.4 mm
Weight	8.15 lb	3.70 kg
Through Hole (ID)	Ø.945 in	Ø24.00 mm
Gear Reduction	200:1	
Torsional Stiffness	340,000 in-lb/rad (38,400 Nm/rad), typical	
Moment Stiffness	1.1e6 in-lb./rad (125 K Nm/rad), typical	
Electrical		
Motor Type	3-phase, redundant windings, 1.5-deg stepper motor	
Voltage, Nominal	24 Vdc	
Resistance, Room Temperature	50 Ω	
Power (@ -10 °C)	<16 W	
Encoder Accuracy	±0.01°	
Encoder Power Consumption	<1 W	
Thermal		
Temperature, Operating	+14 °F to +122 °F	-10 °C to +50 °C
Temperature, Survival	+5 °F to +131 °F	-15 °C to +55 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

SOLAR ARRAY DRIVES

C14C-40A Twist Capsule Solar Array Drive Assembly (SADA)
C14E-40A Twist Capsule Solar Array Drive Assembly (SADA)
C14E-60A Slip Ring Solar Array Drive Assembly (SADA)
C14-30A Slip Ring Solar Array Drive Assembly (SADA)
C14-110A Slip Ring Solar Array Drive Assembly (SADA)
C25C-70A Twist Capsule Solar Array Drive Assembly (SADA)
C25E-70A Twist Capsule Solar Array Drive Assembly (SADA)
EH25-60A Solar Array Drive Assembly (SADA)
EH50-12.5A Solar Array Drive Assembly (SADA)

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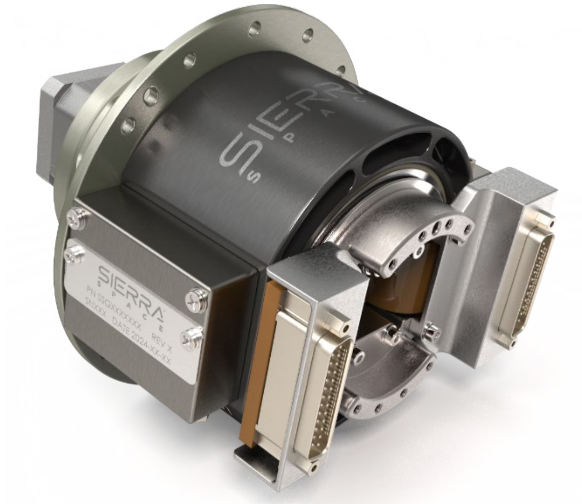
C14C-40A Twist Capsule Solar Array Drive Assembly (SADA)

Design Description

The C14C-40A Twist Capsule Solar Array Drive Assembly (SADA) was developed to support lower power solar arrays (up to 1.5 kW @ 36 Vdc) in new space and constellation applications where high reliability products are needed with reduced cost targets, expedited lead times and often at higher quantities. The C14C-40A Twist Capsule SADA design leverages Sierra Space heritage design architecture but is optimized for Class C/D missions willing to accept commercial approaches and a streamlined path to design verification and acceptance testing.

The SADA's actuator contains a hybrid stepper motor driving a strain wave gearset available in two different ratios. The motor and transmission are designed as free-standing units that allow for modular combinations of motor and transmission to easily adapt to a variety of applications.

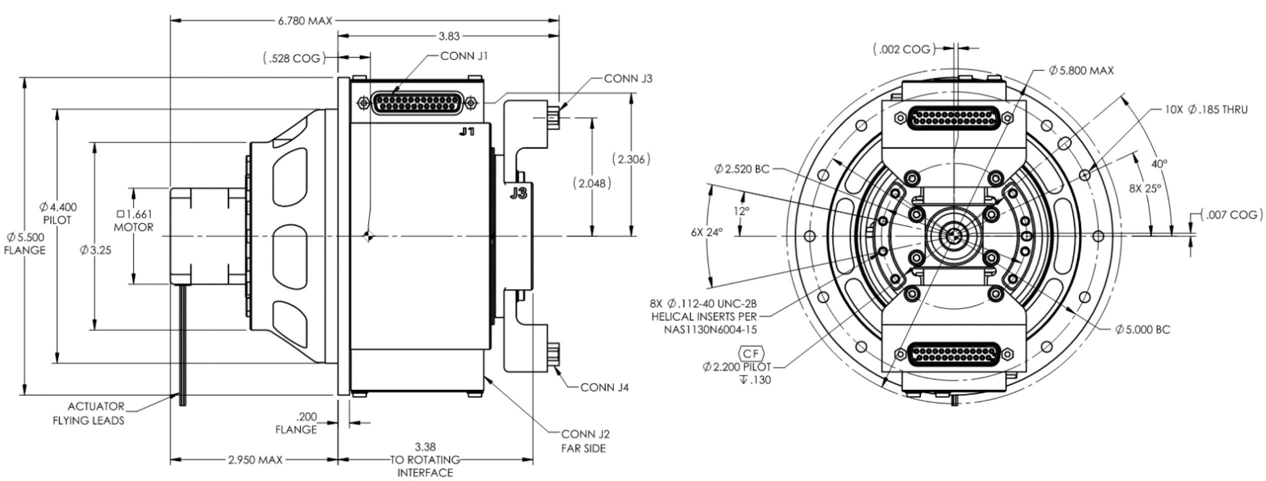


C14C-40A Twist Capsule SADA

The SADA's twist capsule contains two flexible circuit assemblies that carry power and signal across the rotating interface. The twist capsule is capable of 340 degrees of motion and contains hard stops at each end of travel to protect circuit assemblies from over-rotation. The flexible circuit assemblies provide a robust and cost-effective solution for power/signal transfer.

C14C-40A Twist Capsule SADA Features	
• 2-phase motor winding	• Zero backlash strain-wave gearset
• Step size options of 0.0225 degrees (80:1) or 0.0180 degrees (100:1)	• High stiffness and load capacity
• 40A pass-through power via flex cable assemblies	• Integral mechanical hard stop

Dimensions



Note: All dimensions above are in inches

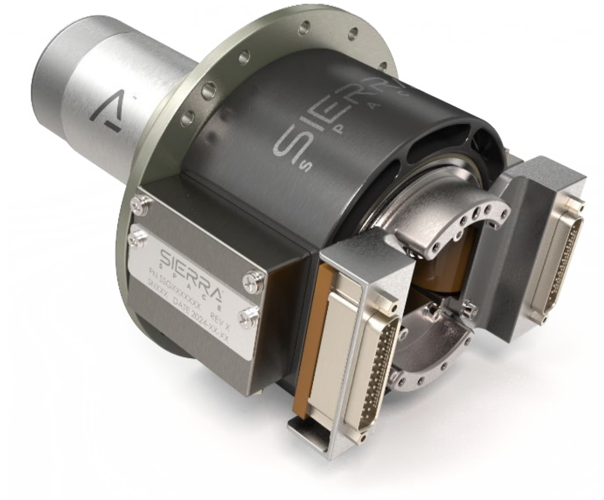
Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	5.0 lbm	2.26 kg
Output Step Size, nominal	0.0225 deg (80:1) or .0180 deg (100:1)	
Slew Rate @ no load	>9 deg/s (80:1)	
Output Torque @ 4 deg/s @ ambient Temperature	160 in-lb (80:1)	18 N-m (80:1)
Unpowered Holding Torque (minimum)	8.7 in-lbf (80:1)	1 N-m (80:1)
Torsional Stiffness	20,000 in-lbf/rad	2,260 N-m/rad
Electrical		
Winding Resistance (nominal)	30 Ω	
Input current	0.5 A	
Motor Wiring	4 lead, 2-phase bipolar	
Environmental		
Operating temperatures	-40 °F to +158 °F	-40 °C to +70 °C
Non-Operating temperatures	-76 °F to +194 °F	-60 °C to +90 °C
Twist Capsule		
Range of Travel	340 deg	
Number of Power Transfers (2 Transfers per circuit, typ)	30	
Number of Signal Transfers (2 Transfers per circuit, typ)	20	
Connectors	2X 25 Pin SD D-subminiature	
Passthrough Circuit Current Rating	40 A	
Note: This data is for information only and subject to change. Slew rate and output torque capability can depend greatly on motor driver selection. Contact Sierra Space for design data.		

C14E-40A Twist Capsule Solar Array Drive Assembly (SADA)

Design Description

Derived from the successful heritage of the C14 Incremental Rotary Actuator delivered in support of many Class A missions, the C14E-40A Twist Capsule Solar Array Drive Assembly (SADA) is a lower cost, shorter lead time alternative that is designed for Class B/C applications. The C14E-40A Twist Capsule SADA leverages key elements from the heritage design ensuring very high reliability and maximum performance, but pivots to a more standardized path in the design verification and acceptance testing to expedite delivery and reduce program costs.

The actuator contains a permanent magnet stepper motor driving a strain wave gearset. The motor and transmission are designed as free-standing units that allow for modular combinations of motor and transmission to easily adapt to a variety of applications. The actuator contains integral coarse position telemetry feedback (potentiometer).

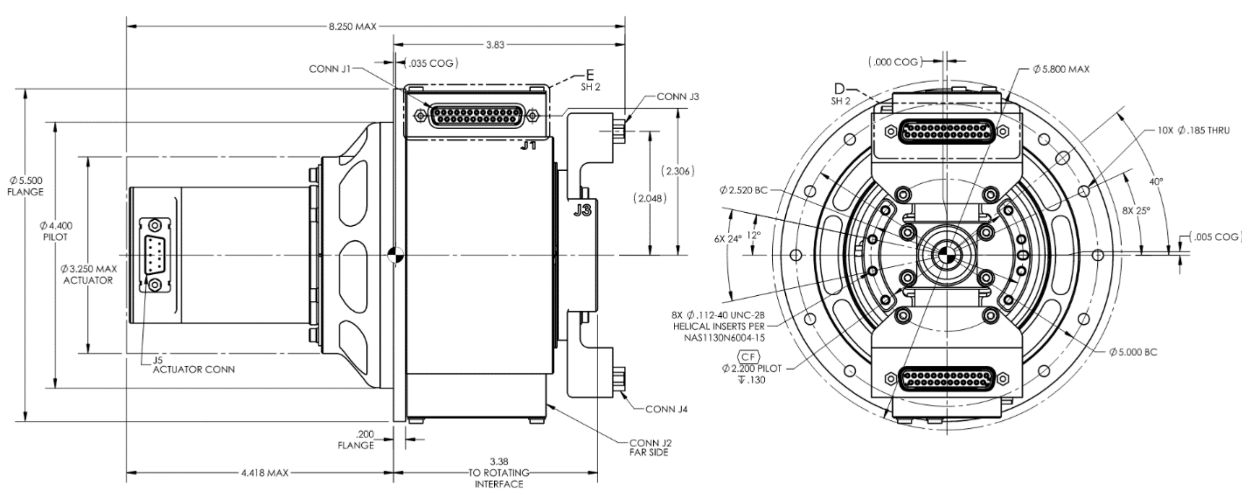


C14E-40A Twist Capsule SADA

The SADA's twist capsule contains two flexible circuit assemblies that carry power and signal across the rotating interface. The twist capsule is capable of 340 degrees of motion and contains hard stops at each end of travel to protect circuit assemblies from over-rotation. The flexible circuit assemblies provide a robust and cost-effective solution for power/signal transfer.

C14E-40A Twist Capsule SADA Features	
• 2-phase motor winding	• Zero backlash strain-wave gearset
• Potentiometer for position sensing	• High stiffness and load capacity
• 40A pass-through power via flex cable assemblies	• Integral mechanical hard stops

Dimensions



Note: All dimensions above are in inches

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Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	6.4 lbm	2.7 kg
Output Step Size, nominal	0.0625 deg	
Slew Rate @ no load	>9 deg/s	
Output Torque @ 4 deg/s @ ambient Temperature	125 in-lb	14 N-m
Unpowered Holding Torque (minimum)	8.8 in-lbf	1.0 N-m
Torsional Stiffness	20,000 in-lbf/rad	2,260 N-m/rad
Electrical		
Winding Resistance (nominal)	57 Ω	
Winding Inductance (typical)	30 mH	
Input voltage range	24-32 Vdc	
Position Sensor	Potentiometer, 3.5 deg accuracy standard	
Environmental		
Operating temperatures	-22 °F to +149 °F	-30 °C to +65 °C
Non-Operating temperatures	-40 °F to +167 °F	-40 °C to +75 °C
Twist Capsule		
Range of Travel	340 deg	
Number of Power Transfers (2 Transfers per circuit, typ)	30	
Number of Signal Transfers (2 Transfers per circuit, typ)	20	
Connectors	2X 25 Pin SD D-subminiature	
Passthrough Circuit Current Rating	40 A	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

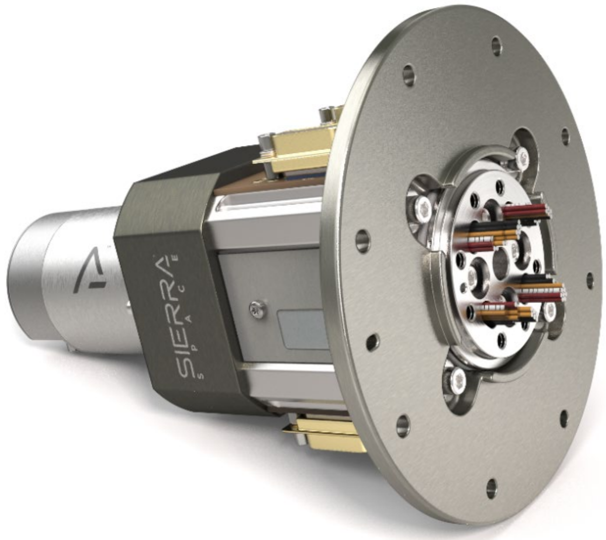
C14E-60A Slip Ring Solar Array Drive Assembly (SADA)

Design Description

Derived from the successful heritage of the C14-30A Slip Ring SADA, the C14E-60A Slip Ring is a higher capacity, lower cost, and shorter lead time alternative that is designed for applications targeting a more commercial approach to the design verification and acceptance testing.

The C14E actuator is used as a part of the approach to reduced cost and lead times. Additional design details can be found on the C14E Incremental Rotary Actuator datasheet.

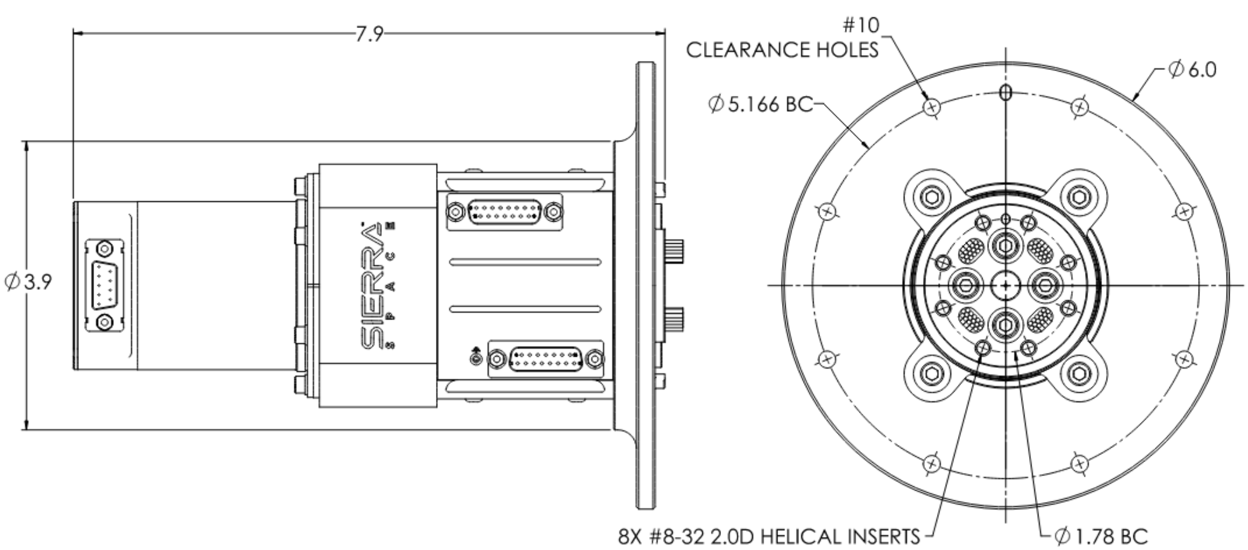
The slip ring assembly is capable of 360 degrees continuous rotation, built in accordance with Sierra Space specifications. The slip ring is a monofilament gold-on-gold design with successful flight heritage. Each of the 30 transfer rings is contacted by four brushes and has 4.0A capacity after derating for vacuum operation.



C14E-60A Slip Ring SADA

C14E-60A Slip Ring Solar Array Drive Assembly Features	
• Reduced cost and lead time	• Zero backlash strain-wave gearset
• High-heritage 2-phase motor winding	• High stiffness and load capacity
• Potentiometer for position sensing	• High-power transfer density

Dimensions



Note: All dimensions above are in inches

Applications
• Solar Array Drives

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass, max	6.6 lbm	3.0 Kg
Output Step Size, typ	0.0625 deg	
Slew Rate @ no load	>4.5 deg/s	
Output Torque @ 4°/s @ ambient Temperature	125 in-lb	14 N-m
Unpowered Holding Torque, min	8.8 in-lbf	1.0 N-m
Torsional Stiffness, min	20,000 in-lbf/rad	2,260 N-m/rad
Electrical		
Winding Resistance (nominal)	57 Ω	
Winding Inductance (typical)	30 mH	
Input voltage range	22-36 Vdc	
Position Sensor	Potentiometer	
Independent Load Ratings (Consult Sierra Space engineering for combined loads)		
Axial	2,300 lb	10.2 kN
Radial	290 lb	1.3 kN
Moment	800 in-lb	90 N-m
Environmental		
Operating temperatures	-31 °F to +158 °F	-35 °C to +70 °C
Non-Operating temperatures	-58 °F to +185 °F	-50 °C to +85 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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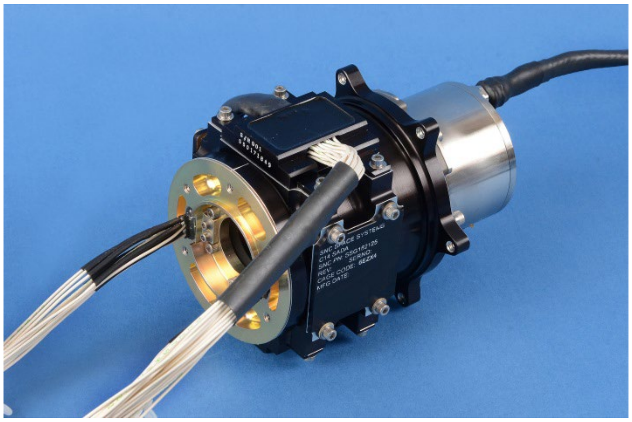
C14–30A Slip Ring Solar Array Drive Assembly (SADA)

Design Description



C14-30A Solar Array Drive Assembly with slip rings.

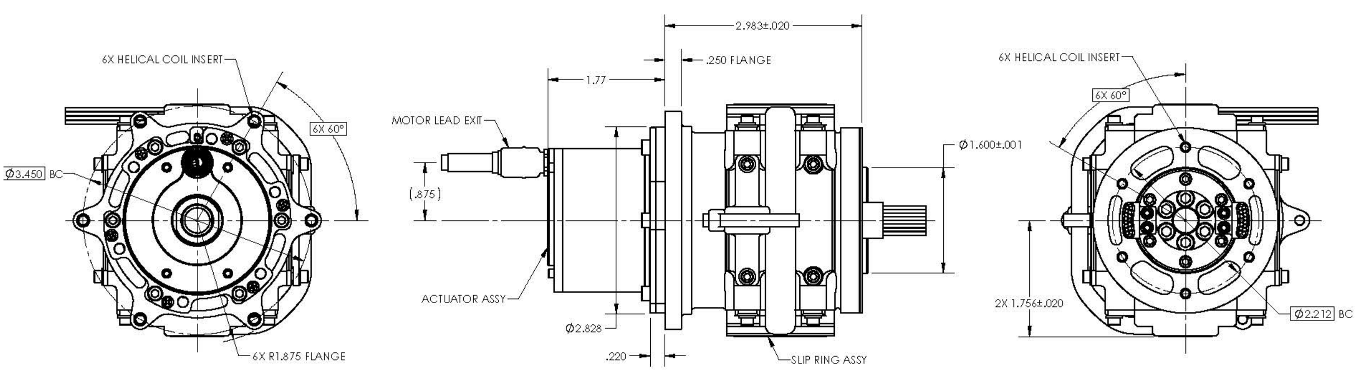
Sierra Space offers a lightweight, incremental Solar Array Drive Assembly (SADA) developed specifically for spacecraft solar array deployment and pointing applications. The C14-30A SADA is derived from an actuator that has many years of flight heritage and a slip-ring assembly that has been used on multiple spacecraft.

The actuator uses a 2-phase permanent magnet stepper motor to drive a zero-backlash harmonic drive. An optional 3-phase motor is also available. Magnetic modeling and optimization ensure the permanent magnet stepper motor takes full advantage of the available volume for maximum performance per unit weight. Redundant versions are fully isolated with Nomex-Kapton insulators to prevent failure propagation. High capacity 440C stainless steel ball bearings support the output shaft for maximum stiffness and life. The actuator's all-titanium construction ensures high strength and consistent performance over a wide temperature range.

A high stiffness, stainless steel harmonic drive with modified tooth profile and circular spline provides outstanding stiffness and torque capability with extremely low weight. A custom Oldham coupling between the motor assembly and transmission allows for a large through hole that can be used for wire routing, RF rotary joints, or waveguides. The motor and transmission are designed as freestanding units that allow for modular combinations of motors and transmissions to adapt the assembly easily to a variety of applications. The slip ring assembly is built in the USA in accordance with Sierra Space specifications. The slip ring is a monofilament gold-on-gold design with many years of successful flight heritage. Each ring is contacted by four brushes and has 2-A capacity after derating for vacuum operation.

C14-30A Slip Ring Solar Array Drive Features	
• Compact design, volume-, and mass-efficient configuration	• Lightweight, all-titanium construction
• High performance, 2-phase motor windings	• 440C stainless steel harmonic drive/ABEC 7 ball bearings
• 3-phase or 4-phase winding configurations available	• High stiffness and load capacity in a small package
• Potentiometer for position telemetry	• Electrical redundancy available

Dimensions



Note: All dimensions above are in inches.

Applications
• Solar Array Drives

Heritage Programs	
• OrbView-3 and -4 (actuator)	• Geosynchronous Space Situational Awareness Program (GSSAP) 1, 2, 3, and 4 (actuator)
• Multiple restricted satellite programs (slip rings)	• Space Test Program Satellite-5 (STPSat-5)
• Samaritan (actuator)	• Gladiator Space Program

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	2.3 lb excluding cables ~3.5 lb with 40-in cables	1.05 kg excluding cables ~1.6 kg with 1 m cables
Step Size	0.0625 deg	
Slew Rate	>9 deg/s @ no load	
Output Torque @ 4 deg/s	125 in-lb typical @ 77 °F	14 Nm typical @ 25 °C
Unpowered Holding Torque	8 in-lb min	0.9 Nm min
Torsional Stiffness	20,000 In-lb/rad	2,260 Nm/rad
Electrical		
Slip Ring Capacity	30 transfers, each derated to 2 A	
Motor Winding Resistance	57 Ω (nominal, two phase)	
Motor Winding Inductance	30 mH typical	
Potentiometer Linearity	0.25% over 350 deg (357 deg total electrical range)	
Independent Load Ratings (Consult Sierra Space Engineering for Combined Loads)		
Axial Load Capacity	2,300 lb	10.2 kN
Radial Load Capacity	290 lb	1.3 kN
Moment Load Capacity	800 in-lb	90 Nm
Thermal Environment		
Operating Temperatures	-40 °F to +158 °F	-40 °C to +70 °C
Nonoperating Temperatures	-139 °F to +185 °F	-95 °C to +85 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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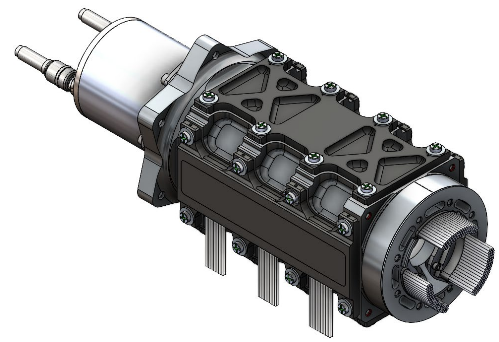
C14-110A Slip Ring Solar Array Drive Assembly (SADA)

Design Description

Sierra Space offers an incremental Solar Array Drive Assembly (SADA) developed specifically for spacecraft solar array pointing applications. The C14-110A SADA uses an actuator that has many years of flight heritage and a slip ring assembly whose design is a direct derivative of successful space flight hardware.



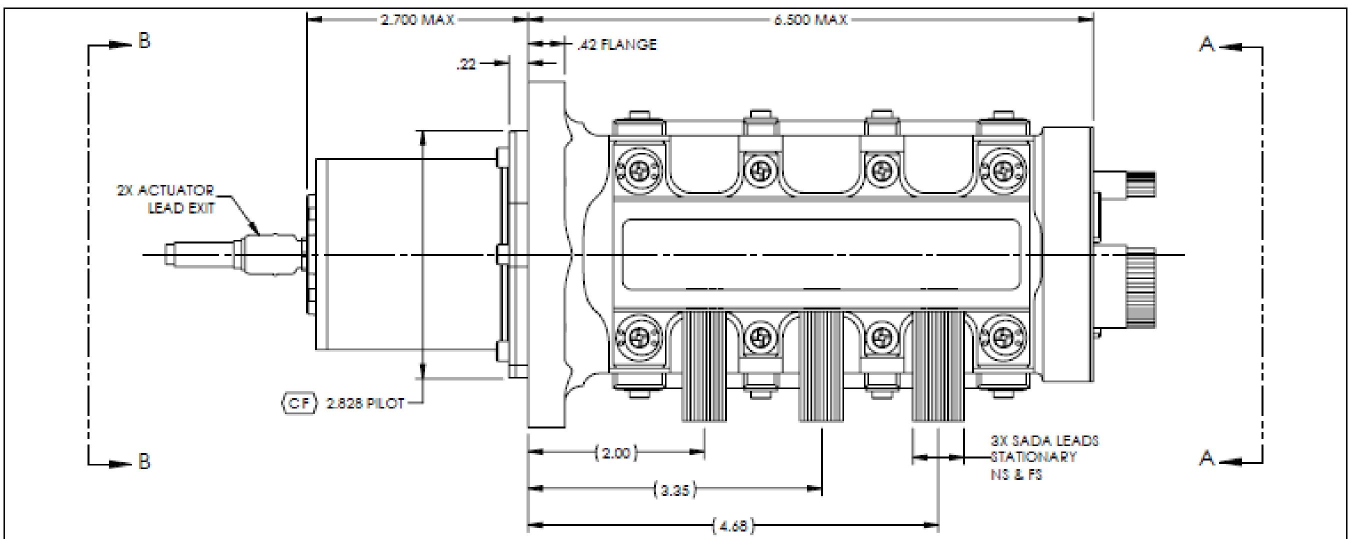
C14-110A Slip Ring SADA.

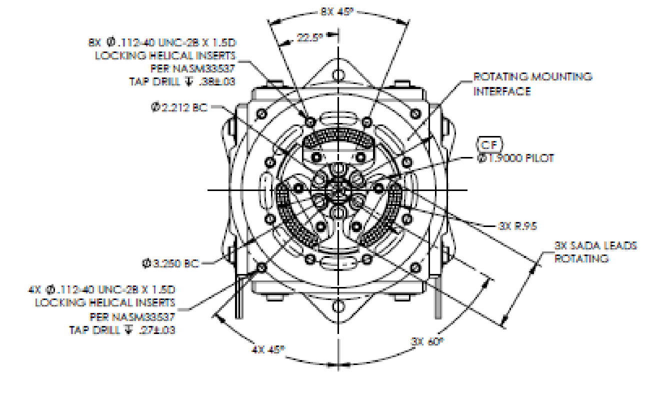
The actuator uses a 2-phase permanent magnet stepper motor to drive an 80:1 geared output that is comprised of a high-stiffness, zero backlash harmonic drive. Magnetic modeling and optimization ensure the permanent magnet stepper motor takes full advantage of the available volume for maximum performance per unit weight. The actuator is electrically redundant and fully isolated to prevent failure propagation. High-capacity stainless steel ball bearings support the output shaft for maximum stiffness and life. The actuator's titanium construction ensures high strength and consistent performance over a broad temperature range.

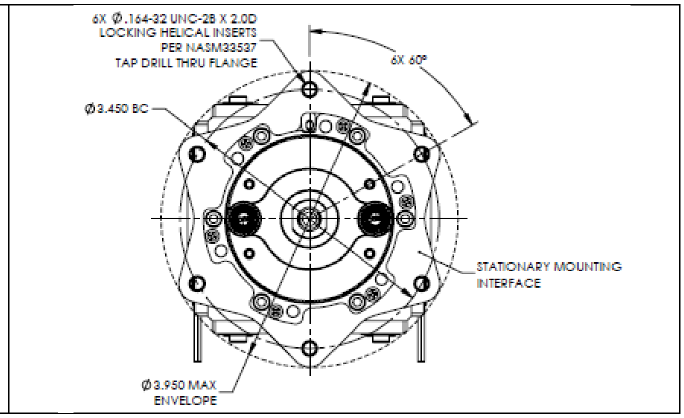
The slip ring assembly is comprised of a durable slip ring rotor and two epoxy-filled brush blocks that securely capture the gold alloy brushes. The slip ring includes 70 total electrical transfers, which are split between 26 signal transfers and 44 power transfers. The signal transfers are rated for currents up to 2.5 A while the power transfers are rated for currents up to 5.0 A, capable of over 13 kW of power transfer operating at 120 V.

C14-110A Slip Ring SADA Features	
• High stiffness and load capacity	• Potentiometer for position telemetry
• Precise pointing resolution at 0.0625 degrees per step	• 2-phase stepper motor
• Internal heaters with temperature sensors optional	• Continuous rotation
• Space-qualified Braycote and Pennzane lubrication	• Electrically redundant motor windings and potentiometer

Dimensions







Note: All dimensions above are in inches.'

Applications

• Solar Array Drives	• Power/Signal transfer to moving payload

Heritage Programs

• Actuator: ➢ OrbView-3 and -4; Samaritan; Gladiator; Geosynchronous Space Situational Awareness Program (GSSAP) 1, 2, 3, and 4	• Slip Ring: ➢ ESPAStar-HP – 1st Flight in 2024

Product Specifications

	U.S.	SI
Mechanical		
Mass	<7.5 lbm, including 76.2 cm of flying lead harnesses	<3.4 kg, including 76.2 cm of flying lead harnesses
Step Size	0.0625 deg	
Slew Rate	1.0 deg/s	
Output Torque @ 1.0 deg/s	11 in-lb typical at 77 °F	1.2 Nm
Inertial Load	>86,452.6 lb-in^2	>25.3 kg-m^2
Unpowered Holding Torque	>0.6 in-lb	>0.07 Nm
Travel	360 deg, continuous	
Electrical		
Motor Winding Resistance	52.5 Ω (nominal, 2-phase)	
Slip Ring Power Transfers	44 transfers @ 5.0 amps max	
Slip Ring Signal Transfers	26 transfers @ 2.5 amps max	
Voltage	28 Vdc	
Potentiometer Resistance	10 kΩ	
Qualified Thermal Environment		
Temperature, Operating	-31 °F to 160 °F	-35 °C to 71 °C
Temperature, Nonoperating	-112 °F to 205 °F	-80 °C to 96 °C

Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.

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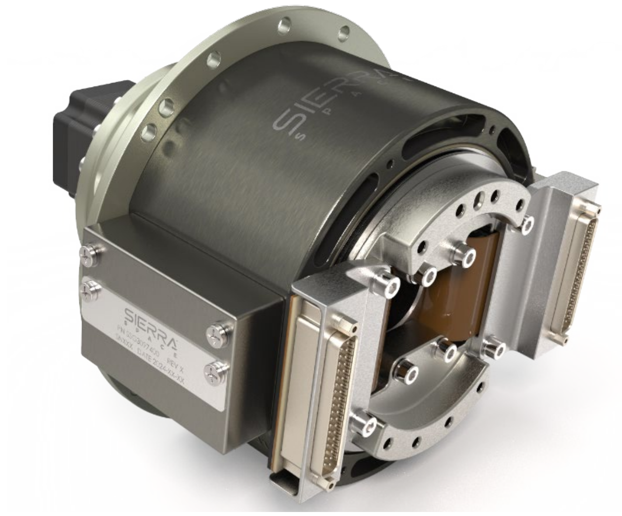
C25C-70A Twist Capsule Solar Array Drive Assembly (SADA)

Design Description

The C25C-70A Twist Capsule Solar Array Drive Assembly (SADA) was developed to support medium power solar arrays (up to 2.5 kW @ 36 Vdc) in new space and constellation applications where high reliability products are needed with reduced cost targets, expedited lead times and often at higher quantities. The C25C-70A Twist Capsule SADA design leverages Sierra Space heritage design architecture but is optimized for Class C/D missions willing to accept commercial approaches and a streamlined path to design verification and acceptance testing.

The SADA's actuator contains a hybrid stepper motor driving a strain wave gearset available in multiple ratios (160:1 is standard). The motor and transmission are designed as free-standing units that allow for modular combinations of motor and transmission to easily adapt to a variety of applications.

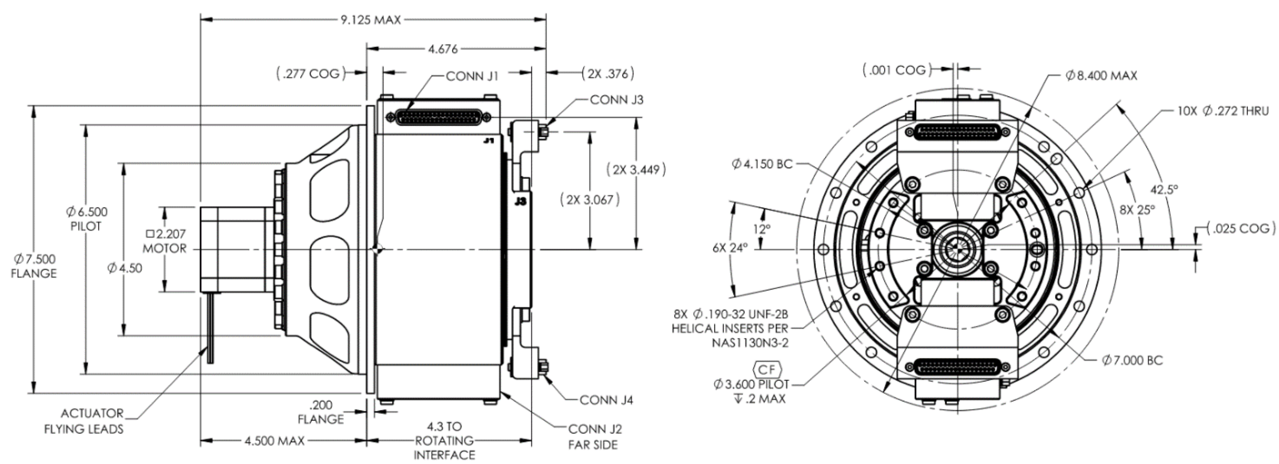


C25C-70A Twist Capsule SADA

The SADA's twist capsule contains two flexible circuit assemblies that carry power and signal across the rotating interface. The twist capsule is capable of 340 degrees of motion and contains hard stops at each end of travel to protect circuit assemblies from over-rotation. The flexible circuit assemblies provide a robust and cost-effective solution for power/signal transfer.

C25C-70A Twist Capsule SADA Features	
• 2 phase motor winding	• Zero backlash strain-wave gearset
• Multiple gear ratios available (160:1 standard)	• High stiffness and load capacity
• 70A pass-through power via flex cable assemblies	• Integral mechanical hard stops

Dimensions



Note: All dimensions above are in inches

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	13.5 lbm	6.1 Kg
Output Step Size, nominal	0.01125 deg	
Max Slew Rate @ no load	>2 deg/s	
Output Torque @ 1 deg/s @ ambient Temperature	450 in-lb	51 N-m
Unpowered Holding Torque (minimum)	65 in-lbf	7.3 N-m
Torsional Stiffness	300,000 in-lbf/rad	33,900 N-m/rad
Electrical		
Winding Resistance (nominal)	21.5 Ω	
Input current	0.6 A	
Motor Wiring	4-lead, 2-phase bipolar	
Environmental		
Operating temperatures	-22 °F to +149 °F	-30 °C to +65 °C
Non-Operating temperatures	-40 °F to +167 °F	-40 °C to +75 °C
Twist Capsule		
Range of Travel	340 deg	
Number of Power Transfers (2 Transfers per circuit, typ)	42	
Number of Signal Transfers (2 Transfers per circuit, typ)	32	
Connectors	2X 37 Pin SD D-subminiature	
Passthrough Circuit Current Rating	70 A	
Note: This data is for information only and subject to change. Slew rate and output torque capability can depend greatly on motor driver selection. Contact Sierra Space for design data.		

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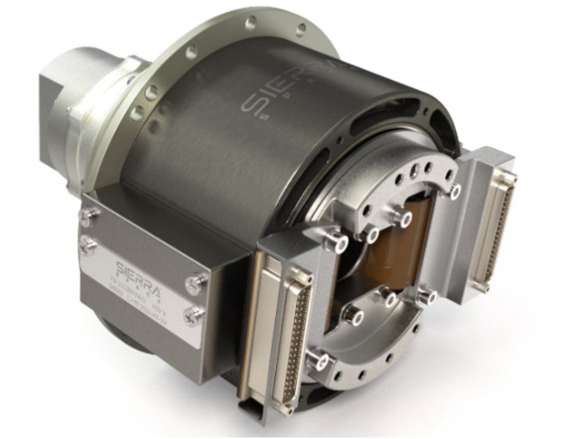
C25E-70A Twist Capsule Solar Array Drive Assembly (SADA)

Design Description

Combining the high-rate CEH25 actuator variant with a standard twist capsule, the C25E-70A Twist Capsule Solar Array Drive Assembly (SADA) is ideal for applications requiring high torque capability and moderate power transfer (up to 2.5 kW @ 36 Vdc). The C25E-70A Twist Capsule SADA leverages key elements from the heritage design ensuring very high reliability and maximum performance, but pivots to a more standardized path in the design verification and acceptance testing to expedite delivery and reduce program costs.



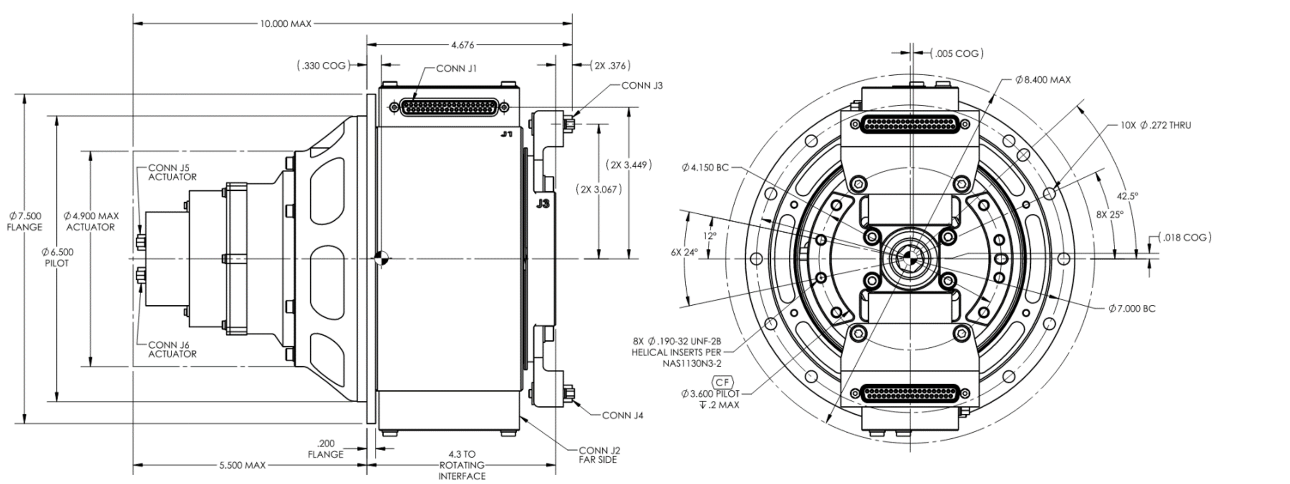
C25E-70A Twist Capsule SADA

The actuator features a lower profile 28 Vdc, 3-phase, permanent magnet, 1.5-degree stepper motor with redundant windings that are insulated from one another to prevent failure propagation. The actuator transmission is an advanced hybrid consisting of a planetary gearbox manufactured to fit completely within a high-stiffness, zero-backlash harmonic drive. The combined transmission provides high internal torque margins throughout the performance range, allowing reduction in the required motor size and resulting in a significantly lighter actuator with exceptional output capability. The actuator contains integral, redundant coarse position telemetry feedback (potentiometer).

The SADA's twist capsule contains two flexible circuit assemblies that carry power and signal across the rotating interface. The twist capsule is capable of 340 degrees of motion and contains hard stops at each end of travel to protect circuit assemblies from over-rotation. The flexible circuit assemblies provide a robust and cost-effective solution for power/signal transfer.

C25E-70A Twist Capsule SADA Features	
• Redundant 3-phase motor winding	• High-powered and unpowered torque capability
• Redundant potentiometer for position sensing	• Zero backlash strain-wave gearset
• Fine-pointing resolution, 0.00246 degrees per step	• High stiffness and load capacity
• 70A pass-through power via flex cable assemblies	• Integral mechanical hard stops

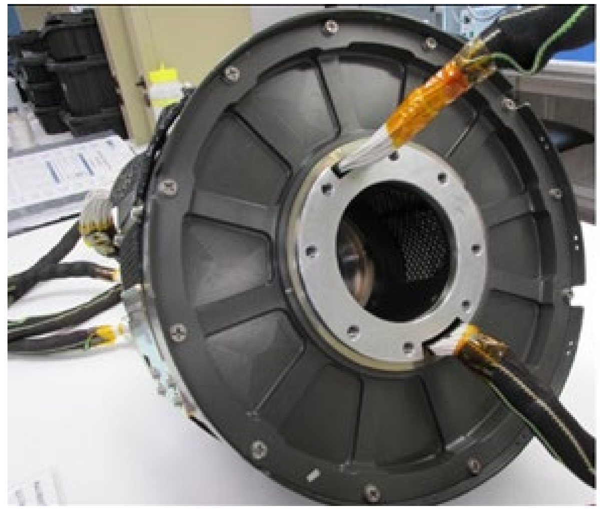
Dimensions



Note: All dimensions above are in inches

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	14.0 lbm	6.35 Kg
Output Step Size, nominal	0.00246 deg	
Max Slew Rate @ no load	>0.5 deg/s	
Operating Torque, typ	300 in-lb	33.9 N-m
Maximum Torque	2,500 in-lb	282.5 N-m
Unpowered Holding Torque (minimum)	>600 in-lbf	>67.8 N-m
Torsional Stiffness	300,000 in-lbf/rad	33,900 N-m/rad
Electrical		
Motor Typ	3-phase, wye-wound, redundant, 1.5-deg stepper	
Voltage, nominal	28 Vdc	
Winding Resistance (nominal)	20 Ω	
Power, nominal	8.3 W	
Position Sensor	Redundant Potentiometer, 3.5 deg output accuracy (standard)	
Environmental		
Operating temperatures	-40 °F to +185 °F	-40 °C to +85 °C
Non-Operating temperatures	-76 °F to +212 °F	-60 °C to +100 °C
Twist Capsule		
Range of Travel	340 deg	
Number of Power Transfers (2 Transfers per Circuit)	42	
Number of Signal Transfers (2 Transfers per Circuit)	32	
Connectors	2X 37 Pin SD D-subminiature	
Passthrough Circuit Current Rating	70 A	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

EH25-60A Twist Capsule Solar Array Drive Assembly (SADA)



EH25-60A Twist Capsule SADA.

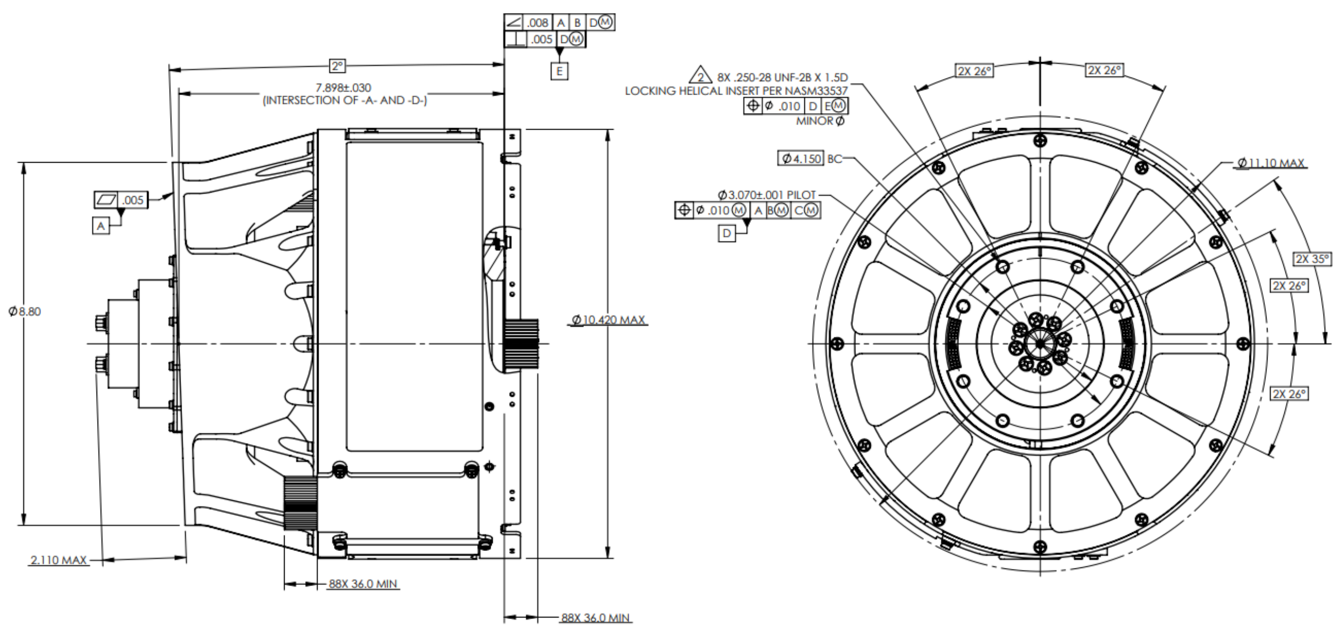
Design Description

Sierra Space offers an incremental solar array drive assembly (SADA) developed specifically for spacecraft solar array pointing applications. The EH25-60A Twist Capsule SADA is derived from an actuator that has many years of flight heritage and a twist capsule that has been qualified for use on the *Dream Chaser*® solar array wing.

The actuator uses a 3-phase, permanent magnet stepper motor to drive an advanced hybrid transmission, consisting of a planetary geartrain within a high-stiffness, zero backlash harmonic drive. Magnetic modeling and optimization ensure the permanent magnet stepper motor takes full advantage of the available volume for maximum performance per unit weight. Electrically redundant versions are fully isolated to prevent failure propagation. High-capacity stainless steel ball bearings support the output shaft for maximum stiffness and life. The actuator's titanium construction ensures high strength and consistent performance over a broad temperature range.

The SADA's twist capsule houses two molded cable assemblies in a clock-spring arrangement. The number and type of circuits may be modified to meet specific application requirements. The adapter bracket is used to attach the assembly to the spacecraft and serves to offload large moment loads from the actuator. Similarly, the adapter bracket may be modified to suit specific installation requirements.

Dimensions



Note: All dimensions above are in inches.

EH25-60A Twist Capsule SADA Features	
• High stiffness and load capacity	• Potentiometer for position telemetry
• Fine pointing resolution from 0.0025 degrees per step	• Motor available as 2-, 3- or 4-phase stepper
• Internal heaters with temperature sensors optional	• Mechanical stops included
• Space-qualified Braycote or Pennzane lubrication	• Redundant power circuits

Applications	
• Solar array drives	• Power/Signal transfer to moving payload

Heritage Programs	
• Actuator: Star One C4, Intelsat ISDLA-1 and 2, AsiaSat-6 and more (reference EH-25 datasheet)	• Solar Array Drive Assembly (SADA): *Dream Chaser* – first flight in 2024

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	<31.3 lbm, including 36 inches of cabling and adapter bracket	<14.2 kg, including 91.4 cm of cabling and adapter bracket
Step Size	0.0025 deg	
Slew Rate	>0.5 deg/s at no load	
Output Torque @ 0.5 deg/s	200 in-lb typical at 77 °F	22.6 Nm
Inertial Load	>80,300 lb-in^2	>23.5 kg-m^2
Unpowered Holding Torque	>400 in-lb	>45 Nm
Travel	340 deg, total (as shown)	
Electrical		
Motor Winding Resistance	117 Ω (nominal, 3-phase)	
Twist Capsule Power	18 circuits @ 6.5 amps max (as shown)	
Twist Capsule Signal	6 circuits @ 1 amp (as shown)	
Voltage	60 Vdc	
Potentiometer Resistance	10 kΩ	
Qualified Thermal Environment		
Operating Temperatures	-30 °F to 151 °F	-34 °C to 66 °C
Nonoperating Temperatures	-64 °F to 200 °F	-53 °C to 93 °C

Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.

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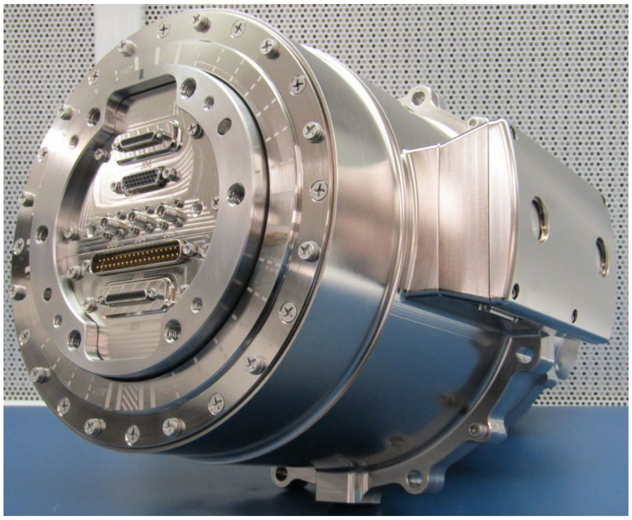
EH50-12.5A Twist Capsule Solar Array Drive Assembly (SADA)

Design Description

Sierra Space offers an incremental Solar Array Drive Assembly (SADA) developed specifically for spacecraft solar array pointing applications.

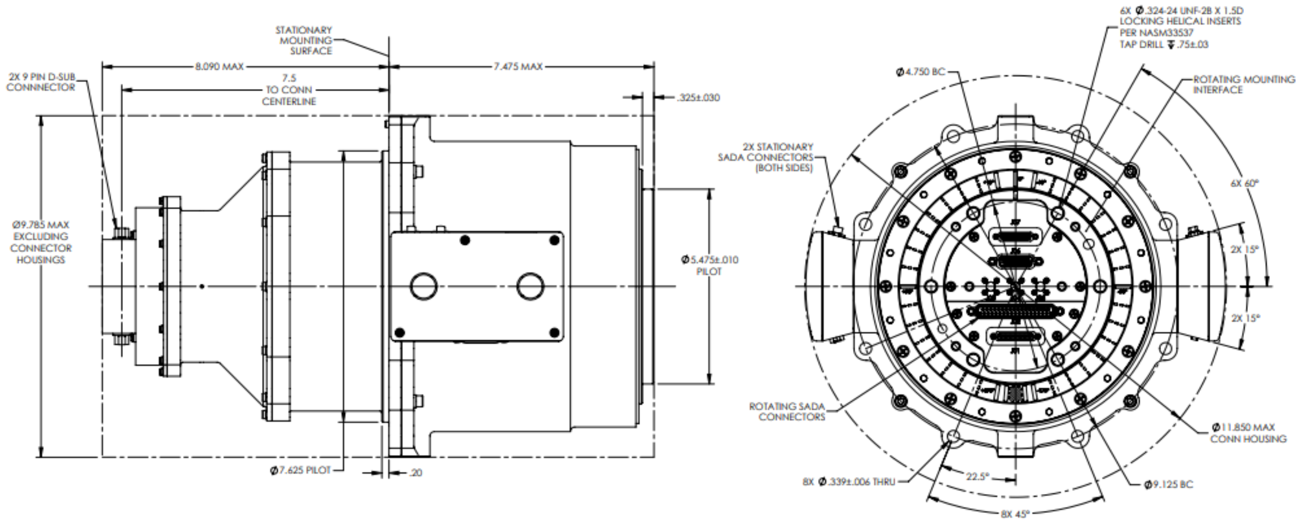
The actuator uses a 3-phase permanent magnet stepper motor to drive an advanced hybrid transmission, consisting of a planetary geartrain within a high-stiffness, zero backlash harmonic drive. Magnetic modeling and optimization ensure the permanent magnet stepper motor takes full advantage of the available volume for maximum performance per unit weight. Electrically redundant versions are fully isolated to prevent failure propagation. High-capacity stainless steel ball bearings support the output shaft for maximum stiffness and life. The actuator's titanium construction ensures high strength and consistent performance over a broad temperature range.



EH50-12.5A Twist Capsule SADA

The SDA's twist capsule houses four flexible cable assemblies and three radio frequency cables in a clock-spring arrangement. The number and type of circuits may be modified to meet specific application requirements.

Dimensions



Note: All dimensions above are in inches.

EH50-12.5A Twist Capsule SADA Features	
• High stiffness and load capacity	• Potentiometer for position telemetry
• Fine pointing resolution from 0.008 degrees per step	• Motor available as 3-phase stepper
• Space-qualified lubrication	• Internal mechanical stops included

Applications	
• Solar Array Drives	• Power/Signal transfer to moving payload

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	< 55 lbm	< 24.9 kg
Step Size	0.008 deg	
Slew Rate	>1.1 deg/s at no load	
Output Torque @ 1.1 deg/s	800 in-lb typical at 77 °F	90.3 Nm
Inertial Load	> 2,700,000 lb-in^2	>790.1 kg-m^2
Unpowered Holding Torque	>800 in-lb	>90.3 Nm
Travel	350 deg, total (as shown)	
Electrical		
Motor Winding Resistance	9.5 Ω (nominal, three-phase)	
Twist Capsule Power	5 circuits @ 2.5 amps max (as shown)	
Twist Capsule Signal	12 circuits @ 1 amp (as shown) 32 circuits @ 0.5 amp (as shown)	
Voltage	60 Vdc	
Potentiometer Resistance	10 kΩ	
Qualified Thermal Environment		
Operating Temperatures	-49 °F to 133 °F	-45 °C to 56 °C
Nonoperating Temperatures	-112 °F to 158 °F	-80 °C to 70 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

BRUSHLESS DC MOTORS

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ECLSS Pump Motor

Design Description

One of several highly optimized environmental pump motors, the Environmental Control and Life Support System (ECLSS) Pump Motor is a high reliability brushless motor and rotor. This motor can include Hall Effect Devices for commutation or can be driven with sensorless commutation. It also includes an integrated temperature sensor.

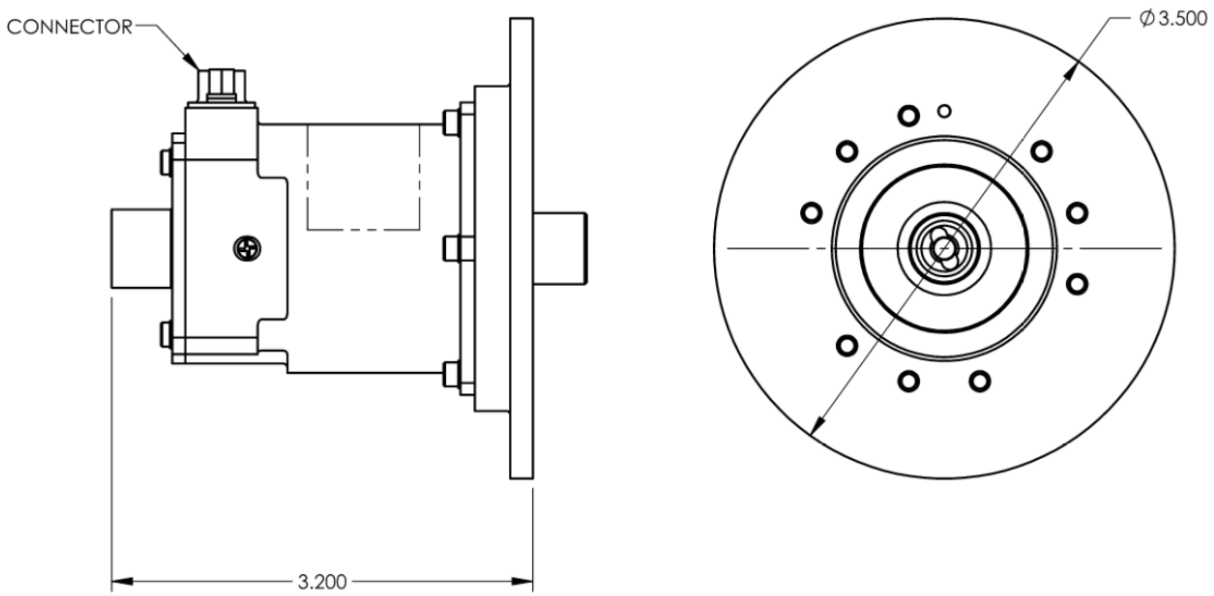
The motor features a sealed internal cavity to separate the working fluid from the ambient environment. The rotor, contained within the internal cavity, is enveloped by the working fluid. The fluid is pumped through the back of the motor housing to lubricate journal bearings that ride on the chrome plated surfaces of the rotor shaft.

The ECLSS Pump Motor can be configured to suit the customer's requirements and tailored for numerous applications, including a variety of working fluids that are common to Environmental Control and Life Support Systems.

ECLSS Pump Motor

ECLSS Pump Motor Features	
• Optimized motor design for high efficiency	• Balanced rotor assembly
• 17.6 to 34.0 VDC nominal voltage	• MIL-STD-461 EMC compliant
• Designed for operating pressures up to 300 psig	• Precision chrome journal bearings

Dimensions



Note: All dimensions above are in inches

Applications	
• Environmental Control System fluid pump	• Qualified for the Parker Solar Probe

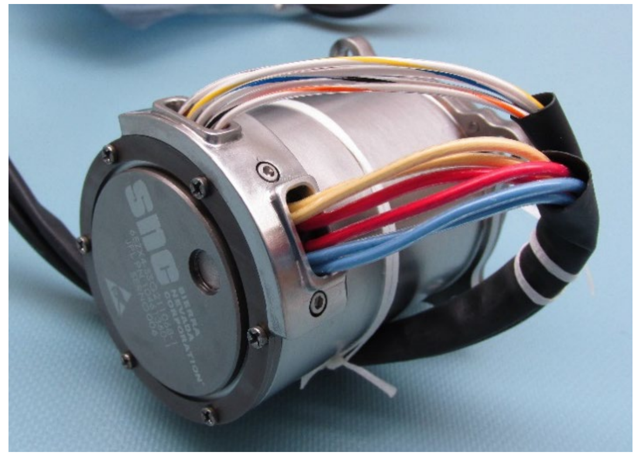
Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope dimensions	Ø3.5 in x 3.2 in	Ø8.89 cm x 8.13 cm
Mass	1.3 lbm Stator / 0.2 lbm Rotor	.59 kg Stator / 0.09 kg Rotor
Cycle Life	500 On/Off Cycles	
Operational Life	7 years	
Lubrication	Working Fluid (deionized water; alternate fluids possible)	
Speed Range	4,000 to 6,000 rpm	
Maximum Input Power	30.5 Watts	
Maximum Torque	Up to 5.5 in-oz	Up to 38.84 mNm
Operating Pressure	300 psig	∆2.068 MPa
Electrical		
Input Voltage Range	17.6 - 34.0 VDC Motor, 10 - 16 VDC HEDs	
Max Average Input Current	2.5 A	
Electromagnetic Interference	Meets MIL-STD-461: RE102, CS114	
Environmental		
Operating Temperatures	68 °F to +257 °F	20 °C to +125 °C
Non-Operating Temperatures	32 °F to +302 °F	0 °C to +150 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

M45L Motor

Design Description

Sierra Space, in support of missions to Mars, has designed, tested, and delivered a 45-mm brushless DC motor optimized for high torque and high speed, robust enough to operate in a functional vibration environment.

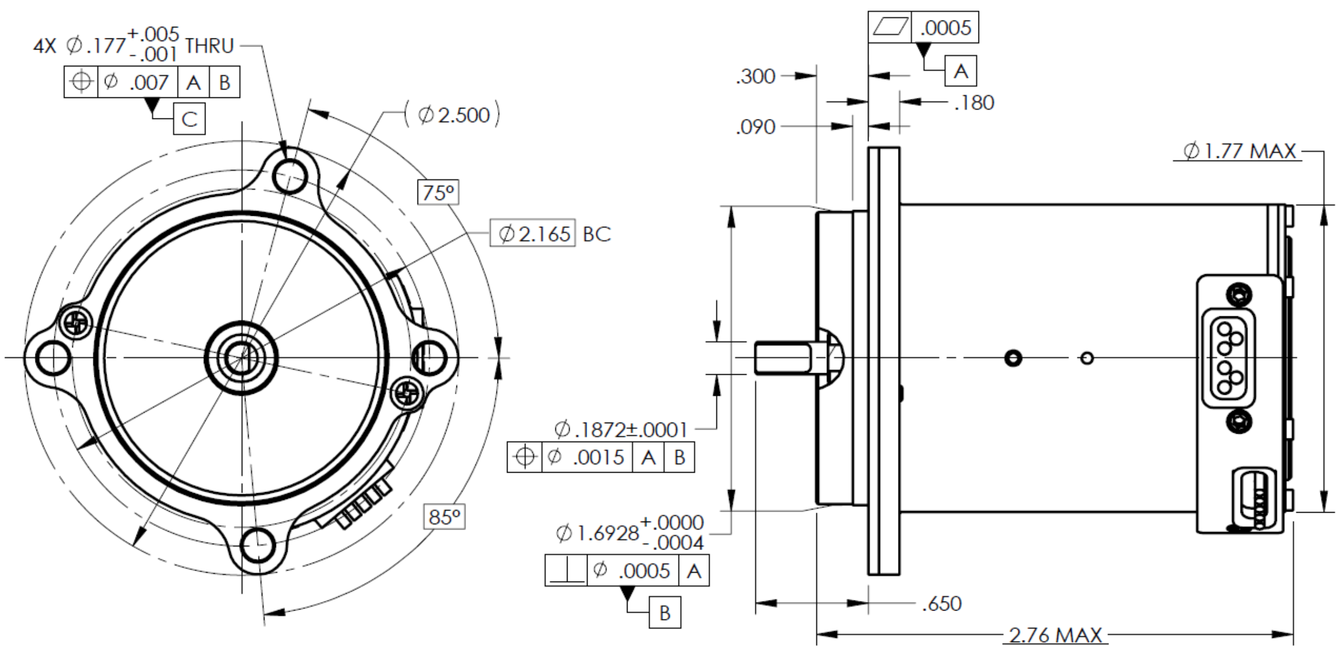
These high output motors are central to the percussion drill mechanism of NASA Jet Propulsion Laboratory's (JPL) Mars 2020 rover. Designed for low torque variation over temperature, the motor output torque, including viscous losses from lubrication, can be predicted to within ±10 mNm to across a temperature range from -70 °C to +70 °C. The motors are capable of operation and qualified for life at temperatures as low as -70 °C. M45L motors incorporate space-rated lubricant Brayco 815Z oil and Braycote 600EF grease.



M45L Motor.

M45L Motor Features	
• 3-phase brushless DC operation	• Qualified for long life (>50,000,000 revolutions with 2X margin)
• Low winding resistance	• Broad operation and non-operational temperature range
• Robust mounting interface	

Dimensions



Note: All dimensions above are in inches.

Applications	
• Robotics applications	• High speed/torque applications
• Planetary Gearmotor applications	• High vibration applications

Heritage Programs
• Mars 2020

Product Specifications	M45L	
	U.S.	**SI**
Mechanical		
Envelope Dimensions	Ø 2.50 in x 2.76 in	Ø 63.5 mm x 70.1 mm
Mass, Less Cables	1.1 lbs	0.48 kg
No Load Speed	11,075 rpm	
Maximum Motor Torque, Type	56.6 in-oz	400 mNm
Holding Torque Type (i.e., Brake, Detent)	Detent	
Life (2X Margin)	15,000,000	
Electrical		
Voltage, Nominal (range)	26.9 Vdc (15.3-31.5 Vdc)	
Motor Kt, Nominal	3.31 in-oz/A	23.4 mNm/A
Winding Resistance	0.27 Ω	
Winding Inductance	0.24 mH	
Driver Type	3-phase	
Lubrication	Brayco 815Z and Braycote 600EF	
Environmental		
Operating and Qualified Temperature	-94 °F to +158 °F	-70 °C to +70 °C
Non-Operating Temperature	-211 °F to +257 °F	-135 °C to +125 °C
Random Vibration	10 Grms	
Pyrotechnic Shock	1,000 gs @ 3,500 Hz	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

M45S Motor Brake

Design Description

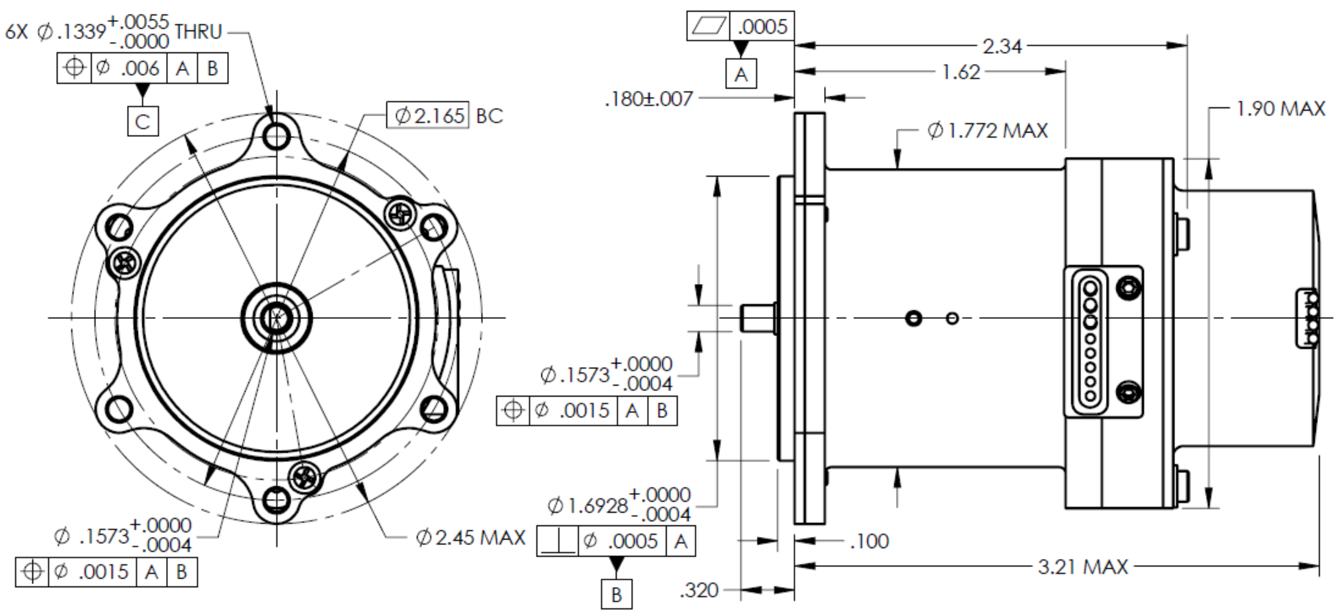
Sierra Space, in support of missions to Mars, has designed, tested, and delivered a 45-mm brushless DC motor with a solenoid friction brake to increase holding torque capability, ideal for robotic applications that require reliable station keeping when unpowered.

These highly capable motors are the prime movers and brakes in each joint of the external robotic arm of NASA Jet Propulsion Laboratory's (JPL) Mars 2020 rover. Designed to balance the demands of long-life and low-torque variation over temperature, the motor output torque, including viscous losses from lubrication, can be predicted to within ±10 mNm to across a temperature range from -70 °C to +70 °C. The motors are capable of operation at temperatures as low as -70 °C and are qualified for long life missions with a minimum temperature of -55 °C. M45S motors incorporate space-rated lubricant Brayco 815Z oil and Braycote 600EF grease.

M45S Motor Brake.

M45S Motor Brake Features	
• 3-phase brushless DC operation	• Qualified for long life (>50,000,000 revolutions with 2X margin)
• Redundant brake coils for actuation	• Broad operation and non-operational temperature range
• Robust mounting interface	• Low winding resistance

Dimensions



Note: All dimensions above are in inches.

Applications	
• Robotics applications	• Holding torque applications
• Planetary Gearmotor applications	

Heritage Programs
• Mars 2020

Product Specifications	M45S	
	U.S.	**SI**
Mechanical		
Envelope Dimensions	Ø 2.45 in x 3.21 in	Ø 62.3 mm x 81.5 mm
Mass, Less Cables	1.2 lbs	0.55 kg
No Load Speed	7,120 rpm	
Maximum Motor Torque, Type	36.8 in-oz	260 mNm
Min Unpowered Holding Torque	38 in-oz	270 mNm
Holding Torque Type	Friction Brake	
Life (2X Margin)	52,600,000	
Electrical		
Voltage, Nominal (range)	26.9 Vdc (15.3-31.5 Vdc)	
Motor Kt, Nominal	5.24 in-oz/A	37.1 mNm/A
Winding Resistance	1.67 Ω	
Winding Inductance	1.32 mH	
Driver Type	3-phase	
Redundancy	Brake coil only	
Lubrication	Brayco 815Z and Braycote 600EF	
Environmental		
Operating Temperature Range	-94 °F to +158 °F	-70 °C to +70 °C
Qualified Temperature Range	-67 °F to +158 °F	-55 °C to +70 °C
Non-Operating Temperature Range	-211 °F to +257 °F	-135 °C to +125 °C
Random Vibration	10 Grms	
Pyrotechnic Shock	1,000 gs @ 3,500 Hz	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

GEARED BRUSHLESS DC MOTORS

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DM45L Gearmotor

Design Description

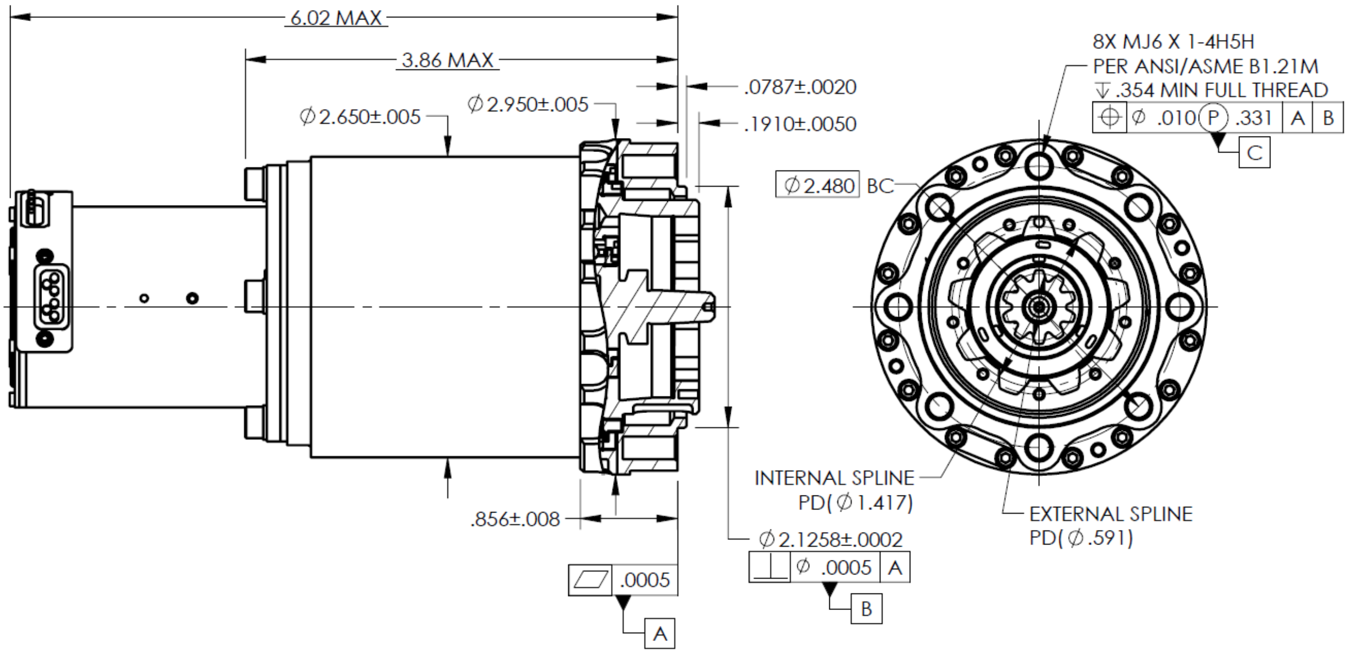
Sierra Space, in support of missions to Mars, has designed, tested, and delivered a unique dual-mode planetary gearmotor. DM45L includes two output shaft splines operated at two different gear ratios to allow the user to select either a high-speed or high-torque option. Qualified for use in a percussive drill device, this unit can operate throughout a functional vibration environment.

This distinctive gearmotor uses our M45L motor and transmits torque simultaneously through both 2-stage and 4-stage planetary geartrains to high-strength output spline features. The gearbox includes high-quality stainless-steel gears (Q10), supported by 440C ball bearings and silicon nitride roller bearings. The gearmotor is capable of operation and qualified for life at temperatures as low as -70 °C. The DM45L gearmotor incorporates space-rated lubricant Brayco 815Z oil and Braycote 600EF grease.

DM45L Gearmotor

DM45L Gearmotor Features	
• 3-phase brushless DC motor operation	• High-strength output spline features
• High-speed (350 rpm) and high-torque (560 in-lbf) outputs	• Qualified for operation in functional vibration environment
• 32:1 and 507:1 gear ratio	• Broad operation and non-operational temperature range

Dimensions



Note: All dimensions above are in inches.

Applications	
• Robotics applications	• High-speed and high-torque applications
• High-vibration applications	• Drill mechanisms

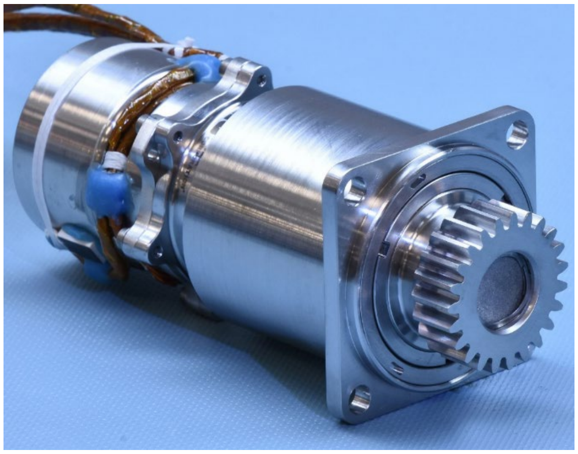
Heritage Programs	
• Mars 2020 Perseverance Rover Mission	• Mars Science Laboratory (gearbox)

Product Specifications				
	U.S.	**SI**	**U.S.**	**SI**
Mechanical				
Gear Ratio	506.67:1		31.67:1	
Envelope Dimensions	Ø 2.95 in x 6.02 in	Ø 75 mm x 153 mm	Ø 2.95 in x 6.02 in	Ø 75 mm x 153 mm
Mass, Less Cables	<4.38 lb	<2.0 kg	<4.38 lb	<2.0 kg
Operating Torque	Contact Engineering		Contact Engineering	
Maximum Torque	668.2 in-lbf	64 Nm	62 in-lbf	7 Nm
No Load Speed, Maximum	21.9 rpm		350 rpm	
Unpowered Holding Torque, Minimum	N/A	N/A	N/A	N/A
Torsional Stiffness, Type	7,740 in-lbf/rad	875 Nm/rad	1,742 in-lbf/rad	197 Nm/rad
Backlash, Type	6 mrad		53 mrad	
Lubrication	Brayco 815Z and Braycote 600EF		Brayco 815Z and Braycote 600EF	
Life (2X Margin)	>1,200 revs		>244,000 revs	
Electrical				
Motor Type	3-phase Sierra Space M45L Brushless DC			
Voltage, Nominal (range)	26.9 Vdc (15.3-31.5 Vdc)			
Winding Resistance	0.27 Ω			
Winding Inductance	0.24 mH			
Motor Driver	3-phase			
Environmental				
Operating and Qualified Temperature	-94 °F to +158 °F	-70 °C to +70 °C	-94 °F to +158 °F	-70 °C to +70 °C
Non-Operating Temperature	-211 °F to +257 °F	-135 °C to +125 °C	-211 °F to +257 °F	-135 °C to +125 °C
Random Vibration	10 Grms			
Pyrotechnic Shock	1,000 gs @ 3,500 Hz			
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.				

HT32-948 Gearmotor

Design Description

Sierra Space, in support of missions to Mars, has designed, tested, and delivered this high-torque planetary gearmotor. The HT32-948 includes a 32-mm motor with a magnetic detent wheel to increase holding torque capability, ideal for robotic applications that require locking/unlocking or reliable station keeping when unpowered.

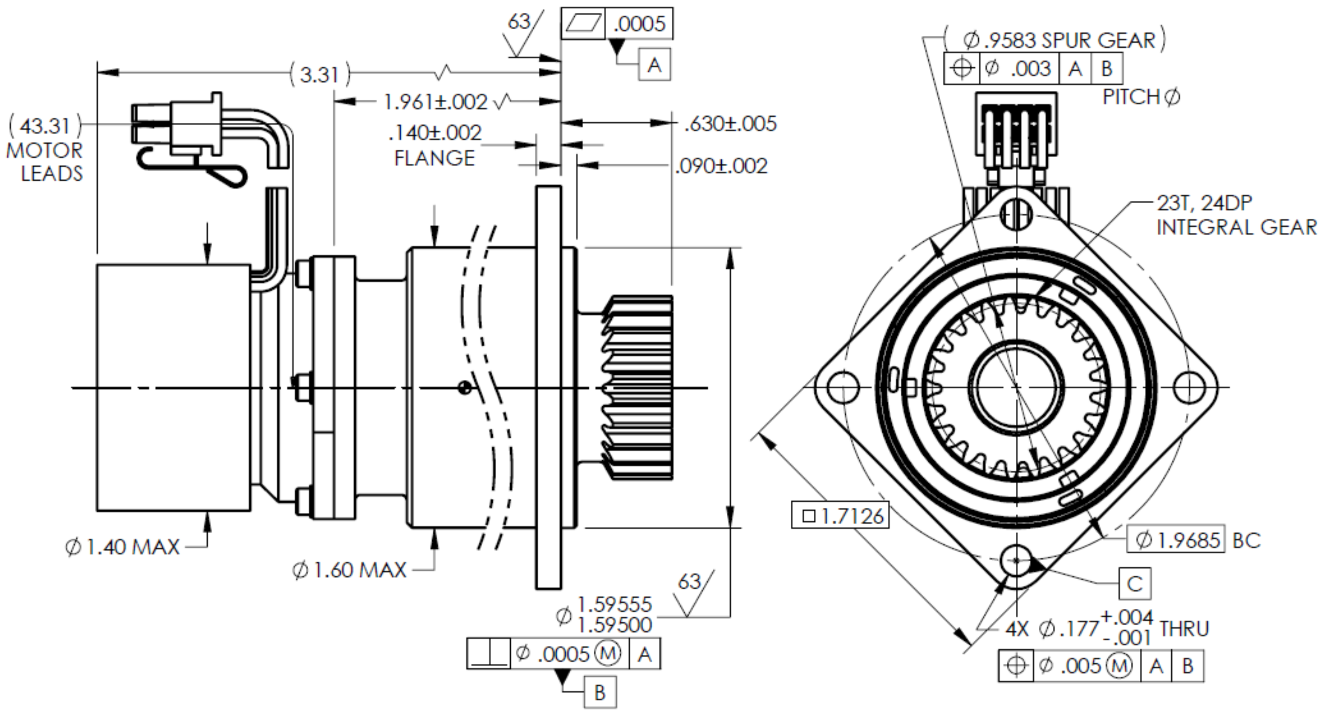


HT32-948 Gearmotor.

This precision gearmotor uses a customized commercial M32 motor with two holding torque capability options and transmits torque through a 4-stage planetary geartrain to a high-strength stainless-steel output carrier, able to accommodate with multiple attachment features (integral 23T, 24DP gear shown). Gearboxes include high-quality stainless-steel gears (Q10), supported by 440C ball bearings and weight-efficient porous bronze bushings. The gearmotor is capable of operation and qualified for life at temperatures as low as -70 °C. HT32-948 gearmotors incorporate space-rated lubricant Brayco 815Z oil and Braycote 600EF grease.

HT32-948 Gearmotor Features	
• 3-phase brushless DC motor operation	• Output carrier attachment options
• Magnetic detent wheel to increase holding torque	• High external load capability
• Low backlash (<16 mrad)	• Broad operation and non-operational temperature range

Dimension



Note: Dimensions above are in inches.

Applications	
• Robotics applications	• Slow speed applications
• Deployment mechanisms	• Lock/Unlock mechanisms

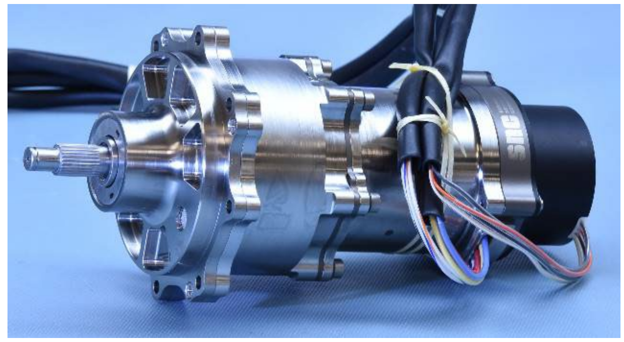
Heritage Programs	
• Mars 2020 Perseverance Rover Mission	• Mars Science Laboratory (gearbox)

Product Specifications	HT32-948	
	U.S.	**SI**
Mechanical		
Gear Ratio	948.6:1	
Envelope Dimensions	Ø 1.71 in x 3.30 in	Ø 44 mm x 84 mm
Mass, Less Cables	<1.28 lb	<0.58 kg
Operating Torque	Contact Engineering	
Maximum Torque	182.5 in-lbf	20.6 Nm
No Load Speed, Maximum	5.3 rpm	
Unpowered Holding Torque, Minimum	146 in-lbf	16.5 Nm
External Loads	Contact Engineering	
Torsional Stiffness, Type	94,200 in-lbf/rad	10,640 Nm/rad
Backlash, Type	8.0 mrad	
Lubrication	Brayco 815Z and Braycote 600EF	
Life (2X Margin)	>1,000 revs	
Electrical		
Motor Type	3-phase M32 Brushless DC with High-Torque Magnetic Detent Wheel (Low-Torque Detent Optional)	
Motor Holding Torque, Nominal	2.83 in-oz (1.42 in-oz)	20 mNm (10 mNm)
Voltage, Nominal (range)	28 Vdc (12-28 Vdc)	
Winding Resistance	14 Ω	
Motor Driver	3-phase	
Environmental		
Operating and Qualified Temperature	-94 °F to +158 °F	-70 °C to +70 °C
Non-Operating Temperature	-211 °F to +257 °F	-135 °C to +125 °C
Random Vibration	10 Grms	
Random Vibration	10 Grms	
Pyrotechnic Shock	1,000 gs @ 3,500 Hz	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

HT45S-178 Gearmotor with Brake

Design Description

Sierra Space, in support of missions to Mars, has designed, tested, and delivered two variants of a high-torque planetary gearmotor. Both include a 45-mm motor with a solenoid brake to increase holding torque capability, ideal for robotic applications that require reliable station keeping when unpowered.

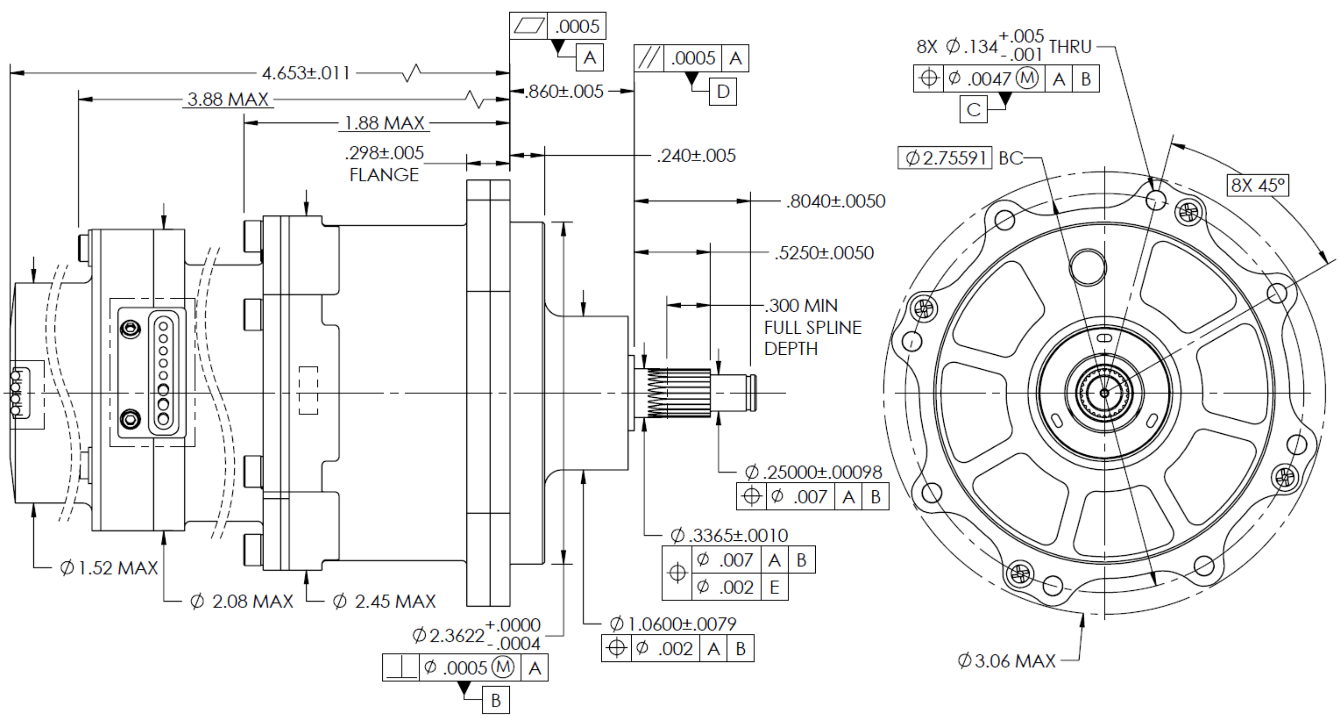


HT45S-178 Gearmotor with Brake (HT45S-81 not shown).

These high-capacity gearmotors uses our M45S motor brake and transmit torque through a 3-stage planetary geartrain to a high-strength stainless-steel output spline, which allows for straightforward integration at the next-higher level of assembly. Gearboxes include high-quality stainless-steel gears (Q10), supported by 440C ball bearings and weight-efficient porous bronze bushings. The gearmotors are capable of operation at temperatures as low as -70 °C and are qualified for long-life with a minimum temperature of -55 °C. HT45S-178 gearmotors incorporate space-rated lubricant Brayco 815Z oil and Braycote 600EF grease.

HT45S-178 Gearmotor Features	
• 3-phase brushless DC motor operation	• Integral high-strength output shaft spline
• Redundant brake coils for actuation	• Qualified for long life
• 81:1 and 178:1 gearbox option	• Broad operation and non-operational temperature range

Dimensions



Note: All dimensions shown above apply to HT45S-178 and are in inches. HT45S-81 similar.

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Applications	
• Robotics applications	• High torque applications
• Deployment mechanisms	

Heritage Programs	
• Mars 2020	• Mars Science Laboratory (gearbox)

Product Specifications	HT45S-81		HT45S-178	
	U.S.	SI	US	SI
Mechanical				
Gear Ratio	81.19:1		178.34:1	
Envelope Dimensions	Ø 2.56 in x 4.30 in	Ø 65 mm x 109 mm	Ø 3.06 in x 4.65 in	Ø 77.6 mm x 118 mm
Mass, Less Cables	<2.1 lb	<0.92 kg	<2.7 lb	<1.24 kg
Operating Torque	Contact Engineering		Contact Engineering	
Maximum Torque	110.6 in-lbf	12.5 Nm	230.1 in-lbf	26.0 Nm
No Load Speed, Maximum	87.7 rpm		39.9 rpm	
Unpowered Holding Torque, Minimum	101.8 in-lbf	11.5 Nm	262.9 in-lbf	29.7 Nm
Torsional Stiffness, Type	13,000 in-lbf/rad	1,470 Nm/rad	13,000 in-lbf/rad	1,470 Nm/rad
Backlash, Type	27.5 mrad		26.0 mrad	
Lubrication	Brayco 815Z and Braycote 600EF		Brayco 815Z and Braycote 600EF	
Life (2X Margin)	315,000 revs		203,000 revs	
Electrical				
Motor Type	3-phase Sierra Space M45S Brushless DC with Solenoid Brake			
Voltage, Nominal (range)	26.9 Vdc (15.3-31.5 Vdc)			
Winding Resistance	1.67 Ω			
Winding Inductance	1.32 mH			
Motor Driver	3-phase			
Environmental				
Operating Temperature	-94 °F to +158 °F	-70 °C to +70 °C	-94 °F to +158 °F	-70 °C to +70 °C
Qualified Life Temperature Range	-67 °F to +158 °F	-55 °C to +70 °C	-67 °F to +158 °F	-55 °C to +70 °C
Non-Operating Temperature	-211 °F to +257 °F	-135 °C to +125 °C	-211 °F to +257 °F	-135 °C to +125 °C
Random Vibration	7.1 Grms			
Pyrotechnic Shock	1,000 gs @ 3,500 Hz			
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.				

LT32 Gearmotor

Design Description

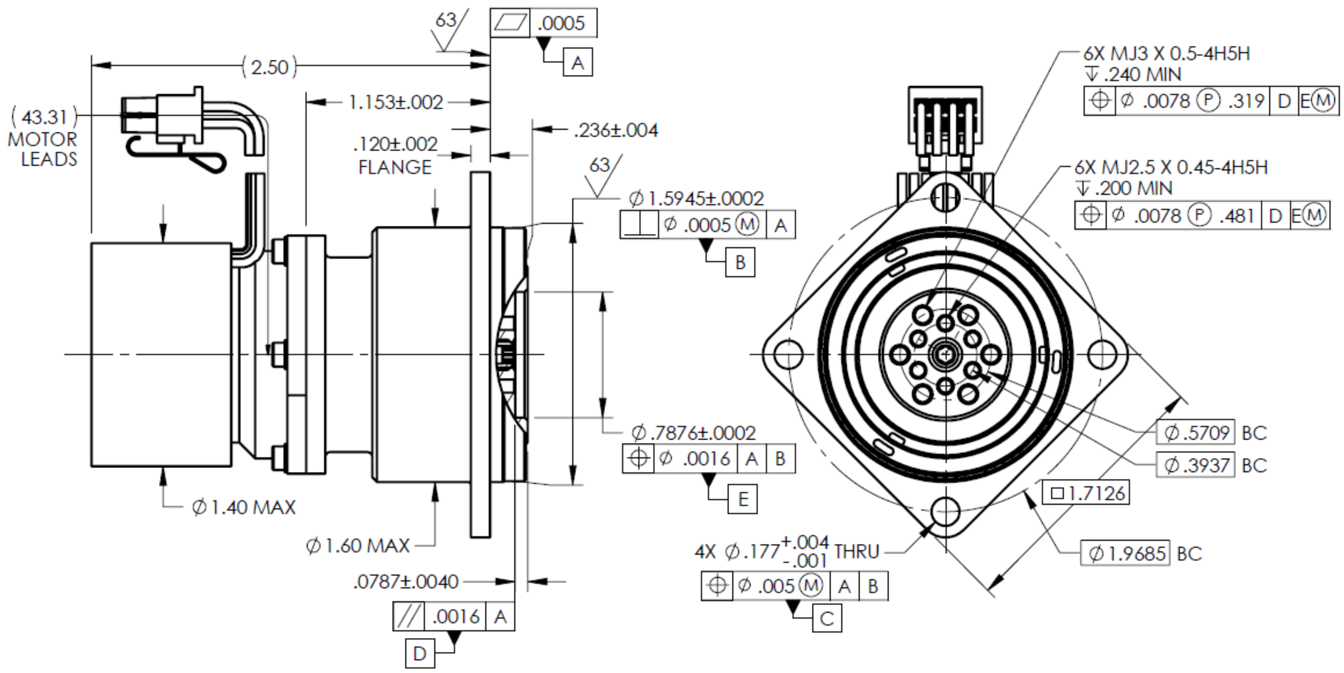
Sierra Space, in support of missions to Mars, has designed, tested, and delivered two variants of a low-torque planetary gearmotor. Both include a 32-mm motor with a magnetic detent wheel to increase holding torque capability, ideal for robotic applications that require reliable station keeping when unpowered.

LT32 Gearmotors (LT32-30, left; LT32-169, right).

These precision gearmotors use a customized commercial M32 motor with two holding torque capability options and transmit torque through a multi-stage planetary geartrain to a high-strength stainless-steel output carrier with multiple attachment features. This allows a single gearmotor design to drive multiple mechanisms. Gearboxes include high-quality stainless-steel gears (Q10), supported by 440C ball bearings and weight-efficient porous bronze bushings. The gearmotors are capable of operation at temperatures as low as -70 °C and are qualified for long life with a minimum temperature of -55 °C. LT32 gearmotors incorporate space-rated lubricant Brayco 815Z oil and Braycote 600EF grease.

LT32 Gearmotor Features	
• 3-phase brushless DC motor operation	• Multiple output carrier attachment features
• Magnetic detent wheel to increase holding torque	• Qualified for long life
• Low backlash (<16 mrad)	• High external load capability
• 30:1 and 169:1 gearbox option	• Broad operation and non-operational temperature range

Dimensions



Note: All dimensions shown above apply to LT32-169 and are in inches. LT32-30 similar.

Applications	
• Robotics applications	• Higher speed applications
• Deployment mechanisms	

Heritage Programs	
• Mars 2020	• Mars Science Laboratory (gearbox)

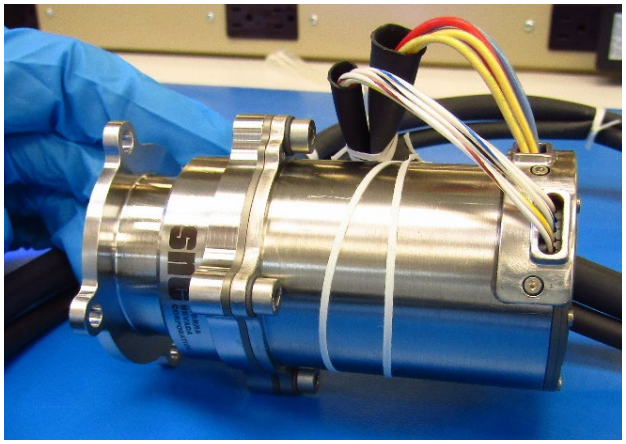
Product Specifications	LT32-30		LT32-169	
	U.S.	SI	US	SI
Mechanical				
Gear Ratio	30.25:1		169.4:1	
Envelope dimensions	Ø 1.73 in x 2.10 in	Ø 44 mm x 53 mm	Ø 1.72 in x 2.50 in	Ø 44 mm x 64 mm
Mass, less cables	<0.68 lb	<0.31 kg	<0.91 lb	<0.42 kg
Operating Torque	Contact Engineering		Contact Engineering	
Maximum Torque	15.9 in-lbf	1.8 Nm	69.0 in-lbf	7.8 Nm
No Load Speed, Maximum	165.3 rpm		29.5 rpm	
Unpowered Holding Torque, Minimum	4.78 in-lbf	0.54 Nm	9.12 in-lbf	1.03 Nm
External Loads	Contact Engineering		Contact Engineering	
Torsional Stiffness, type	2,730 in-lbf/rad	308 Nm/rad	16,790 in-lbf/rad	1,897 Nm/rad
Backlash, type	6.1 mrad		7.4 mrad	
Lubrication	Brayco 815Z and Braycote 600EF		Brayco 815Z and Braycote 600EF	
Life (2X Margin)	532,000 revs		24,300 revs	
Electrical				
Motor Type	3-phase M32 Brushless DC with High-Torque Magnetic Detent Wheel (Low-Torque Detent Optional)		3-phase M32 Brushless DC with Low-Torque Magnetic Detent Wheel (High-Torque Detent Optional)	
Motor Holding Torque, nominal	2.83 in-oz (1.42 in-oz)	20 mNm (10 mNm)	1.42 in-oz (2.83 in-oz)	10 mNm (20 mNm)
Voltage, nominal (range)	28 Vdc (12-28 Vdc)			
Winding Resistance	14 Ω			
Motor Driver	3-phase			
Environmental				
Operating temperature	-94 °F to +158 °F	-70 °C to +70 °C	-94 °F to +158 °F	-70 °C to +70 °C
Qualified life temperature range	-67 °F to +158 °F	-55 °C to +70 °C	-94 °F to +158 °F	-70 °C to +70 °C
Non-Operating temperature	-211 °F to +257 °F	-135 °C to +125 °C	-211 °F to +257 °F	-135 °C to +125 °C
Random Vibration	10 Grms			
Pyrotechnic Shock	1,000 gs @ 3,500 Hz			
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.				

LT45L Gearmotor

Design Description

Sierra Space, in support of missions to Mars, has designed, tested, and delivered a low-torque, high-speed planetary gearmotor. LT45L includes a 45-mm motor, able to reach speeds over 10,000 rpm, ideal for high-speed applications. Qualified for use in a percussion device, this unit can operate throughout a functional vibration environment.

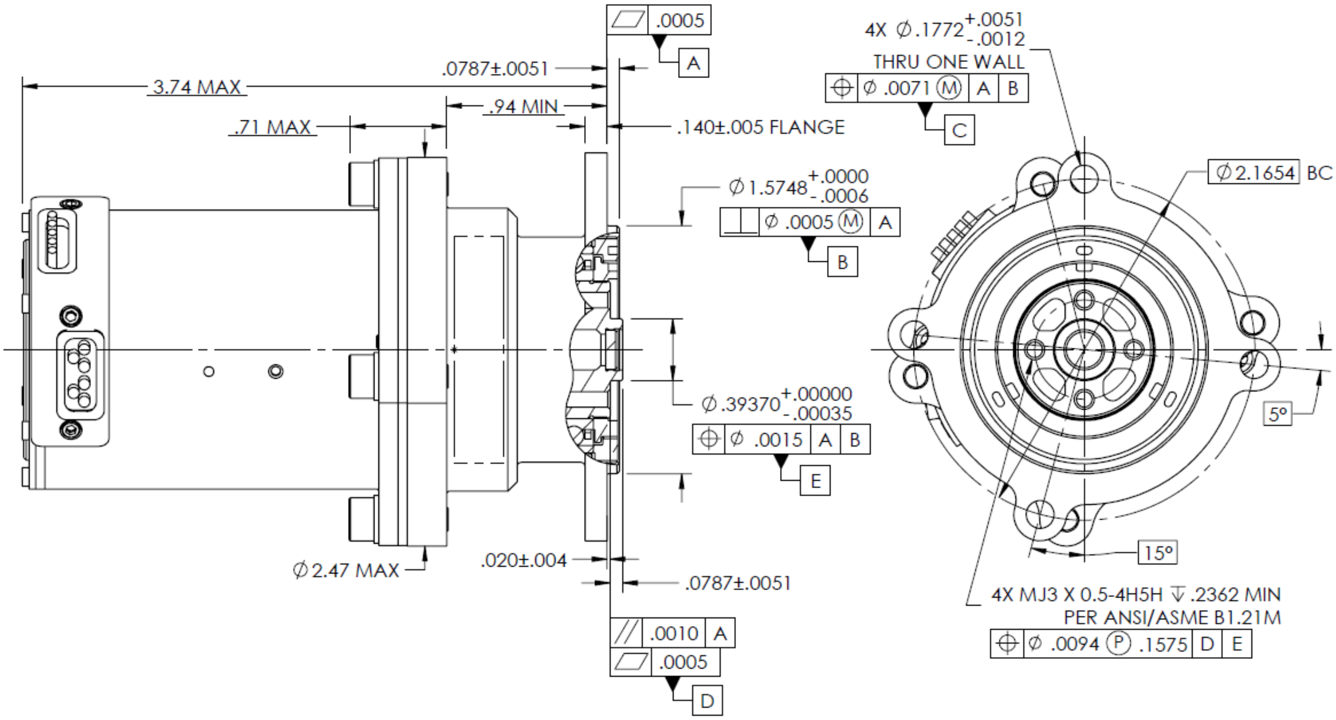
This robust gearmotor uses our M45L motor and transmits torque through a single-stage planetary geartrain to a high-strength anodized titanium output. Gearboxes include high-quality stainless-steel gears (Q10), supported by 440C ball bearings. The gearmotor is capable of operation and qualified for life at temperatures as low as -70 °C. The LT45L gearmotor incorporates space-rated lubricant Brayco 815Z oil and Braycote 600EF grease.



LT45L-3 Gearmotor

LT45L Gearmotor Features	
• 3-phase brushless DC motor operation	• High-capacity output shaft tapped holes
• High-speed gearmotor (>3,400 rpm)	• Qualified for operation in functional vibration environment
• 3.43:1 gearbox	• Broad operation and non-operational temperature range

Dimensions



Note: All dimensions above are in inches.

Applications	
• Robotics applications	• High-speed applications
• High vibration applications	

Heritage Programs	
• Mars 2020	• Mars Science Laboratory (gearbox)

Product Specifications	LT45L-3	
	U.S.	**SI**
Mechanical		
Gear Ratio	3.43:1	
Envelope Dimensions	Ø 2.52 in x 3.74 in	Ø 64 mm x 95 mm
Mass, Less Cables	<1.6 lb	<0.73 kg
Operating Torque	Contact Engineering	
Maximum Torque	11.9 in-lbf	1.3 Nm
No Load Speed, Maximum	3,230 rpm	
Unpowered Holding Torque, Minimum	N/A	N/A
External Loads	Contact Engineering	
Torsional Stiffness, Type	27.2 in-lbf/rad	3.1 Nm/rad
Backlash, Type	4.5 mrad	
Lubrication	Brayco 815Z and Braycote 600 EF	
Life (2X Margin)	>4,350,000 revs	
Electrical		
Motor Type	Sierra Space M45L Brushless DC Motor	
Voltage, Nominal (range)	26.9 Vdc (15.3-31.5 Vdc)	
Winding Resistance	0.27 Ω	
Winding Inductance	0.24 mH	
Motor Driver	3-phase	
Thermal		
Operating and Qualified Temperature	-94 °F to +158 °F	-70 °C to +70 °C
Non-Operating Temperature	-211 °F to +257 °F	-135 °C to +125 °C
Random Vibration	10 Grms	
Pyrotechnic Shock	1,000 gs @ 3,500 Hz	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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LT45S-42 Gearmotor with Brake

Design Description

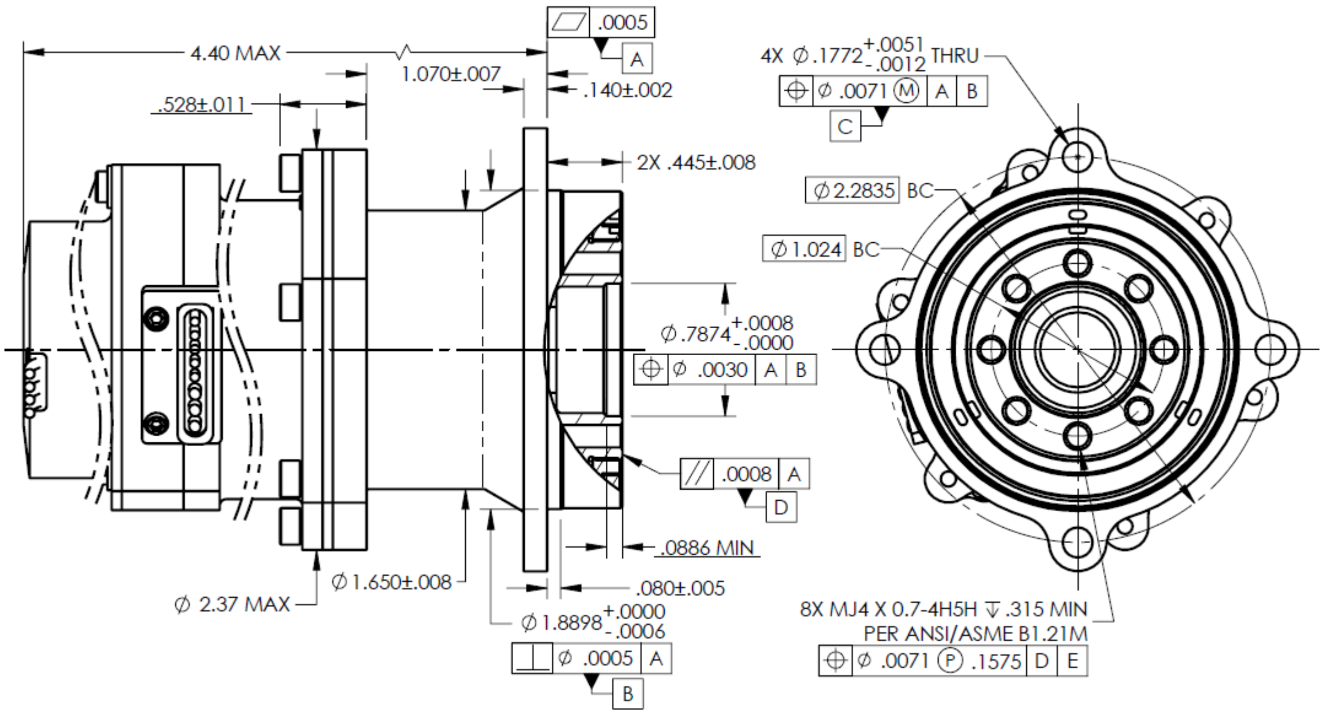
Sierra Space, in support of missions to Mars, has designed, tested, and delivered a low-torque planetary gearmotor with high external load capacity. LT45S-42 includes a 45-mm motor with a solenoid brake to increase holding torque capability, ideal for robotic applications that require reliable station keeping when unpowered.

This highly capable gearmotor uses our M45S motor brake and transmits torque through a 3-stage planetary geartrain to a high-strength anodized titanium output carrier and is designed to withstand over 1,300 lbf (5,800 N) of reversing thrust load. Gearboxes include high-quality stainless-steel gears (Q10), supported by 440C ball bearings. The gearmotor is capable of operation and qualified for life at temperatures as low as -70 °C. The LT45S-42 gearmotor incorporates space-rated lubricant Brayco 815Z oil and Braycote 600 EF grease.

LT45S-42 Gearmotor.

LT45S-42 Gearmotor Features	
• 3-phase brushless DC motor operation	• High-capacity output shaft tapped holes
• Redundant brake coils for actuation	• High external load capability
• 42.3:1 gearbox	• Broad operation and non-operational temperature range

Dimensions



Note: All dimensions above are in inches.

Applications	
• Robotics applications	• High load applications
• Deployment mechanisms	• Lock/Unlock mechanisms

Heritage Programs	
• Mars 2020	• Mars Science Laboratory (gearbox)

Product Specifications	LT45S-42	
	U.S.	**SI**
Mechanical		
Gear Ratio	42.3:1	
Envelope Dimensions	Ø 2.45 in x 4.40 in	Ø 62 mm x 112 mm
Mass, Less Cables	<2.00 lb	<0.91 kg
Operating Torque	Contact Engineering	
Maximum Torque	56 in-lbf	6.3 Nm
No Load Speed, Maximum	168.4 rpm	
Unpowered Holding Torque, Minimum	54 in-lbf	6.1 Nm
External Loads	Contact Engineering	
Torsional Stiffness, Type	54,500 in-lbf/rad	6,160 Nm/rad
Backlash, Type	6.5 mrad	
Lubrication	Brayco 815Z and Braycote 600EF	
Life (2X Margin)	>50,000 revs	
Electrical		
Motor Type	3-phase Sierra Space M45S brushless DC with solenoid brake	
Voltage, Nominal (range)	26.9 Vdc (15.3-31.5 Vdc)	
Winding Resistance	1.67 Ω	
Winding Inductance	1.32 mH	
Motor Driver	3-phase	
Environmental		
Operating and Qualified Temperature	-94 °F to +158 °F	-70 °C to +70 °C
Non-Operating Temperature	-211 °F to +257 °F	-135 °C to +125 °C
Random Vibration	10 Grms	
Pyrotechnic Shock	1,000 gs @ 3,500 Hz	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

ELECTRONIC MOTOR DRIVES

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Electronic Control Unit (ECU) – Multi Axis Microstepper with Position Control Over Low-voltage Differential Signaling (LVDS)

Design Description

Sierra Space's Electronic Control Unit (ECU) is a versatile stepper motor driver providing 12 channels of motor control (redundant 6-channel motor drivers) with modes of micro or cardinal stepping as well as commandable current limit and acceleration control. Each control channel provides five analog inputs, typically motor current, board temperature, actuator temperature, and coarse and fine position data, which are digitized and available as telemetry on the serial data bus.

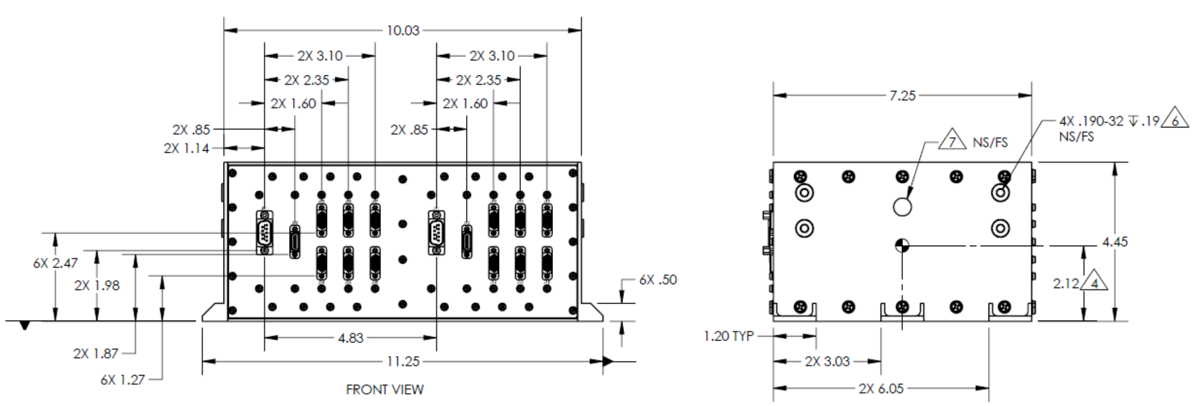
Electronic Control Unit (ECU).

The ECU's microstepping capability enables smooth motion for open-loop control of a stepper motor-driven mechanism. The finest microstep resolution available is automatically adjusted on the fly for each channel based on each motion command. The microstep resolution will be 8, 16, 32, or 64 microsteps per motor detent or cardinal step depending on step rate. The current limit can be commanded to any of eight preset values. Torque disturbances generated by stepper motor operation can be reduced by 1 to 3 orders of magnitude depending on the motor and actuator characteristics. We specialize in the optimization of motors, gearing, and drives for low-torque disturbance applications.

The ECU provides 3-phase bipolar stepper motor control. The unit can provide up to 2 amps of peak current on each channel and operates directly from spacecraft bus voltages of 22 Vdc to 36 Vdc. Current regulation maintains constant peak torque over full input voltage range and variations in motor resistance over temperature. The ECU uses a Sierra Space proprietary drive design to maximize motor performance in microstep mode.

Electronic Control Unit (ECU) Features	
• Optically coupled controller interface uses a low-voltage differential signaling (LVDS) physical layer	• Each channel includes five analog health and status inputs that are digitized and delivered as telemetry over the serial data bus
• Communication bus protocol allows commanding the following: Peak Current Limit, Microstepping On/Off, Acceleration On/Off, Powered Idle On/Off, System Reset, Cancel Step, Set Step Count, and Send Telemetry	• Two independent controllers within the enclosure can be used independently or for primary/redundant operation. Each side contains three motor driver modules that can drive two separate motors each, resulting in a total of 12 motor drive channels

Dimensions



Note: All dimensions above are in inches.

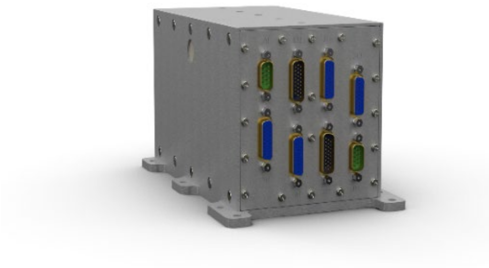
Applications	
• Antenna Pointing Mechanisms (APM)	• Solar Array Drives

Heritage Programs
• Parker Solar Probe (PSP)

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	10.03 in x 7.25 in x 4.45 in	25.47 cm x 18.41 cm x 11.17 cm
Mass	12.94 lb (TBC)	5.86 kg (TBC)
Electrical		
Input Operating Voltage	22-36 Vdc	
Power Dissipation (excluding pass through power)	≤6 W Quiescent (One Side) (TBC)	
Inrush Current	≤1.5 A for 7.5 ms (TBC)	
Power Isolation	≥10 MΩ power to chassis ground (TBC)	
Operation		
Input Commands	Peak Current Limit, Microstep Resolution, Acceleration On/Off, Powered Idle On/Off, System Reset, Cancel Step, Set Step Count, Telemetry Position Request	
Differential Input Logic ‘1’ Input Threshold	100 mV ≤Vd, assumes Vcm = +1.2 V	
Differential Input Logic ‘1’ Input Threshold	-100 mV ≥Vd, assumes Vcm = +1.2 V	
Step Mode	Cardinal stepping or microstepping	
Resolution	Microstepping: 8, 16, 32, or 64 µ-step/step (automatically selected)) Cardinal Step: 5 ms (200 steps/s) to 350 ms (2.86 steps/s)	
Step Rate	Up to 200 cardinal steps per second	
Number of Phases	3-phase (bipolar, configurable)	
Direction Command Sense	Configurable, each channel via communications	
Output Current/Channel	Settable to 500, 600, 700, 800 mA peak current, per channel Can extend range up to 2 A peak current, per channel upon customer request	
Telemetry	Motor current, Board temperature plus three analog input signals per control channel	
Environmental		
Operating Temperature	-13 °F to +149 °F (TBC)	-25 °C to +65 °C (TBC)
Nonoperating Temperature	-58 °F to +185 °F (TBC)	-50 °C to + 85 °C (TBC)
Radiation	50 krad TID (SI) (TBC)	
Vibration	28 G Random	
Note: These specifications can be modified to meet the customer’s requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Gimbal Control Unit (GCU) – Ultra Smooth Closed-Loop Position Control Unit

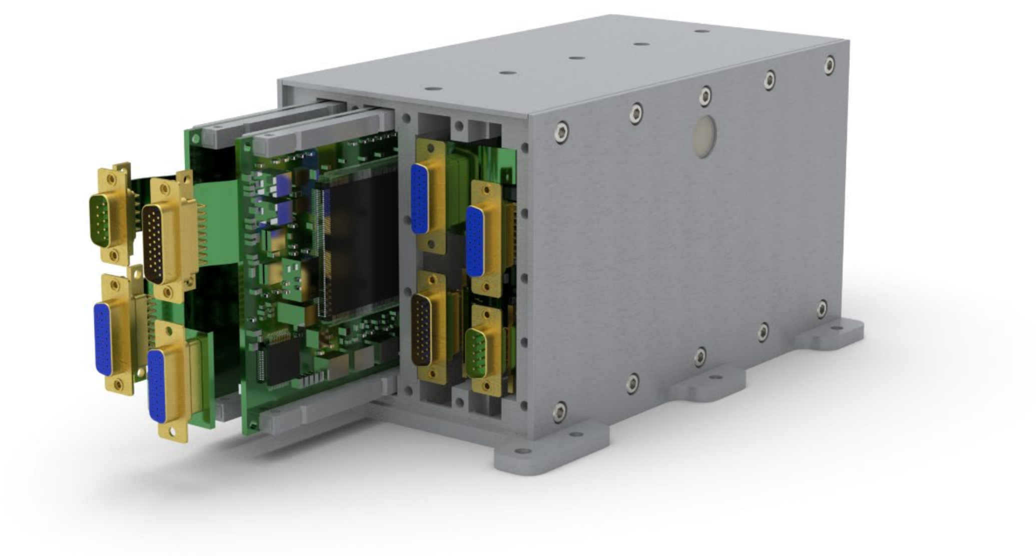
Design Description



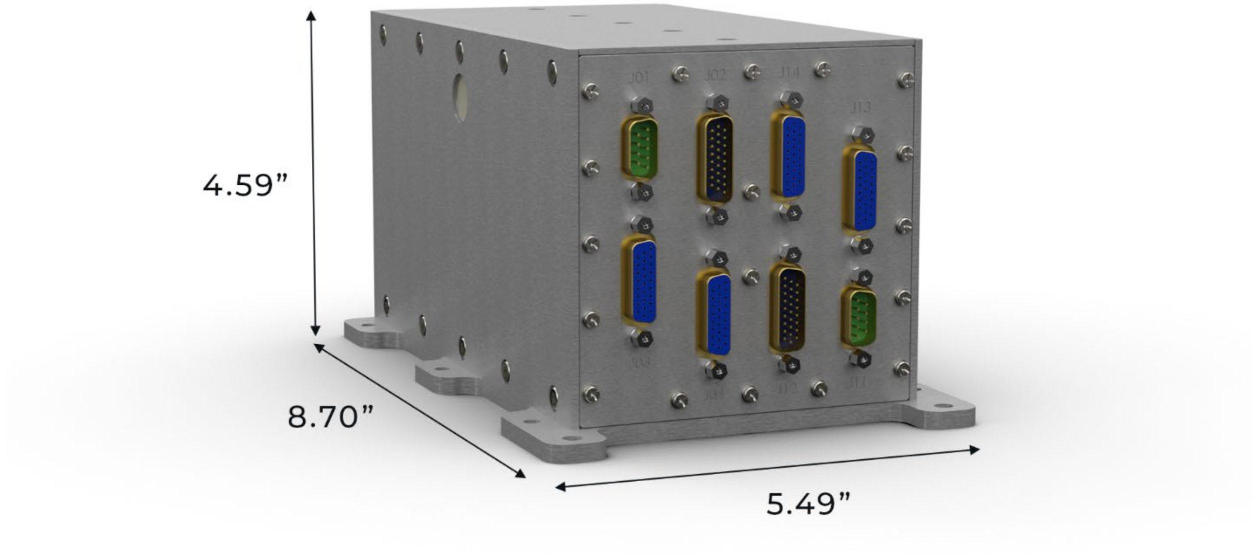
Gimbal Control Unit (GCU).

The Sierra Space Gimbal Control Unit (GCU) is a closed-loop servo controller designed to produce very smooth motion for a brushless direct-drive motor-based gimbal system. The GCU provides two motor control channels per side for a total of four independent motor control channels. Each side is electrically isolated and physically separated by a solid metal barrier. Two printed wire assemblies (PWA) per side, Power and Control, are securely mounted on a wedge lock rail system. The Power PWA has a 28 Vdc input including reverse polarity protection, inrush limiter, and EMI filter along with several isolated DC-DC converters. It also contains two 3-phase inverters and associated current sense circuitry for two independent axes of motor control. The Control PWA provides two controller area network (CAN) bus interfaces for command and telemetry, a reprogrammable RTG4 field programmable gate array (FPGA) implementing the closed-loop control architecture, two resolver excitation drivers, and four resolver-to-digital converters (RDC) supporting one dual-speed resolver per axis of control. Addressable registers enable control parameter updates and built-in test capability in service. Sierra Space controls engineers excel at collaborating with our customers to ensure that the controller is optimized for a specific application. The control loop parameters can be adjusted via the serial bus command interface and internal functionality is available to perform loop testing and recording of internal data to assist in tuning, troubleshooting and optimization of the fully integrated system, even while operating on-orbit.

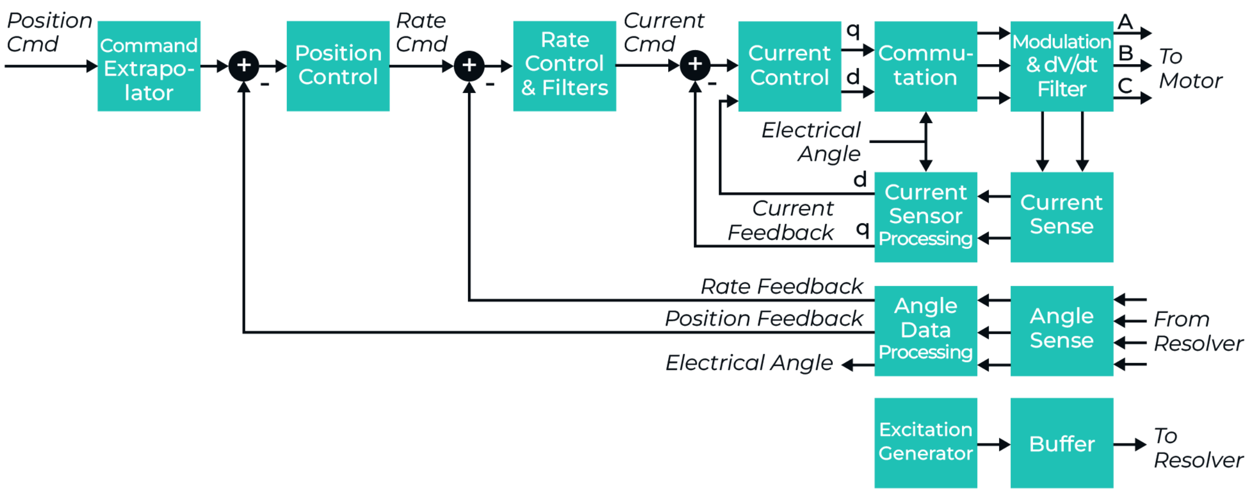
Dimensions



GCU exploded view.



GCU produce dimensions. Note: All dimensions above are in inches.



GCU functional block diagram, per axis.

GCU Features	
• Fully redundant, 2-channel motor drive (or four independent channels)	• Designed to drive a low-disturbance gimbal system ➢ Sub millinewton and millinewton-meter disturbance forces and torques achievable
• Reprogrammable RTG4 FPGA	• Space Vector Modulation (SVM), 3-phase
• Command extrapolator smooths input position command	• Cascade control loops • Position (1 kHz) • Rate (1 kHz) • Current (62.5 kHz PWM)
• Operating modes ➢ Standby ➢ Active	• Tunable control parameters ➢ Range of motion (CW and CCW soft stop limits) ➢ Control gains and limits ➢ Rate loop biquad filter coefficients ➢ Resolver offsets ➢ Warning and fault thresholds and persistence
• Table mode for built-in test	• Electrical pass-throughs (4)
• Input commands • Standby Mode (per axis) • Active mode and position command (per axis) • Request telemetry • Reset FPGA • Clear faults • Clear warnings • Read register • Write register	• Telemetry, axis 1 and axis 2 • System and axis ID • Position (21-bit) • Rate (12-bit) • Motor phase A and B currents (12-bit) • Bus voltage (8-bit) • Coarse (single-seed, 1x) resolver (16-bit) • Fine (multi-speed, 32x) resolver (16-bit) • Motor temperature (12-bit) • GCU temperature (12-bit) • Faults and warnings • Executed command count • Failed command count
• Robust against single event effects (SEE)	• Radiation-hardened components

Applications	
• Antenna pointing	• Optical systems
• Camera pointing	• Low disturbance applications

Product Specifications for a GCU		
• Command Interface: CAN • Cmd. Rate, Nom.: 64 Hz	• Redundancy: Yes	• Drive Channels (per side): 2
• Motor Type: 3-phase	• Input Voltage: 22-36 Vdc	• Input Power, Nom.: 13.5 W (excluding motor power)
• Drive Current, Maximum (per ch.): 3.5 A	• Volume: 8 in x 5.5 in footprint x 4.6 in tall	• Mass: 3.4 kg
• Operating Temperature: -20 °C to +55 °C	• Non-Operating Temperature: -30 °C to +65 °C	• Vibration: 14.9 Grms
• EEE Parts: EEE-INST-002, Level 2	• Position Feedback: Dual-Speed Resolver ➢ Coarse: 1x, Fine: 32x ➢ Excitation: 7 Vrms @ 5 kHz	

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Motor Drive Module (MDM) – 2-Axis Microstepper Board with Position Control Over RS-422

Design Description

Sierra Space has developed a Motor Drive Module (MDM) that can be installed in a customer's avionics enclosure. The MDM controls the stepping motion for two motors and provides telemetry using an RS-422 serial communication bus. The MDM provides:

- 3-phase, current-limiting, dual-channel stepper motor driver
- RS-422 communication via backplane connector
- Flight-commandable functions:
  - Step commanding, counting, direction, and reset
  - Adjustable current limit
  - Cardinal or micro-stepping
  - Acceleration/deceleration mode

Motor Drive Module.

The MDM operates with 12-V, 5-V, and 3.3-V low voltage power supply from the backplane and 24-Vdc to 35-Vdc bus power input on the front panel for motor operation. Bus power is conditioned on the card through a DC-DC converter and includes EMI filtering to reduce noise.

- Eight analog-to-digital converter (ADC) telemetry channels available. Currently configured for Fine Pot (2 channels) and Coarse Pot (2 channels), Channel 1 and Channel 2 Motor Current (2 channels), Motor and Board temp (2 channels).

The MDM is designed to drive two 3-phase bipolar motors with each channel controlling a single set of stepper motor windings and monitoring telemetry. It can perform cardinal stepping or microstepping in response to digital inputs from the command interface connector. Depending on the application, the device can be assembled and qualified to meet EEE-INST-002, Electrical, Electronic and Electromechanical (EEE) Parts Selection Standards and Guidelines, Level 1, or Level 2 spaceflight applications.

The MDM receives command signals and power from the host spacecraft and generates signals to independently drive MDM stepper motors as well as provide eight telemetry pass-throughs for each channel.

The MDM can drive a wide range of stepper motors. Motor winding resistance, motor torque constant, bus voltage, and speed range must be evaluated by Sierra Space engineering for any application to ensure desired performance is achievable.

Motor Drive Module Features	
• 3-phase, current-limiting stepper motor operation	• Independent control of each motor output channel
• Dual or primary/redundant motor channel configurations	• Bus power is conditioned through a DC-DC converter
• RS-422 communication via backplane	• EMI filtering to reduce noise
• Eight ADC telemetry channels available, typically configured for analog position sensor data, temperature, and motor current	• 5 V, 3.3 V, +12 V from the backplane, 24-Vdc to 35-Vdc bus power input.

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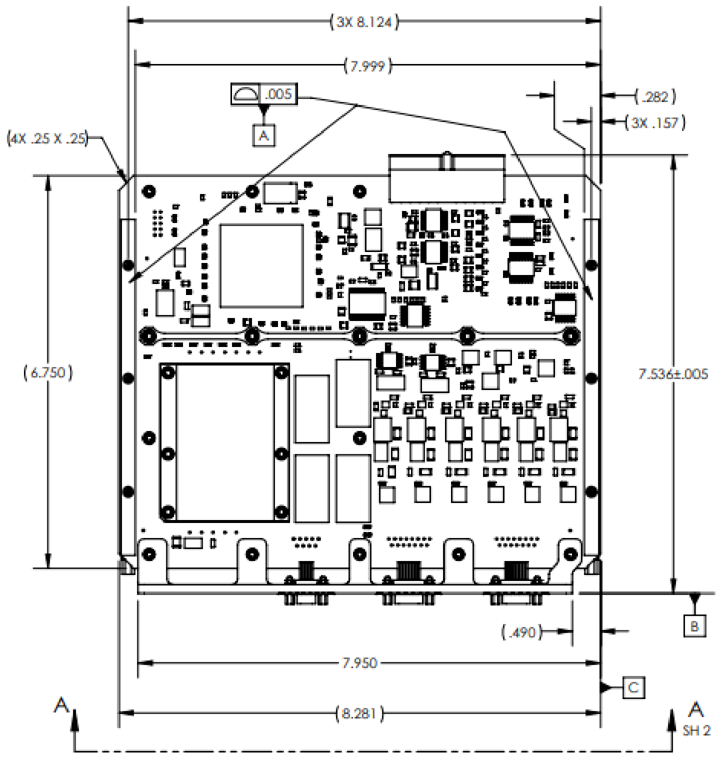
Dimensions

The MDM physical configuration can be adapted by Sierra Space engineering to fit into a customer-specific avionics enclosure. The envelope shown below was for a specific application. The MDM circuitry requires approximately 25-36 square inches minimum of board area when all components are mounted on a single side of the printed wire board (PWB).



Note: All dimensions above are in inches.

Applications	
• Antenna Pointing Mechanism (APM)	• Solar array drives
• Bi-axis gimbals	• Actuators

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	6.750 in x 8.281 in	17.145 cm x 21.034 cm
Mass	<1.3 lb	<0.6 kg
Electrical		
Input Operating Voltage	24-35 Vdc	
Power Dissipation (excluding Pass through Power)	<4.5 W quiescent, <20 W operational (Primary/Redundant version)	
Inrush Current	≤4.3 A for 2 ms	
Power Isolation	≥1 MegaΩ power to chassis ground	
Motor Current Output	Adjustable 0.5A-1.2 A	
Motor Winding Type	3-phase bipolar	

Product Specifications		
	U.S.	**SI**
Operational		
Input Commands	Step commanding, counting, and reset, adjustable current limit Cardinal or micro-stepping, start/stop acceleration ramp	
Step Rate Capability	0-200 steps/sec	
Reverse Voltage	No internal protection	
Telemetry Outputs	Step Count, Motor Current, Temperature, Position and Status are built in. Up to eight analog signals may be passed through the MDM from the motor to unused pins in the serial bus connector with no processing.	
Environmental		
Operating Temperature Range	-40 °F to 167 °F	-40 °C to 75 °C
Non-Operating Temperature Range	-40 °F to 212 °F	-40 °C to 100 °C
Radiation	-211 °F to +257 °F	-135 °C to +125 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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Microstepping Motor Controller (MMC)

Design Description

Developed by Sierra Space, the Microstepping Motor Controller (MMC) is a versatile and efficient two-phase bipolar stepper motor controller including microstepping. Two channels are provided with RS422 input for open loop motion control.

The controller can be independently configured by channel to full step, half step, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, or 1/256 microstepping.

Torque disturbances generated by the stepper motor operation can be reduced by 1 to 3 orders of magnitude depending on the motor and actuator characteristics. Sierra Space specializes in the optimization of motors, gearing, and drives for low-torque disturbance applications.

Multi-Motion Controller (MMC)

Microstepping Motor Controller (MMC) Applications	
• Solar array drive electronics	• Antenna pointing systems

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	6.5 in x 5 in x 1 in	16.5 cm x 12.7 cm x 2.54 cm
Mass	4.0 lb	1.8 kg
Electrical		
Input Voltage Range	28 Vdc ±6 Vdc	
Inrush Current	*Pending Test*	
Power Isolation	≥10 mΩ power to chassis ground	
Operational		
Input Commands	RS422	
Phase Configuration	2 Phase, Bi-polar	
Channels	2 Channels	
Environmental		
Operating Temperatures	-40 °F to +140 °F	-40 °C to +60 °C
Storage Temperature	-40 °F to +158 °F	-40 °C to +70 °C
Radiation	30 krad TID (Si) *pending analysis and/or test*	
Vibration	*Pending analysis and/or test*	
Note: This data is for information only and subject to change. Slew rate and output torque capability can depend greatly on motor driver selection. Contact Sierra Space for design data.		

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Rotary Drive Electronics (RDE) – 2-Axis Microstepper Position Control Box Over MIL-STD-1553

Design Description

Sierra Space's Rotary Drive Electronics (RDE) is a robust redundant motor controller designed to operate in the extreme environments of space. The RDE provides the interface platform between spacecraft commands and the permanent magnet stepper motor of the Rotary Drive Assembly (RDA).

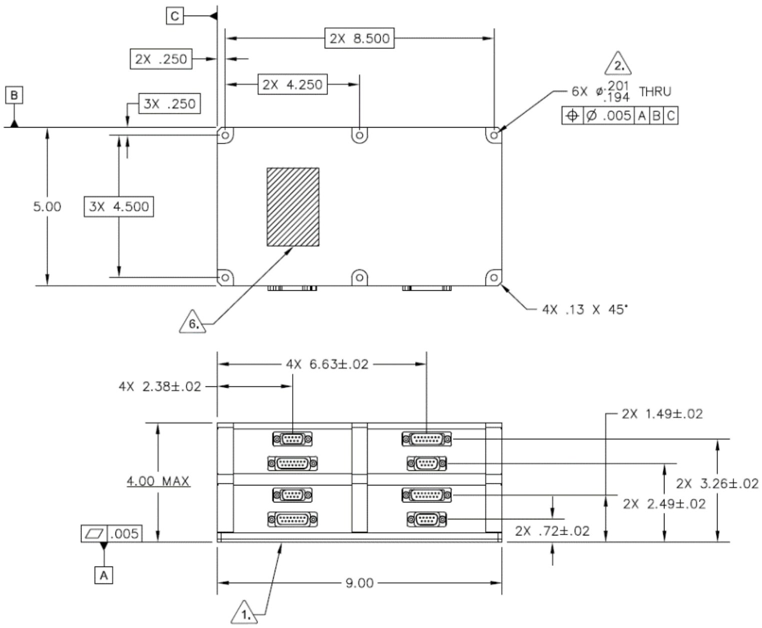
Rotary Drive Electronics (RDE).

As a stand-alone unit, the single-channel RDE receives commands and transmits telemetry via a MIL-STD-1553 serial data bus. An internal field programmable gate array (FPGA) controls the input/output (I/O) through the 1553 bus. Commands are received and processed to determine the appropriate RDA motion sequence. The FPGA controls motion through a collection of control signals and data lines that in turn control output amplifiers. The RDE can also process RDA status information (e.g., rotational position telemetry) and transmit collected information when requested via the 1553 interface.

In the microstep operational mode, the RDE controls individual motor phases with two quadrature sinusoidal signals. The phase and frequency of the sinusoidal drive signals are controlled by a commanded step rate. This ability to drive stepper motors in microstep mode provides the added benefits of control stability and low disturbance torque.

RDE Features	
• 2-phase stepper motor controller, redundant	• Flight-qualified; heritage design
• 1553 command Interface	• Electromagnetic interference/compatibility (EMI/EMC) compliant enclosure
• Telemetry processing (rotary potentiometer)	• Radiation-hardened components

Dimensions



Note All dimensions above are in inches.

Applications
• Solar Array Drive Assembly (low-disturbance torque)

Heritage Programs	
• WorldView-1 and –2	• Joint Polar Satellite System (JPSS-1)
• Suomi National Polar-orbiting Partnership (formerly known as NPOESS Preparatory Project (NPP))	

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope	5.0 in x 9.0 in x 4.0 in	12.7 cm x 22.9 cm x 10.2 cm
Weight	≤8.5 lb	≤3.9 kg
Electrical		
Supply Voltage	22-35 Vdc	
Power Consumption	11.8 W (max) @ 35 Vdc, single channel 0.1 W (max), quiescent	
Command Interface	MIL-STD-1553 serial data bus	
Microstep Range	2 deg to 2^6 µsteps per step	
Operational Modes	Position (angle), Track (rate) Idle (disabled); Stop (no step, enabled)	
Interface Connectors	D-Subminiature per MIL-C-24308	
Environmental		
Temperature (Operational)	-4 °F to +140 °F	-20 °C to +60 °C
Vibration (Random)	≤12 Grms	N/A
Vacuum	<1 x 10^{-5} Torr	<133 x 10^{-5} Pa
Life	>7.5 years	N/A
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Simple Stepper Driver (SSD) – Incremental Stepper with Discrete Input Commands

Design Description

Sierra Space's Simple Stepper Driver (SSD) provides two fully independent motor control channels using an analog design that has many benefits including low-cost.

Simple Stepper Driver (SSD).

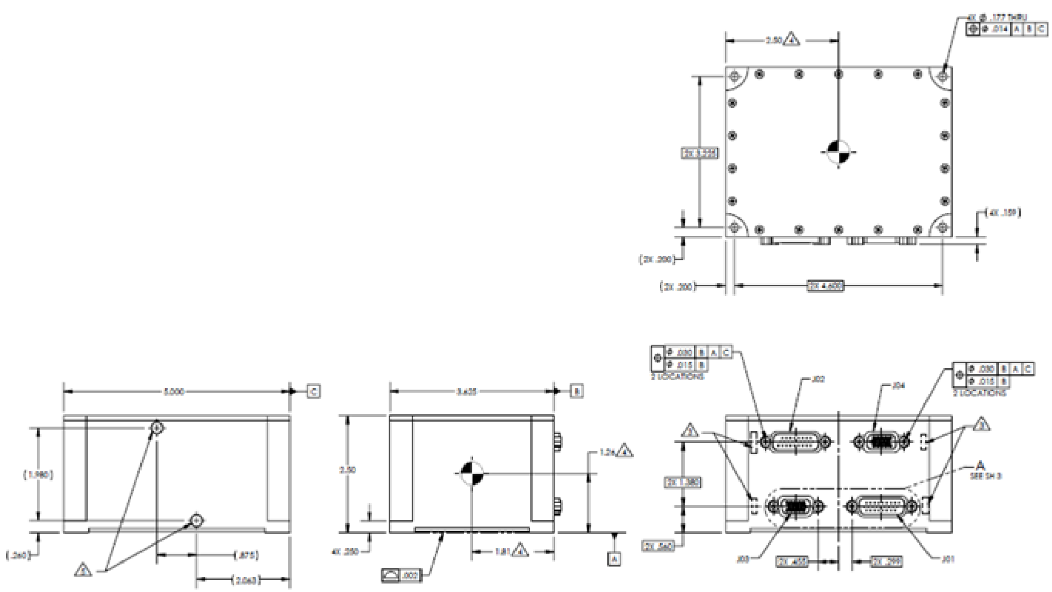
The SSD is designed to drive two 3-phase bipolar motors and consists of two completely block redundant channels with each channel controlling a single set of stepper motor windings. It can perform cardinal stepping via digital inputs from the command interface connector. Depending on the application, the device can be assembled and qualified to meet EEE-INST-002 Level 1 or Level 2 spaceflight applications.

The SSD receives command signals and power from the host spacecraft and generates signals to independently drive two stepper motors as well as provide eight telemetry pass-throughs for each channel.

The SSD can drive a wide range of stepper motors. Motor winding resistance, motor torque constant, bus voltage, and speed range need evaluation for any application to ensure desired performance is possible.

SSD Features	
• 3-phase bipolar stepper motor operation	• Independent control of each motor output channel
• Primary and secondary are fully block redundant	• PWM generation 70-90 kHz motor switching frequency
• No FPGA or microprocessor lowers cost/complexity	• Current limiter (two configurable current levels)
• Linear power supply (no switching converter)	• Integrator based current controller

Dimensions



Note: All dimensions above are in inches.

Applications	
• Antenna pointing	• Solar array drives
• Bi-axis gimbals	• Actuators

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelop Dimensions	5.0 in x 3.625 in x 2.5 in	12.7 cm x 9.2 cm x 6.35 cm
Mass	<1.8 lb	<0.82 kg
Electrical		
Input Operating Voltage	29 Vdc ±7 Vdc	
Power Dissipation (excluding Pass through Power)	<7 W	
Inrush Current	≤4.3 A for 2 ms	
Power Isolation	≥1 mΩ power to chassis ground	
Motor Current Output	<2 A	
Motor Winding Type	3-phase bipolar	
Operational		
Input Commands	Enable/disable, direction, current setpoint, and step	
Step Rate Capability	0 to 2,380 steps per second	
Reverse Voltage	Not damaged by reverse voltage	
Telemetry Outputs	Eight analog pass-throughs available for each axis	
Environmental		
Operating Temperature	-40 °F to 167 °F	-40 °C to 75 °C
Nonoperating Temperature	-40 °F to 212 °F	-40 °C to 100 °C
Radiation	100 krad TID (Si)	
Vibration	25 G (sine sweep) 35 to 70 Hz	
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

Universal Microstepping Control Driver (UMCD) Microstepper with Discrete Input Commands

Design Description

Sierra Space's Universal Microstepping Control Driver (UMCD) is a versatile stepper motor driver providing two channels of motor control with selectable microstep resolution and current limit.

The UMCD's microstepping capability enables smooth motion for open-loop control of a stepper motor driven mechanism. The microstep resolution can be configured independently for each channel to 1, 2, 4, 8, 16, 32, and 64 microsteps per motor detent.

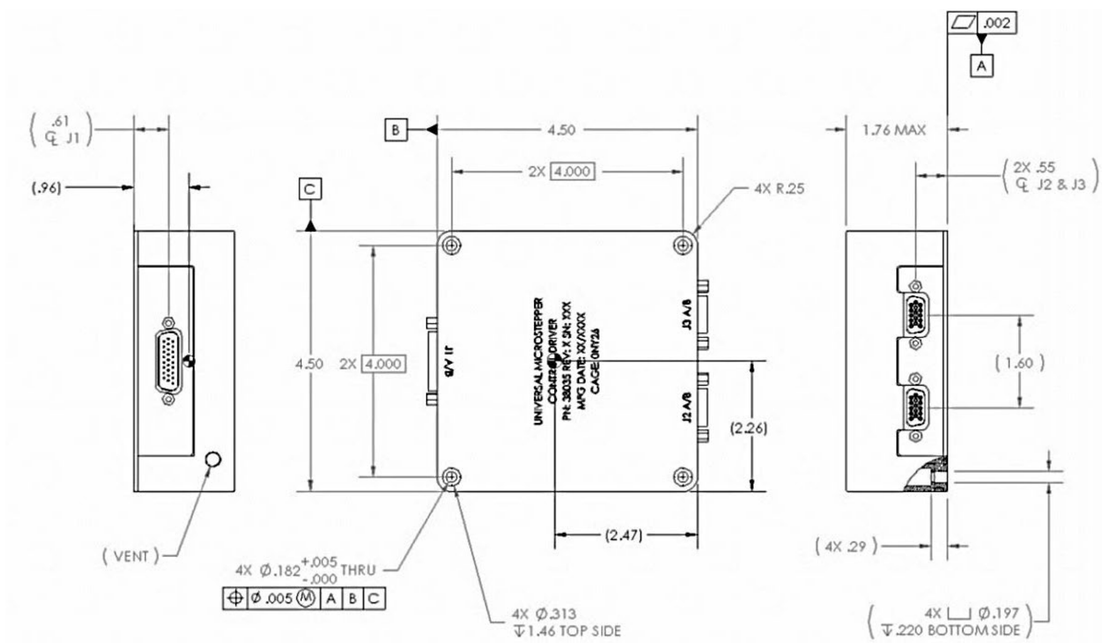
Universal Microstepping Control Driver (UMCD)

Torque disturbances generated by stepper motor operation can be reduced by 1 to 3 orders of magnitude depending on the motor and actuator characteristics. Sierra Space specializes in the optimization of motors, gearing, and drives for low-torque disturbance applications.

The UMCD is configurable for 2- or 3-phase bipolar stepper motor control. The UMCD provides up to 1.2 amps of peak current on each channel and operates directly from spacecraft bus voltages of 22 Vdc to 36 Vdc. Current regulation maintains constant peak torque over full input voltage range and variations in motor resistance over temperature. The opto-isolated logic level inputs include commands to provide power to the motor and select the direction of rotation. In addition, a step command enables the motor to advance by one step or microstep per input pulse.

Universal Microstepping Control Driver (UMCD) Features	
• Optically coupled command lines for use in noisy environments	• Standard STEP, DIRECTION, ENABLE commands optically isolated for each channel
• Two channels independently enabled	• Each channel drives one motor

Dimensions



Note: All dimensions above are in inches.

Applications	
• Antenna Pointing Mechanism (APM)	• Solar array drives

Heritage Programs	
• GeoEye 1	• Samaritan Satellite
• Geosynchronous Space Situational Awareness Program (GSSAP) 1, 2, 3, and 4	• Gladiator Space Program

Product Specifications		
	U.S.	**SI**
Mechanical		
Envelope Dimensions	4.5 in x 4.5 in x 1.75 in	11.4 cm x 11.4 cm x 4.4 cm
Mass	2.0 lb	0.9 kg
Electrical		
Input Operating Voltage	28 Vdc ±6 Vdc	
Power Dissipation (excluding Pass through Power)	≤1.0 W	
Inrush Current	≤1.5 A for 7.5 ms	
Power Isolation	≥10 mΩ power to chassis ground	
Operational		
Input Commands	Enable, Direction, Step	
Logic ‘1’ Input Level	3.8 V ≤V in ‘1’ ≤5.5 V, 5.1 ma ≤I in '1' ≤18 ma	
Logic ‘0’ Input Level	0 V ≤V in ‘0’ ≤0.7 Vdc, I in ≤50 μa	
Step Mode	Cardinal stepping or microstepping	
Resolution	1, 2, 4, 8, 16, 32, or 64 μ-step/step (configurable)	
Step Rate	10,000 μ-steps/s (max)	
Number of Phases	2- or 3-phase (bipolar, configurable)	
Direction Command Sense	Logic ‘1’ or Logic ‘0’ (configurable, each channel)	
Output Current/Channel	Settable from 200 mA to 850 mA peak, each phase 2-phase mode, 16, 32, and 64 μ-step resolution Settable from 200 mA to 600 mA peak, each phase 2-phase mode, 1, 2, and 8 μ-step resolution Settable from 200 mA to 1.2 A (max) peak, L-2L, 3-phase mode, all resolutions	
Environmental		
Operating Temperature	-40 °F to +140 °F	-40 °C to +60 °C
Nonoperating Temperature	-58 °F to +158 °F	-50 °C to +70 °C
Radiation	100 krad TID (Si)	
Vibration	25 G (sine sweep) 35 to 70 Hz	
Note: These specifications can be modified to meet the customer’s requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

SPECIAL PURPOSE MECHANISMS

eMotor with Integral Brushless DC Electronic Drive

Pivot Platform Mechanism (PPM)

T25 Dual Antenna Pointing System

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eMotor with Integral Brushless DC Electronic Drive

Design Description

Sierra Space's eMotor is a high reliability alternative to brush motors. The eMotor uses integrated electronics to drive a brushless motor with only a DC input voltage.

The onboard electronics contain current limiting and active damping features, which are each configurable to specific applications. Direction of rotation is dependent on input voltage polarity. Total travel and speed measurement may be made from a 5-Vdc square-wave signal generated at 600 pulses per revolution. A high-precision, stainless steel, 3-stage planetary gearbox provides gear reduction.

eMotor Brushless DC Motor with Gearhead.

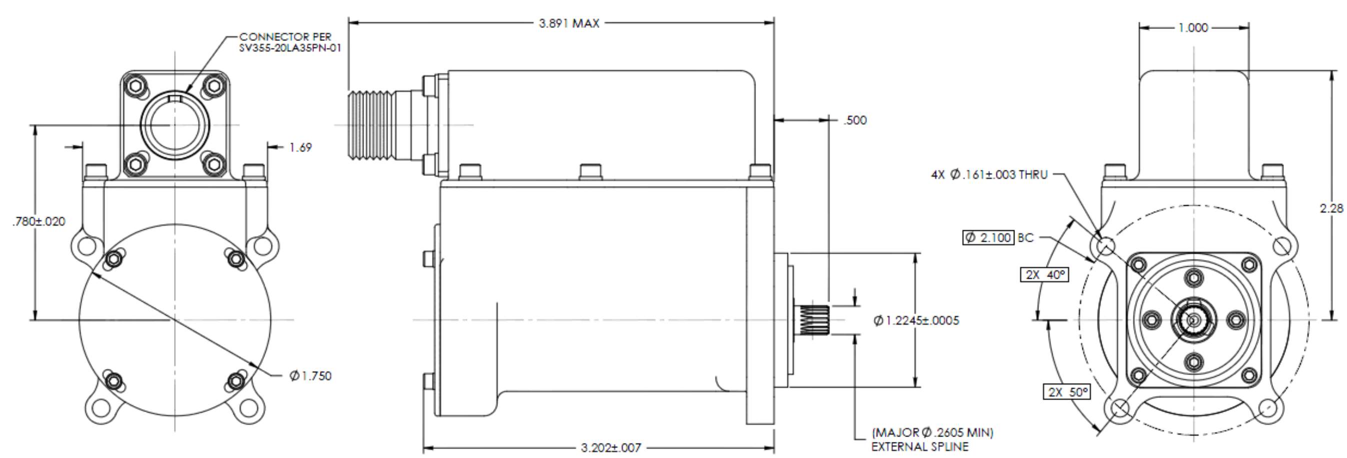
The damping mode protects the electronics during over-speed conditions. The damping mode can also be commanded externally by shorting two connector pins: disconnecting the short turns the damper back into a motor again.

Initially designed to provide valve actuation on the ORION crew module, the eMotor can be configured to suit the customer's requirements.

eMotor Brushless DC Motor Features	
• Current limiting, configurable	• 600 pulse per revolution square wave output signal
• 22–34 Vdc nominal voltage	• MIL-STD-461 EMC compliant
• Rad hard up to 100 krads	• Damping mode for over-speed control

Applications	
• Qualified for the Orion Program's Environmental Control and Life Support System (ECLSS)	• Space systems valve applications
• A drop in, more reliable replacement for existing brush motors	• Deployable and retractable systems

Dimensions



Note: All dimensions are in inches.

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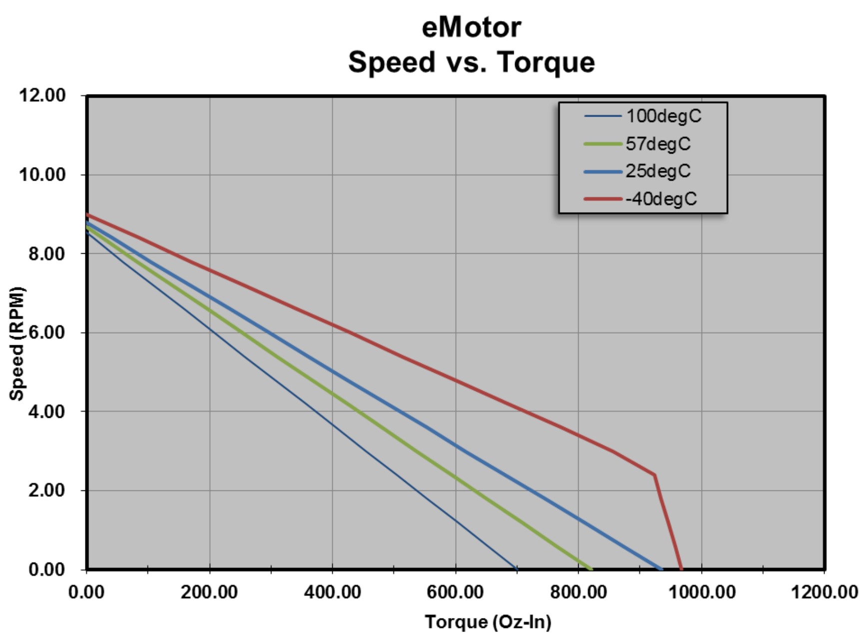
Heritage Programs
• Orion Environment Control and Life Support System (ECLSS)

Product Specifications

	U.S.	SI
Mechanical		
Envelope Dimensions	3.9 in x 1.75 in x 3.25 in	9.9 cm x 4.45 cm x 8.25 cm
Mass	17.5 oz	0.496 kg
Life Cycles	10 launch per landing cycles	
Operation Time	2,500 hours, 4 rpm with 500 in-oz load, 99.9% reliability	
Gear Reduction	Three-stage, 300:1 planetary gearbox	
Lubrication	Bray 815Z/601EF	
No Load Speed	9 rpm	
Maximum Torque	Up to 900 in-oz	Up to 6,355 mNm
Unpowered Holding Torque	200 in-oz min	1,412 mNm min
Electrical		
Input Voltage Range	22–34 Vdc, reduced performance down to 12 Vdc	
Maximum Input Current	500 mA	
Electromagnetic Interference	Meets MIL-STD-461: CS101,114; RE101, RS103; CE101,102 (limit is shifted for CE102 +30 dB above 90 kHz)	
Thermal		
Operating Temperatures	-32.8 °F to +163 °F	-36 °C to +73 °C
Nonoperating Temperatures	-67 °F to +257 °F	-55 °C to +125 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		



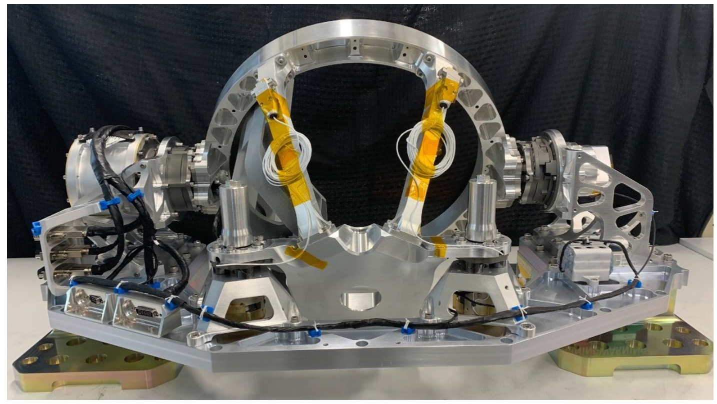
Pivot Platform Mechanism (PPM)

Design Description

The Pivot Platform Mechanism (PPM) represents a system-level solution from Sierra Space that leverages a variety of heritage components.

The PPM is a single axis pointing gimbal designed to carry a 39-lbm (17.7 kg) payload mounted on a ø16.14” (ø410 mm) bolt circle and includes the following elements:

- One CEH25 actuator
- One twist capsule with 80 continuous conductors in both twisted pairs and twisted/shielded pairs
- Two 5K Hold Down Release Mechanisms (HDRM) integrated into launch lock subassemblies
- End-to-end custom harnessing between spacecraft, avionics box, PPM, and payload

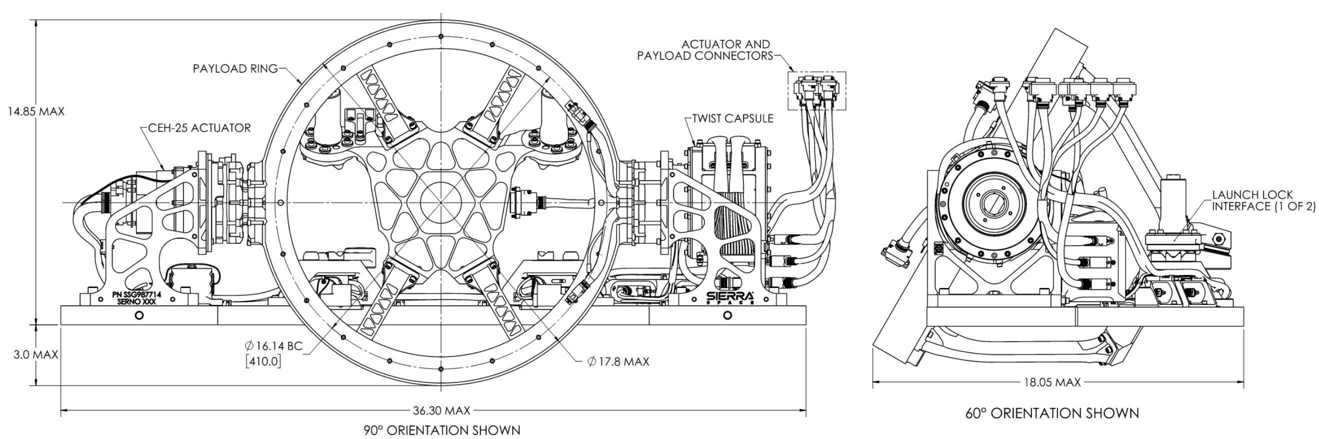


Pivot Platform Mechanism

The PPM integrates all the necessary mechanical and electrical interfaces between the payload and the spacecraft. The PPM was designed to be paired with a motor drive module (MDM), installed in the customer’s avionics box, to power the actuator and provide telemetry feedback.

The PPM incorporates modular actuator and twist capsule subassemblies, allowing the payload interface to be readily adapted to unique customer requirements without impacting other elements on the mechanism.

Dimensions



Note: All dimensions above are in inches.

Pivot Platform Mechanism Features	
• Fully electrically redundant actuator and launch locks	• 120-degree backlash-free range of motion with <0.003-degree output step size
• Redundant potentiometers for position sensing	• Continuous-cable twist capsule with no splices or solder joints
• Highly integrated system with modular elements	• Thermal isolation and tuned dynamic response via structural flexures

Applications	
• Scientific Instrument Pointing Mechanisms	• Optical System Pointing Mechanisms

Product Specifications		
	U.S.	**SI**
Mechanical		
Mass	50.35 lbm	22.84 kg
Output Step Size, nominal	0.00246 deg	
Slew Rate	>0.09 deg/s	
Range of Motion	60 deg (launch lock position) to 180 deg (120 deg travel)	
Output Torque, typical	300 in-lbf	33.9 Nm
Unpowered Holding Torque (minimum)	600 in-lbf	67.8 Nm
Locked Structural Stiffness	>30,000 lbf/in	>5.25e6 Nm
Electrical		
Twist Capsule Complement	22x Twisted Pairs, 24 AWG 16x Twisted Shielded Pairs, 24 AWG 2x Twisted Shielded Pairs, 22 AWG	
Position Sensor	Redundant coarse and fine potentiometers	
Qualified Dynamic Environments with Maximum Installed Payload Mass		
Maximum Installed Payload Mass	39 lbm	17.7 kg
Design Limit Load/Static Acceleration	30 gs	
Random Vibration	13 Grms	
First Mode	>80 Hz	
Environmental		
Operating temperatures	-13 °F to +113 °F	-25 °C to +45 °C
Non-Operating temperatures	-40 °F to +122 °F	-40 °C to +50 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

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T25 Dual Antenna Pointing System

Design Description

The Sierra Space bi-axial gimbal, featuring T25 incremental rotary actuators, developed specifically for the NASA Space Communications and Navigation (SCaN) Testbed for use on the International Space Station. The gimbal supported both Ka and S-band antennas on the output arm with both wave guide and coaxial non-contacting rotary joints on each rotational axis. The antenna arm is held in place on kinematic mounts with a Sierra Space Hold Down Release Mechanism (HDRM).

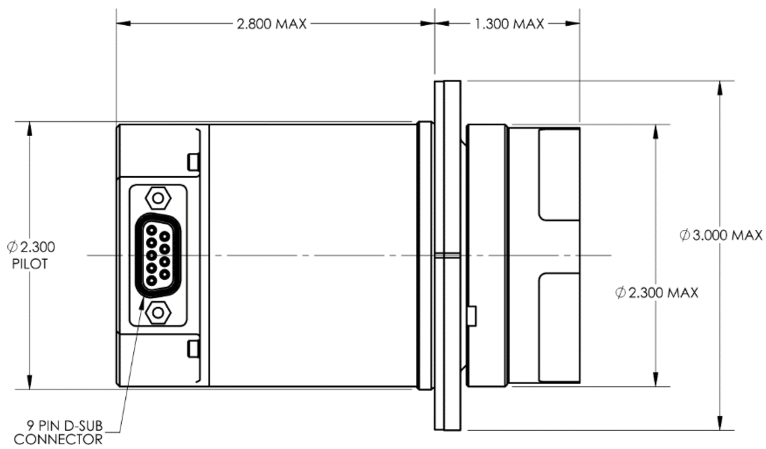
T25 Dual Antenna Gimbal

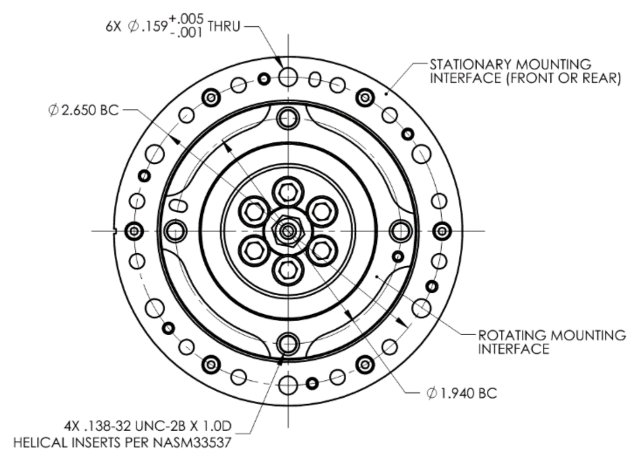
The actuators use redundantly wound 3-phase permanent magnet stepper motors to drive zero-backlash harmonic drives. The T-cup harmonic drives and custom Oldham couplings between the motor and transmission allow for a large through hole to route wire and coaxial cables across each axis or rotation. High capacity 440C stainless steel duplex bearings support each axis to maximize stiffness and life capability.

The gimbal features aerospace grade aluminum base, biaxial, and output arm brackets to optimize for mass and stiffness of the integrated unit.

T25 Dual Antenna Gimbal Features	
• 3-phase motor winding	• 200:1 T-cup harmonic drive transmission
• 1.5 deg stepper motor with redundant windings	• Adjustable hardstops
• Redundant encoder output telemetry	• Coax and Wave Guide RF Rotary Joints

Dimensions





Note: All dimensions above are in inches

Product Specifications		
	U.S.	**SI**
Mechanical		
Weight	65 lbm	29.48 Kg
Gear Reduction	200:1	
Output Step Size	0.0075°	
Output Rotational Rate	>0.5 °/s	
Powered Holding Torque	in-lbf	0. 0 Nm
Unpowered Holding Torque (minimum)	248 in-lbf	28 Nm
Torsional Stiffness (Typical)	340,000 in-lbf/rad	38,400 Nm/rad
Electrical		
Motor Type	3-phase, redundant windings, 1.5-deg stepper	
Winding Resistance (nominal)	50 Ω	
Motor Power (@-10 °C)	<16 W	
Input voltage range	24-32 Vdc	
Encoder Accuracy	±0.01°	
Encoder Power	<1 W	
Environmental		
Operating Temperatures	-14 °F to +149 °F	-10 °C to +65 °C
Non-Operating Temperatures	-40 °F to +167 °F	-40 °C to +75 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.		

PRODUCTION AND TEST CAPABILITIES

Sierra Space's production and test state-of-the-art facilities have more than 100,000 square feet of manufacturing space that is dedicated to spaceflight subsystem and component assembly and test, small satellite end-to-end production, and fabrication of our *Dream Chaser*® multi-mission space utility vehicle. Our Production and Test Center in Louisville, CO performs a wide spectrum of spacecraft integration and test activities such as environmental, thermal vacuum, vibration, and system-level testing for NASA, commercial, and Department of Defense (DOD) customers. The Sierra Space Production Center offers its customers advanced test simulators as well as cable and harnessing services. Other in-house services include a precision machine shop for machining activities of tight-tolerance hardware (±0.0002 inch) from conceptual design to rework of existing designs. Our machining equipment includes multiple precision mills and lathes, computer numeric controlled (CNC) mills and lathes, horizontal mills, 3D printing, and laser marking engraving.

Test Simulator Capabilities

Our Large Area Pulsed Solar Simulator (LAPSS) is used to verify solar array performance. The LAPSS, located in a large-scale testing zone of the Production and Test Center, simulates the Sun to obtain accurate electrical performance measurements of solar panels. Our LAPSS is capable of measuring panels that are 3.5 m x 3.5 m square with the AM0 (air mass zero) spectrum at a rate of 10 pulses per minute.

Large Area Pulsed Solar Simulator (LAPSS)
(See Test Simulator Capabilities section)

Cable and Harnessing Capabilities

Our in-house Cable Laboratory is supported by NASA-certified and trained technicians with more than 25 years of combined experience. Sierra Space Cable Lab personnel routinely manufacture, repair, and integrate flight and test harnessing and cables for a variety of applications.

Cable and Harnessing Capabilities

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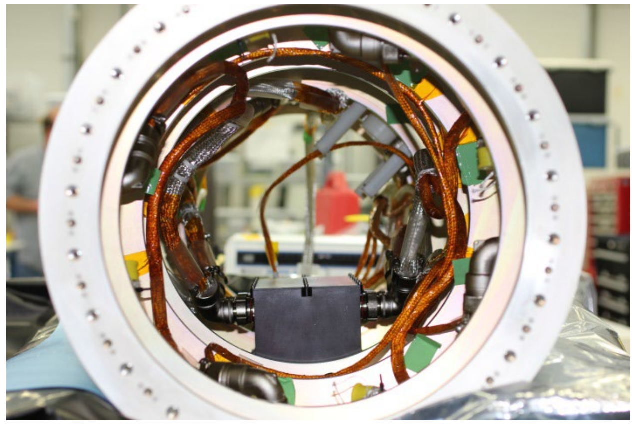
Cable and Harnessing Capability

Design Description

Sierra Space maintains an in-house Production and Test Center Cable and Harnessing Laboratory supported by our NASA-certified and trained technicians with more than 25 years of combined experience. Our Cable and Harnessing Laboratory personnel routinely manufacture, repair, and integrate flight and test harnessing and cables for NASA, commercial, and DOD customers for a variety of applications.

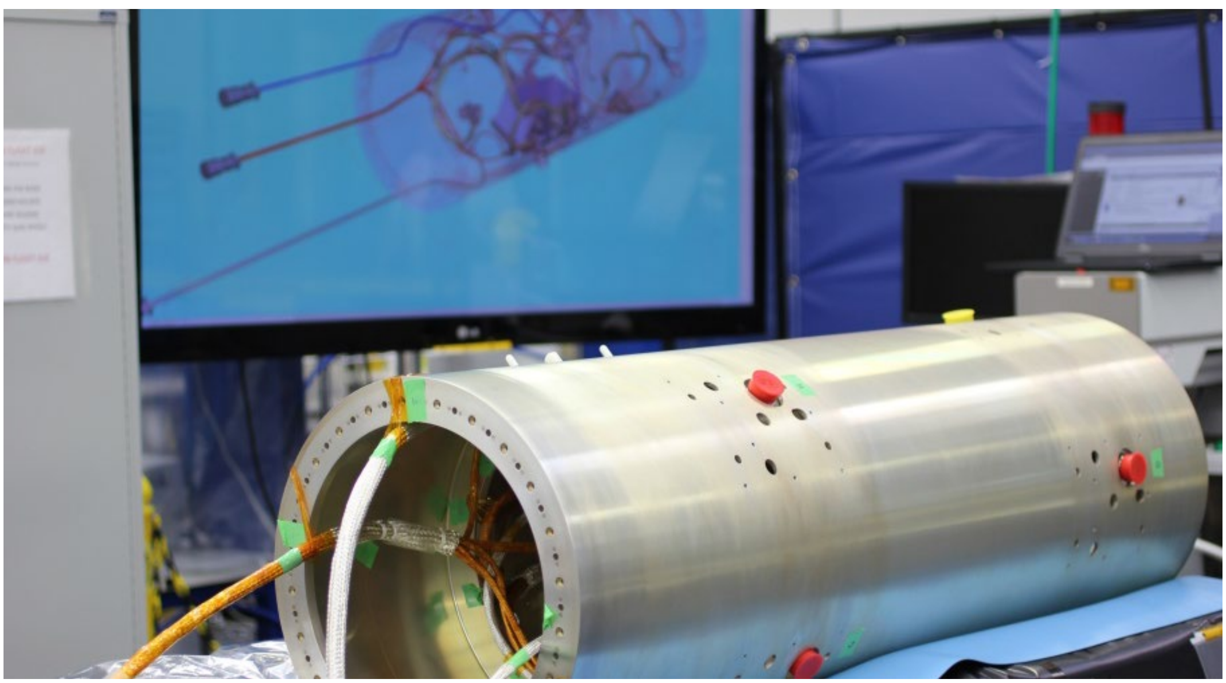
Sierra Space recently completed cable and harnessing for NASA's Cyclone Global Navigation Satellite System (CYGNSS) Deployment Module, which was source inspected and qualified in April 2016. The team completed all CYGNSS cable and harness activities on time and under budget.



Cable and harnessing for NASA's CYGNSS Program

Our Cable and Harnessing Laboratory capabilities meet NASA's upper-tier flight cable and harnessing electrical connective requirements including NASA-STD-8739.3, *Soldered Electrical Connections*, or the equivalent standard, IPC-J-STD-001E, *Requirements for Soldered Electrical and Electronic Assemblies*. Our Cable Lab also meets NASA's standard for harnessing and wiring, NASA-STD-8739.4, *Crimping, Interconnecting Cables, Harnesses, and Wiring*.

Sierra Space integration and test production personnel follow stringent guidelines, processes, and procedures to ensure flight-qualification requirements are met. The following electrical tests, including tests to chassis ground (i.e., connector body) and isolated shields, are performed prior to assembly certification. Tests include 1) end-to-end pinout continuity/resistance test; 2) insulation resistance testing in accordance with MIL-STD-202, *Electronic and Electrical Component Parts*, method 302 (250 Vac, 60 second, ≤2.5 mA); and 3) DC resistance testing in accordance with MIL-STD-202, method 303 (250 Vdc, 60 sec, ≥1 mohm). An example of our harnessing test activities for the CYGNSS electrical interface is shown below.



Cable and Harnessing Laboratory. Recently completed cable harnessing and testing for the CYGNSS module meeting strict NASA standards.

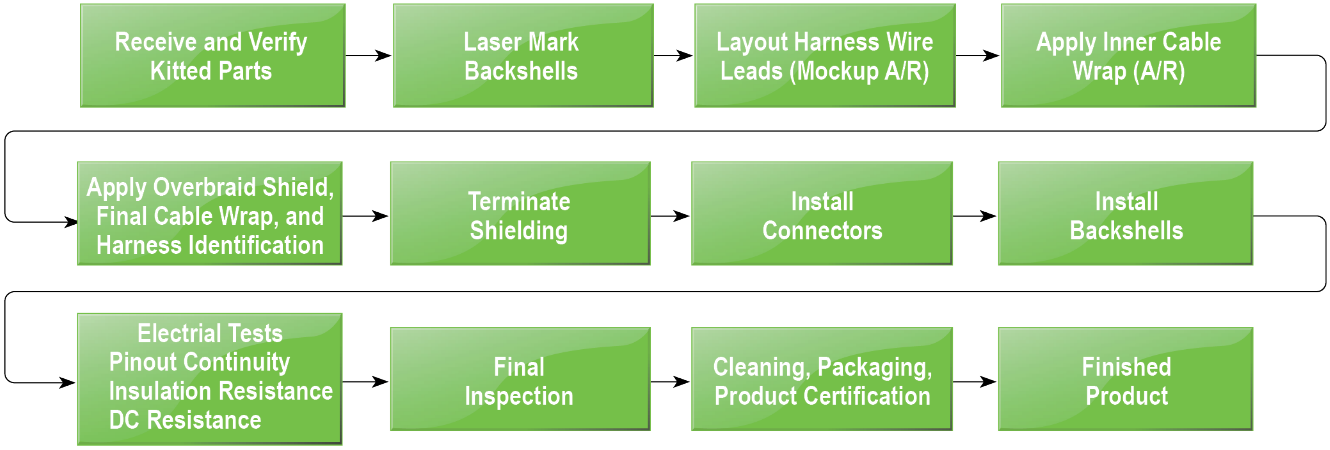
Cable and Harnessing Features	
• Fully certified in-house cable and harnessing laboratory	• Staffed with 25 plus years of experience
• Conformance with NASA and government standards	

Applications
Space flight harness assemblies for spacecraft and launch vehicles.

Heritage Programs	
• NASA Cyclone Global Navigation Satellite System (CYGNSS) Deployment Module	• ORBCOMM Generation 2 (OG2)
• Space Test Program Satellite (STPSat-5)	• NASA Commercial Crew Development (CCDev); Commercial Resupply Services 2 (CRS2) programs—Test harnessing and cables for the *Dream Chaser*® Engineering Test Article (ETA)

Reference Documents (Process Procedures)			
D20234	Kit Verification Work Instruction	P5009	Staking Procedure
P1001	Cleaning of Flight Hardware	P5013	Torque Procedures for Threaded Fasteners
P2004	Identification and Marking of Hardware	P5014	Kitting Materials and Parts
P3001	Guidelines for Dimensional Inspection of Materials, Parts, and Assemblies	P5016	Shrink Tube Installation
P3007	Criteria for Visual Inspection of Hardware	P5026	Crimping and Installation of Crimp Contacts and Terminals
P4001	Product Certification Post Kit	P8002	General Packaging
P4003	Part Certification, Pre-Kit	P10001	Contamination Control Procedure
P5008	Preparation of Two-Part Compounds	P10002	Electrostatic Discharge (ESD) Control
ISO-4020	Product Realization	ISO-4021	Control of Nonconformances

Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs. "P" and "D" document numbers reference internal Sierra Space procedures.



Typical Harness Process and Flow Procedures.

PROPULSION

Sierra Space is an established provider of chemical propulsion solutions for a wide variety of applications including launch vehicle upper stages, spacecraft maneuvering and reaction control, and missile and glide vehicle missions. Our unique VORTEX® engine designs offer improved packaging and reliability, drawing upon decades of lessons learned from manufacturing and delivery of flight hardware. Our state-of-the-art rocket propulsion test facility offers four flexible test cells that operate with a wide range of propellants and are capable of testing engines producing up to 150,000 lbf thrust with cryogenic propellants, altitude testing, and material thermal property characterization. The company's long history with development of a wide variety of engines and thrusters, current staff of technical and manufacturing expertise, and commitment to expansion of its existing product line allow it to provide optimized solutions ranging from basic propulsion components with established flight heritage to customized systems requiring an efficient and comprehensive development program to ensure reliable flight unit delivery.

Catalog data sheets for Sierra Space's propulsion technology area include:

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CATALYST BED

Hydrogen Peroxide Catalyst Bed

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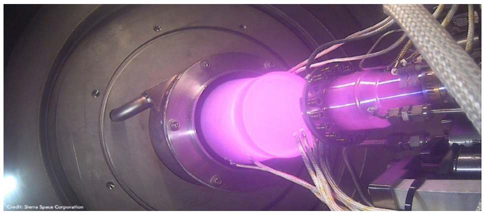
Hydrogen Peroxide Catalyst Bed

Design Description

Sierra Space developed a family of industry leading, long-life hydrogen peroxide catalyst beds for a wide variety of in-space applications including thrusters, gas generators, and ignitors. These catalyst beds can be sized for flow rates (thrust levels) anywhere from 0.005 lbm/sec (<1 lbf) to 30 lbm/sec (~5,000 lbf). Cumulative life has been demonstrated through hours of usage with thousands of thermal cycles.

The catalyst beds can be provided as a stand-alone item prepared for delivery or included in a thruster derived from our VRP series of qualified flight hardware.



Industry leading catalyst beds power the VRP110-B thruster used on the Dream Chaser® Spaceplane

Hydrogen Peroxide Catalyst Bed Features	
• Catalyst Bed compatible with high test hydrogen peroxide	• Scalable for a variety of flow rates and thrust levels
• Used with thrusters, gas generators, and ignitors	

Applications	
• Reaction control	• Deorbit
• Gas generators	• Ignitors
• Non-toxic propellant applications	

Product Specifications
Mechanical
0.005 lbm/sec - 30 lbm/sec
Can be made to suit customer diameter and length needs
Can be incorporated into fully integrated thruster assembly
Electrical
Electrical heater recommended (not required) to preheat catalyst bed for rapid start-up response
Environmental
Accommodates propellant inlet temperatures from 40 °F to 130 °F
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.

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ENGINE

Hybrid Pump-fed HTPB/MON 2,000-lbf Thrust Engine

VR35K-A Upper Stage Engine

VRM1500-H Hypergolic MMH/MON 1,500-lbf Pump-fed Engine

VRM5500-H Hypergolic Hydrazine/MON 5,500-lbf Pump-fed Engine

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Hybrid Pump-fed HTPB/MON 2,000-lbf Thrust Engine

Design Description

The modular and highly scalable hybrid engine allows multi-mission capability with a single design configuration and achieves real-time energy management by using an electric pump for fine control of oxidizer flow rate and ultimately engine output. Reliability, consistency, and low cost are achieved by careful selection of all components. The hybrid design allows for simple and inexpensive manufacturing of the solid fuel section, as a complex fuel geometry is not necessary for the hybrid architecture. Extensive development and test of multiple thrust levels and propellant combinations has been performed by the company to allow for an optimized design based on specific mission requirements.

Throttling, shutdown, and restart capability demonstration of the Sierra Space Hybrid Propulsion System allows greater crossrange capability and flexibility to support multiple missions.

VH2000 MON/HTPB Hybrid Engine Features	
• Insensitive munition	• Simple, flexible design for multiple mission types
• 6:1 throttling ratio	• Multi-restart capable
• Readily scalable architecture	

Applications	
• Missiles	• Deorbit
• Launch vehicle upper stages	• Orbit transfer

Benefits
• Safe, long-term storage, lower handling costs
• Extended cross-range capability
• Real-time energy management

Product Specifications	
Fuel	HTPB-based (Hydroxyl-terminated Polybutadiene)
Oxidizer	MON
Thrusts, Vacuum	2,000 lbf
Specific Impulse, Vacuum	300 s (Ref)
Overall System Length (with tank)	160 in
Stage Diameter	15 in
Nozzle Exit Diameter	29.75 in
Nozzle Area Ratio	Mission specific
Number Starts	10
Throttling Range	6:1
Engine Cycle	Pump-fed
Total Impulse	Mission specific
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

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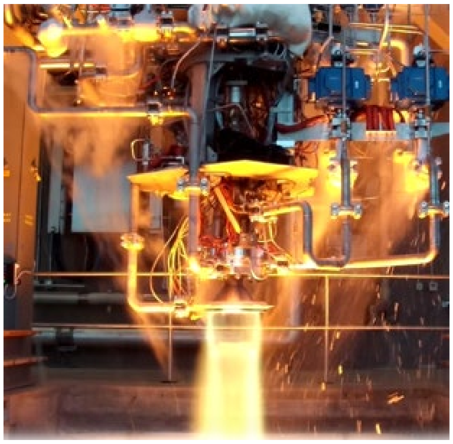
VR35K-A Upper Stage Engine

Design Description

Currently undergoing final integration and testing, the VR35K-A is a high-performance liquid oxygen/liquid hydrogen pump-fed engine capable of producing 35,000 lbf thrust at 465 seconds of vacuum-specific impulse and provides for a lower payload cost/kg and extended mission duration required for enhanced mission concept of operations (CONOPS) such as propellant depot applications. The VR35K-A features a fuel-rich staged combustion cycle designed specifically with low-cost manufacturing methods in mind. Its VORTEX thrust chamber allows it to achieve high reliability and stable combustion in a compact size and low per unit cost.



VR35K-A upper stage engine undergoing development testing at the company's rocket engine test facility in Wisconsin. Once qualification is complete, the engine will provide launch providers with greater payload capacity and the ability to reach higher orbits at a lower cost.

VR35K-A Upper Stage Engine Features	
• High-specific impulse	• Multi-restart capable
• Reusable	• Compact design

Applications	
• Launch vehicles	• Orbit transfer
• Landers	

Benefits
• Lower payload cost per kg
• High performance enables missions that cannot be performed with lower performing engines
• Compact design enables more room for tanks and payload

Product Specifications	
Fuel	Liquid hydrogen in accordance with MIL-PRF-27201, Type II
Oxidizer	Liquid oxygen in accordance with MIL-PRF-25508, Type II, Grade B
Thrusts, Vacuum	35,000 lbf
Specific Impulse, Vacuum	465 s
Nominal Mixture Ratio (O/F)	5.8
Mixture Ratio Range	5.3 - 6.4
Maximum Single Burn Duration	1,000 s
Maximum Mission Burn Duration	1,200 s
Mission Starts	5
Throttling Range	70 – 100%
Gimbal Capability	4.5 deg
Dry Mass (without TVC System)	841 lbm
Engine Length	112 in
Nozzle Exit Diameter	70 in
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

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VRM1500-H Hypergolic MMH/MON 1,500-lbf Engine

Design Description

The VRM1500-H engine currently in development is a regeneratively cooled, closed-cycle engine using MMH/MON-3 propellants to produce 1,500 lbf thrust for spacecraft orbital insertion, orbit change and deorbit, and medium size extraterrestrial landers. The engine is available in both pump or pressure-fed variants and a variety of nozzle geometries intended to optimize performance for each specific application.

VRM1500-H engine has been extensively tested to provide proven capability for a wide range of missions including space vehicle deorbit, landers, rapid orbit change and multiple missile applications.

VRM1500-H Hypergolic MMM/MON 1,500-lbf Engine Features	
• High-specific impulse	• Multiple restart capable
• Long-life operation	• Pump-fed or pressure-fed configurable
• Igniter-less design	

Applications	
• Abort	• Deorbit
• Landers	• Orbit transfer
• Launch vehicles	

Benefits
• High reliability for long duration in-space operations
• Broad thrust range enables multiple types of operational missions
• High thrust for rapid maneuvers
• Reliable start and restart

Product Specifications				
Fuel	Monomethyl Hydrazine (MMH)			
Oxidizer	Nitrogen Tetroxide (MON-3)			
Thrusts, Vacuum	1,500 lbf			
O/F Mixture Ratio	1.65			
Maximum Single Burn Duration	1,800 s			
Maximum Mission Burn Duration	150,000 (TBR) s			
Nozzle Area Ratio	35		120	
Engine Cycle	Pressure-fed	Electric pump-fed, fuel regeneratively cooled nozzle	Pressure-fed	Electric pump-fed, fuel regeneratively cooled nozzle
Specific Impulse, Vacuum	310 s		323 s	
Chamber Pressure	150 psia	500 psia	150 psia	500 psia
Engine Length	30 in	20.2 in	49.1 in	30.7 in
Nozzle Exit Diameter	15.8 in	8.6 in	28.6 in	15.7 in
Dimensions	Dependent upon nozzle geometry selected. See specifications above for examples.			
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.				

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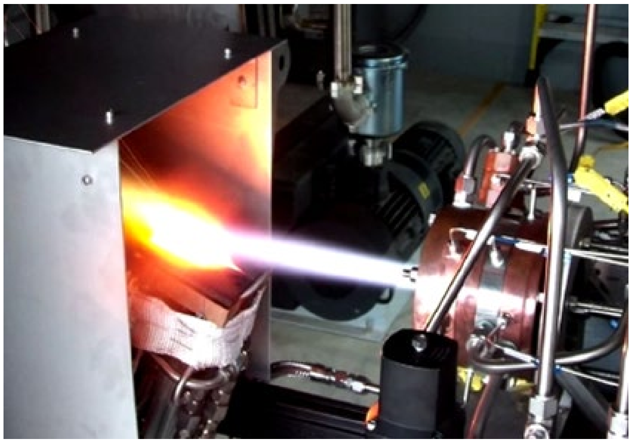
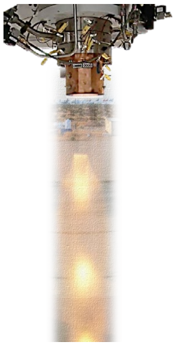
VRM5500-H Hypergolic Hydrazine/MON 5,500-lbf Pump-fed Engine

Design Description

The VRM5500-H engine is a throttable, fuel-rich staged combustion, regeneratively cooled engine using hydrazine/MON-3 propellants to produce 5,500-lbf of high performance thrust for upper-stage launch vehicles, spacecraft providing precise orbital insertion, rapid orbit change and deorbit, and medium to large extraterrestrial landers.





Material test bed using rocket jet.

VRM5500-H uses a high-performance fuel-rich staged combustion cycle making it ideal for lander spacecraft and other applications where performance and reliability are of primary concern.

VRM5500-H Hypergolic Hydrazine/MON-5 5,500-lbf Pump-fed Engine Features	
• High-specific impulse	• Multiple restart capable
• Long-life operation	• Pump-fed or pressure-fed versions available

Applications	
• Abort	• Deorbit
• Landers	• Orbit transfer
• Launch vehicles	

Benefits
• High reliability for long duration in-space operations
• Broad thrust range enables multiple types of operational missions
• High thrust for rapid maneuvers
• Support propellant depot missions throughout the cislunar volume

Product Specifications	
Fuel	Pure Anhydrous Hydrazine (N_2H_4)
Oxidizer	Nitrogen Tetroxide (MON-3)
Thrusts, Vacuum	5,500 lbf
Specific Impulse, Vacuum	340 s
O/F Mixture Ratio	1.44
Chamber Pressure	1,000 psia
Nozzle Exit Diameter	30 in
Nozzle Area Ratio	240:1
Engine Length	61 in
Number Starts	>11
Throttling Range	6:1
Dry Mass (target)	180 lbm (target T/W-30)
Engine Cycle	Fuel-Rich Staged Combustion
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

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THRUSTER

VR100-A GOX/GH_2 100-lbf Thruster

VR650-D GOX/CH_4 650-lbf Thruster

VRP110-B Non-Toxic Tri-Mode Thruster

VRPX-B Non-Toxic Low-Cost dual-Mode Thruster

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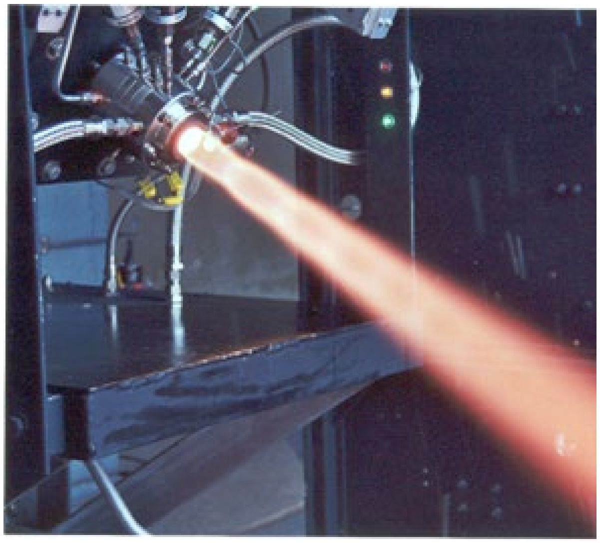
VR100-A GOX/GH2 100-lbf Thruster

Design Description

The VR100-A is a high-performance gaseous reaction control thruster designed for upper stage, O_2/H_2-based launch vehicles where carrying multiple types of propellant is cost and weight prohibitive. Sierra Space has also performed development work to investigate potential use of this thruster for future interplanetary vehicles able to refuel from *in-situ* resources for oxygen/hydrogen and oxygen/methane propellant combinations. This thruster is scalable and is also readily available in a 50-lbf thrust level variant.



VR100-A thruster designed to take advantage of residual propellant in LOX/LH2 (liquid oxygen/liquid hydrogen) upper stage rockets.

VR100-A GOX/GH2 100-lbf Thruster Features	
• High-performance	• Compact
• Long-life operation	• Available in other thrust levels, including a 50-lbf variant

Applications	
• Reaction control	• Deorbit
• Guidance	• Landers
• Orbit transfer	

Benefits
• Lowest total operational cost
• Broad thrust range enables multiple types of operational missions
• High reliability

Product Specifications	
Fuel	Gaseous Hydrogen (GH_2)
Oxidizer	Gaseous Oxygen (GOX)
Thrusts, Vacuum	100 lbf
Specific Impulse, Vacuum	420 s
O/F Mixture Ratio	3.5 ±0.5
Chamber Pressure	500 psia
Engine Area Ratio	35:1
Engine Length	7 in
Nozzle Exit Diameter	2.28 in
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

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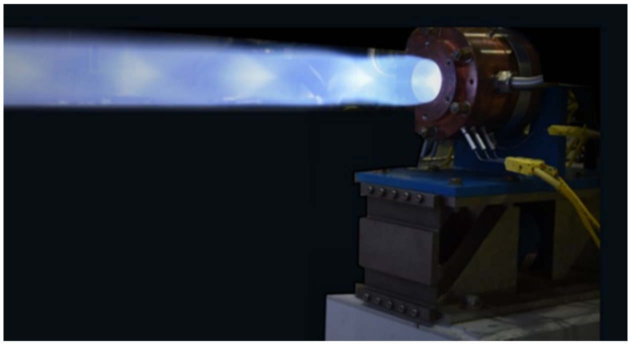
VR650-D GOX/CH_4 650-lbf Thruster

Design Description

The VR650-D is a pressure-fed thruster using gaseous oxygen and methane intended for launch vehicle Reaction Control System (RCS), in-space vehicles, high-thrust propulsion, and extraterrestrial landers. Like all of Sierra Space's in-house developed thrusters, it can be quickly modified to perform with a variety of propellant combinations and thrust levels.



VR650-D Maneuvering Engine designed for LNG/LOX (liquid natural gas/liquid oxygen) main propellants.

VR650-D GOX/CH_4 650-lbf Thruster Features	
• High-specific impulse	• Compact
• Long-life operation	• Able to make use of remaining cryogenic propellant

Applications	
• Reaction control	• Deorbit
• Guidance	• Orbit transfer
• Launch vehicles	• Landers

Benefits
• Broad thrust range enables multiple types of operational missions
• High reliability

Product Specifications	
Fuel	Methane (GCH_4)
Oxidizer	Gaseous Oxygen (GOX)
Thrusts, Vacuum	650 lbf
Specific Impulse, Vacuum	340 s
Engine Cycles	Pressure-fed
Engine Length	21.7 in
Nozzle Exit Diameter	10 in
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

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VRP110-B Non-Toxic Tri-Mode Thruster

Design Description

The VRP110-B is a tri-mode thruster used for reaction control of in-space vehicles with mission durations of 12 months or less. Initially developed for the *Dream Chaser*® spaceplane, it uses non-toxic high-test peroxide (HTP) and kerosene propellants for ease of handling and to minimize cost of ground operations. It is capable of thrust levels of 42, 65, and 113 lbf. At low thrust levels it operates in a monopropellant mode using catalyzed HTP, thus eliminating the need for a separate ignition source and increasing reliability. For high-thrust maneuvers, the thruster operates in a bi-propellant high Isp mode by also injecting kerosene into the combustion chamber. Tested for over 21 minutes of continuous operation, its VORTEX-designed engine chamber ensures that the engine runs cool and stable for long life and reliability over multiple missions. This thruster is designed to be robust enough to survive the harsh environments of many launches, in-space, and return to Earth operations without maintenance.

VRP110-B is a non-toxic, tri-mode thruster designed to deliver optimized propulsion even with large variations in space vehicle mass.

VRP110 Non-Toxic Tri-Mode Thruster Features	
• Non-toxic propellants	• Three thrust modes
• Long-life operation	• Compact
• Igniter-less start	

Applications	
• Reaction control	• Deorbit
• Guidance	• Landers
• Orbit transfer	• Human-rated spacecraft

Benefits
• Low total operational cost
• High reliability
• Broad thrust range enables multiple types of operational missions

Product Specifications

	Low Thrust Monopropellant	Medium Thrust Monopropellant	High Thrust
Propellants	High-Test Peroxide (HTP)	High-Test Peroxide (HTP)	High-Test Peroxide (HTP) + RP-1
Thrusts, Vacuum	42 lbf	65 lbf	113 lbf
Specific Impulse, Vacuum	163 s	165 s	283 s
Minimum Impulse Bit (MIB)	2 lbf s	3 lbf s	15 lbf s
Life (minimum)	45,000 cycles	7,000 cycles	4,500 cycles
Application	*Dream Chaser*®	*Dream Chaser*®	*Dream Chaser*®
Dimensions:	Length 14 in , diameter 4.25 in , mass 16 lbm		

Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.

VRPX-B Non-Toxic Low-Cost Dual-Mode Thruster

Design Description

The VRPX-B is a low-cost variant of the VRP110-B. It uses a nontoxic propellant combination that can either run in a monopropellant mode with catalyzed high-test peroxide (HTP) or in a higher thrust, higher performance bi-propellant mode with kerosene injection. It is designed for lowest operational cost while maintaining high performance and low mass while offering ease of handling with its non-toxic propellant.

VRPX-B is a lower cost version of our Dream Chaser® Reaction Control System (RCS) thruster for applications having less stringent requirements.

VRPX-B Non-Toxic Low-Cost Dual-Mode Thruster Features	
• Non-toxic propellants	• Compact
• Igniter-less restart	• Simple operation

Applications	
• Reaction control	• Compact
• Guidance	• Simple operation

Benefits
• Lowest total operational cost
• Dual mode thrust
• High reliability

Product Specifications

	Medium Thrust	High Thrust
Propellants	High-Test Peroxide (HTP)	High-Test Peroxide (HTP) + RP-1
Thrust, Vacuum	65 lbf	113 lbf
Specific Impulse, Vacuum	165 s	283 s
Minimum Impulse Bit (MIB)	3 lbf s	15 lbf s
Life (minimum)	7,000 cycles	4,500 cycles
Maximum Qualified Single Burn Duration	No known limit, 1,320 s (22 min)	1,320 s (22 min)
Weight	15 lbm	
Length	14 in	
Diameter	4.25 in	
Status	Qualification complete July 2023	
Available	2023	

Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.

SPACECRAFT

Sierra Space is a commercial space company with a legacy of nearly 30 years of experience designing, manufacturing and successfully delivering space systems, components, and spacecraft on-orbit. The Orbital Missions and Services (OMS) business area has designed, produced, and launched 23 space vehicles and supported over 400 successful space and interplanetary missions with our subsystems and components. Building on this expertise we are developing a next generation product line of small, high performance, affordable satellites designed from the ground up for on-orbit servicing missions. Using commercial business models, Sierra Space is delivering capabilities faster, with a set of on-orbit commercial services including Inspection, Deorbit, Refueling, Tug/Transfer, Repair, Augmentation, Return and Connectivity. Our goal is to deliver orbital services to commercial, DOD and national security organizations, expanding production capacity to meet the needs of constellation programs. OMS offers turnkey on-orbit services and satellite solutions ready to integrate customer payloads. The SN series of satellites come in a wide variety of form factors with high power, high thrust, and high reliability flight heritage.

Catalog data sheets for our SN series of satellites offer a range of spacecraft platforms which include:

Io Half ESPA Nanosat Spacecraft

HORIZON Multi-Manifest Microsat

VELOSITY ESPA Grande Class Microsat Spacecraft

Titan Propulsed ESPA

Shooting Star

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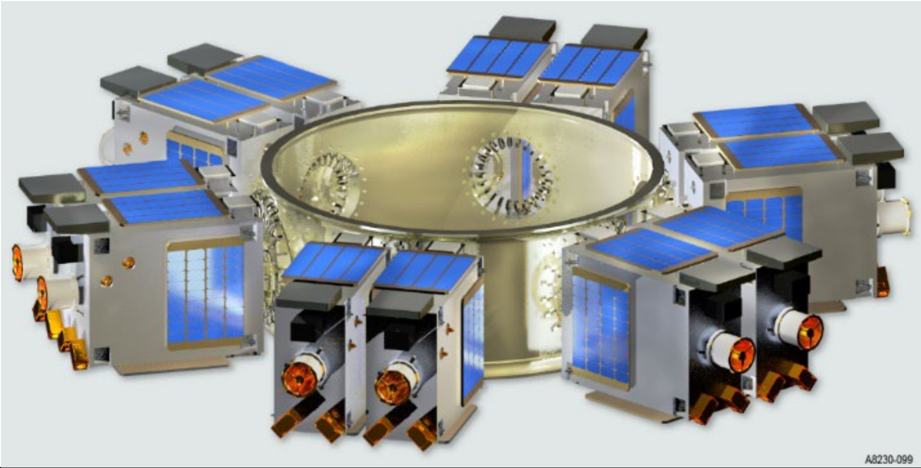
Io Half ESPA Nanosat Spacecraft

Design Description

Sierra Space provides purpose-built mission solutions through proven on-orbit performance of high-rate production commodity spacecraft, payloads, and data processing. We offer our customers a highly capable, half ESPA microsat-class satellite that is based on a flight-proven and scalable spacecraft design, tailorable to provide capabilities for a variety of missions. The Io bus provides geosynchronous orbit capability with an affordable platform and payloads up to 30 kg.

Io Half ESPA Nanosat Spacecraft

Io Half ESPA Nanosat Spacecraft Features	
• Proven avionics and power systems	• Designed for 1 to 3 years in geosynchronous Earth orbit (GEO)
• 6-DOF high delta-V available	

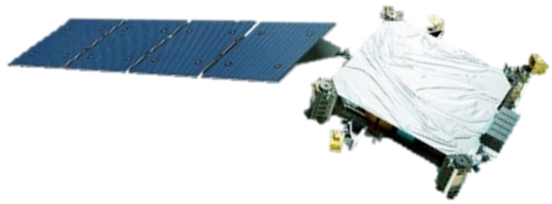


Io Half ESPA class microsat; two within standard ESPA envelope

Product Specifications		
Variant	**LEO**	**GEO**
Dry Bus Mass	50 kg	50 kg
Payload Mass	20 kg	20 kg
Payload Envelope	27 cm x 27 cm x 9.7 cm	27 cm x 27 cm x 9.7 cm
Payload Power	40 W	40 W
Nominal Pointing Accuracy	0.02 degs	0.02
Delta-V	270 m/s	140 m/s
Life	3 years	3
Configuration	½ ESPA	½ ESPA
Note: This data is for information only and subject to change. Contact Sierra Space for design data.		

HORIZON Multi-Manifest Microsat

Design Description


HORIZON Multi-Manifest Microsat

Sierra Space provides purpose-built mission solutions through proven on-orbit performance of high-rate production commodity spacecraft, payloads, and data processing. The HORIZON commodity buses are the baseline for purpose-built LEO through GEO constellations using a modular architecture. This product is ideal for flying smaller payloads, high quantity constellations, and hosting technical demonstration missions. The HORIZON platform has been designed from the ground up to enable high throughput production rate aligned with the needs of next generation constellation services.

Additional capability can be added to the bus depending on mission applications and program requirements. Available launch vehicle volumes provide options for a variety of configurations that allow externally mounted sensors, antennas, and components. Power systems and key components are module and scalable to enable cost optimization in-line with the mission requirements. HORIZON buses are in active production in support of the SDA's Tracking Layer Tranche 2 program among other programs with a focus on highly manufacturable, scalable, and rapid development programs.

HORIZON Multi-Manifest Microsat Features	
• ESPA compatible available upon request	• Robust multi-tiered fault protection system
• Adaptable to all LEO orbits/inclinations	• Ion propulsion capability
• Reconfigurable payload accommodation interfaces	• Scalable payload power systems

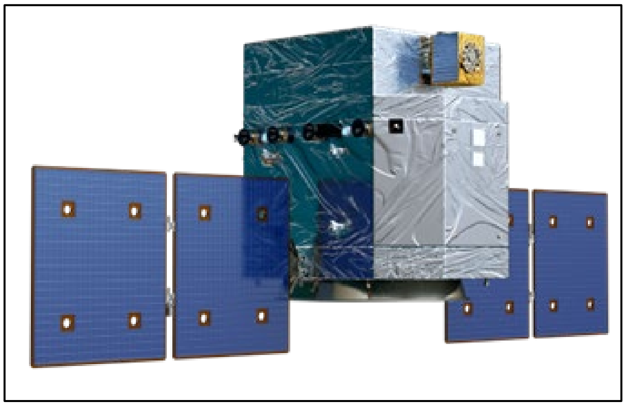
Heritage Programs	
• SDA Tracking Layer Tranche 2	

Product Specifications	
Dry Bus Mass	400 kg
Payload Mass	65-250 kg
Payload Envelope	100+ cm x 100+ cm x 20+ cm
Payload Power	1500+ W OAP
Nominal Pointing Accuracy	0.001 deg
Delta-V	400+ m/s
Life	3-7 years
Configuration	Multi-Manifest Stack
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

VELOCITY ESPA Grande Class Microsat Spacecraft

Design Description

Sierra Space provides purpose-built mission solutions through proven on-orbit performance of high-rate production commodity spacecraft, payloads, and data processing. We offer our customers a highly capable, ESPA Grande microsat-class satellite that is flight-proven and tailorable to provide capabilities for a variety of missions. The VELOCITY ESPA Grande class commodity buses are the baseline for purpose-built LEO/GEO spacecraft using modular mission payloads. The VELOCITY design-for-manufacturing enables large-scale productions and increased flexibility for missions with payloads up to 150 kg.



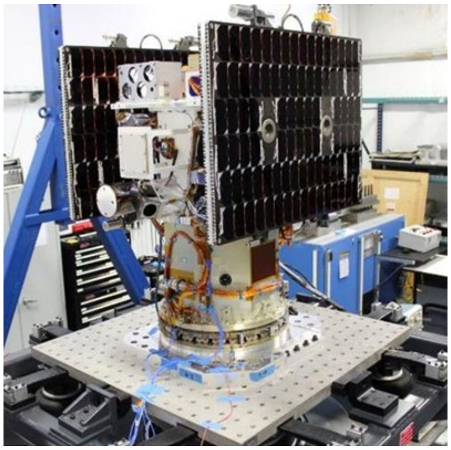
The VELOCITY platform is compatible with complex and challenging missions in LEO, MEO, and GEO with scalable dV and PL SWaP accommodations.

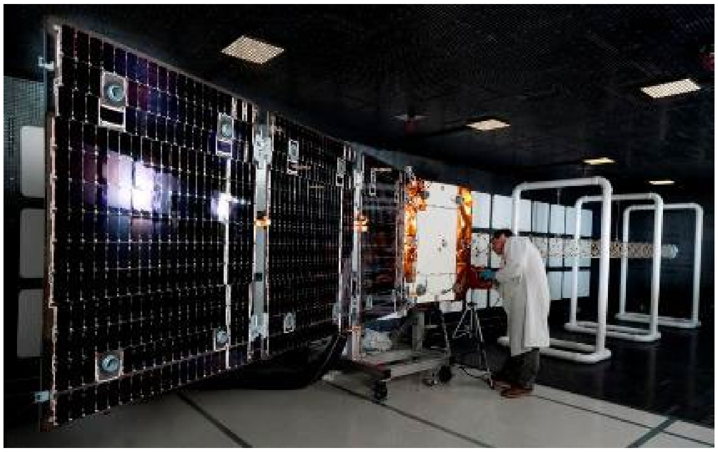
Sierra Space is one of a few companies to successfully design, mass produce, and launch a large constellation of LEO small satellites. Sierra Space produced 18 spacecraft for the ORBCOMM Generation 2 (OG2) communication constellation under a firm fixed-price contract. We produced and integrated the payload at our manufacturing facility in Louisville, CO. At full-scale production rates we were providing three finished buses per month. The space vehicles were designed and tested for a 5-year mission life using commercial industry best practices for mission assurance on Class B/C missions. With more than 7 years of on-orbit performance, this communications constellation is exceeding requirements for this mission.

The OG2 variant provides worldwide machine-to-machine (M2M) communications for commercial customers as well as Automatic Identification System (AIS) data for the U.S. Coast Guard and other users. Sierra Space is the prime contractor for the OG2 constellation, providing the VELOCITY spacecraft bus platform and advanced software-defined radio communication payload.

This platform was also the basis for the DOD Space Test Program's (STP) Space Test Program Satellite-5 (STPSat-5) for Space and Missile Systems Center/Advanced Systems and Development Directorate (SMC/AD). STPSat-5 was designed as a rideshare system for LEO and carried five Government-provided (GP) payloads. Sierra Space was prime contractor for the STPSat-5 satellite that was based on the VELOCITY modular, reconfigurable ESPA-class bus. Sierra Space designed and built the spacecraft bus, integrated the GP payloads, and performed full space vehicle testing and launch/operations support in our Louisville, CO facilities. Spacecraft design upgrades since STPSat-5 include large improvements in processing and propulsion capabilities. Our new high-speed processor offers a significant advancement in payload data throughput.

VELOCITY ESPA Grande Class Microsat Spacecraft Features	
• 3-5-year mission life with end-of-mission (EOM) disposal	• Standard pointing is better than 10 arcsec knowledge, 3σ
• Common bus provides the building blocks for multiple missions and growing adversarial threat solutions	• Flexible payload accommodation capability
• Support payloads up to 150 kg with optional high-power versions for peak power needs	• 3-axis reaction wheel control
• Configurable communications packages, Optical Inter-Satellite Links (OISL) in/cross plane, uplink/downlink, and Link 16 supporting secure mesh networking	• Optional proximity operations sensor suite and high thrust divert thrusters





STPSat-5 (Left) and ORBCOMM Generation 2 Satellite (Right) showing the scalability of the same core architecture

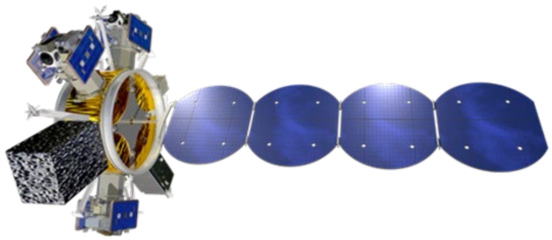
Applications	
• Machine-to-machine communications	• Space weather monitoring
• Special purpose communications	• Technology demonstration/rapid prototyping

Heritage Programs	
• ORBCOMM Generation 2 (OG2)	

Product Specifications	
Dry Bus Mass	115-700 kg
Payload Mass	150-500 kg
Payload External Envelope	>69 cm x >97 cm x >71 cm
Payload Power	400-1500 W OAP
Nominal Pointing Accuracy	0.001 deg
Delta-V	175-800+ m/s
Life	3-7 years in MEO
Configuration	ESPA Grande through Primary
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

Titan Propulsed ESPA

Design Description


Sierra Space Titan

Sierra Space provides purpose-built mission solutions through proven on-orbit performance of high-rate production commodity spacecraft, payloads, and data processing. We offer our customers a highly capable, long duration propulsive ESPA (LDPE) free flyer class satellite that is tailorable to provide capabilities for a variety of missions. The Titan LDPE class platform can host six rideshare payloads per ring in either medium Earth orbit (MEO) or geostationary orbits (GEO). The Titan spacecraft features support refueling operations, rideshare missions, geostationary transfer orbit (GTO) to GEO transfer, multi-rendezvous and cislunar applications.

The Air Force Research Laboratory (AFRL) Space Vehicles Directorate's Demonstration and Science Experiments (DSX) was hosted on a Sierra Space LDPE Titan class bus and launched on a SpaceX Falcon Heavy rocket in June 2019 from Cape Canaveral Space Force Station to MEO. The system, which was designed for 1-year on-orbit life, performed successfully for 2 years in the MEO radiation belts, and was decommissioned in July 2021. The DSX spacecraft had a primary mission of exploring the complex relationship between very low frequency radio waves and the Earth's radiation belts found within MEO. The ESPA-based spacecraft has a pair of 80-meter antenna booms (about 262 feet) successfully deployed making it the largest unmanned structure ever in space.

Results of the DSX experiments enhanced the Department of Defense's (DOD) capability to field space systems that provide persistent global space surveillance and reconnaissance, high-speed satellite-based communication, lower-cost global positioning satellite (GPS) navigation and protection from space weather and environmental effects on a responsive satellite platform. The DSX team performed more than 1,300 experiments, significantly contributing to the understanding of how to build spacecraft capable of reliably operating in harsh environments of MEO and GEO for DOD and other important national security space missions.

Titan Propulsed ESPA Features	
• Integration standardization support the maximum flexibility for late manifest and port allocation decisions	• Expand core capabilities provide improved propulsion delta-V and provide a new re-docking capability
• Advance rideshare capabilities on future LDPE flights	• Increased redundancy can optionally extend life beyond 5-year requirements
• Simplify payload integration, extend mission life, and add additional integrated payload capability that allow new LDPE missions such as on-orbit test range activities, while preserving the baseline six-port rideshare mission	• Design includes command, telemetry, and power services to all six payload ports

Heritage Programs	
• TacSat-2	

Product Specifications	
Dry Bus Mass	900 kg (including ESPA Ring)
Payload Mass	2,100 kg (700/port)
Payload External Envelope	6 ESPA-hosted/deployed payloads
Payload Power	800+ W OAP
Nominal Pointing Accuracy	0.001 deg
Delta-V	>500 m/s
Life	5+ years
Configuration	Free Flying ESPA
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

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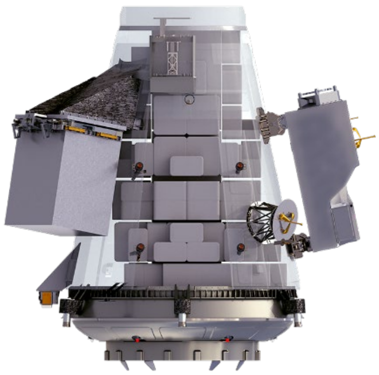
Shooting Star

Design Description

The "Shooting Star" Free Flyer platform is based on a Sierra Space Cargo Module (CM). The CM is attached via a light-band interface on the back of a crewed or Uncrewed Dream Chaser (UDC) or as a dedicated launch payload. External mounting interfaces allow easy attachment and modularity of payloads while the large internal volume can be used for fuel, cargo, or other large payloads such as large optics.



Free Flyer.

Shooting Star Features	
• External and internal payloads	• >6 kW of spacecraft power
• Docking and berthing compatible	• *Dream Chaser®* Cargo Module or dedicated mission

Applications	
• Fuel depot	• On-orbit servicing hub
• Large, hosted payloads	• Secondary missions after cargo delivery

Product Specifications	
Dry Bus Mass	3,500 kg
Payload Mass	2,000 kg
Payload External Envelope	13.6 m^3
Payload Power	>1,700 W
Nominal Pointing Accuracy	0.01 deg
Delta-V	400 m/s
Life	3+ years
Configuration	Dedicated Launch or Rideshare
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.	

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SPACECRAFT SERVICING TECHNOLOGIES

Satellite servicing technologies are truly crosscutting, as they offer a suite of capabilities applicable to such diverse missions as assembling an observatory or habitat in space, catching up with an asteroid, or fixing a spacecraft or ground station on a trip to Mars. They are also game changing, as they allow developing missions a considerably larger trade space to make cost-efficient decisions on redundancy, fault tolerance, and mass allocation.

Sierra Space has developed several products and capabilities that directly support spacecraft servicing applications. Catalog data sheets for our Spacecraft Servicing Technologies product area include:

Advanced Manipulator Technology for Spacecraft Servicing

Orbital Express Capture System

Structural, Power, and Data Port (SPDP)

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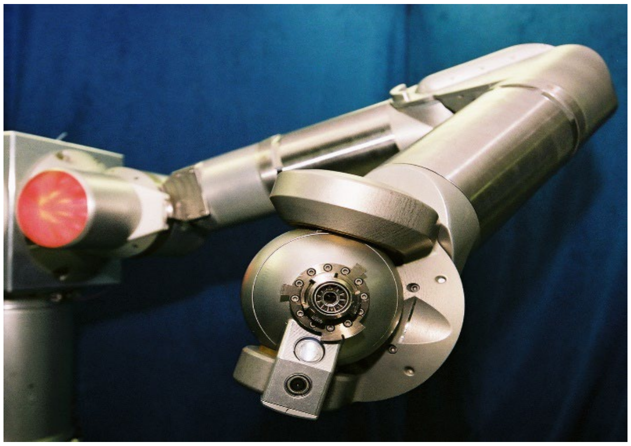
Advanced Manipulator Technology for Spacecraft Servicing

Design Description

Sierra Space has developed an advanced design approach for robotic manipulators, primarily for satellite servicing tasks. The resulting devices are strong, versatile, reliable, straightforward to analyze, and easy to control.

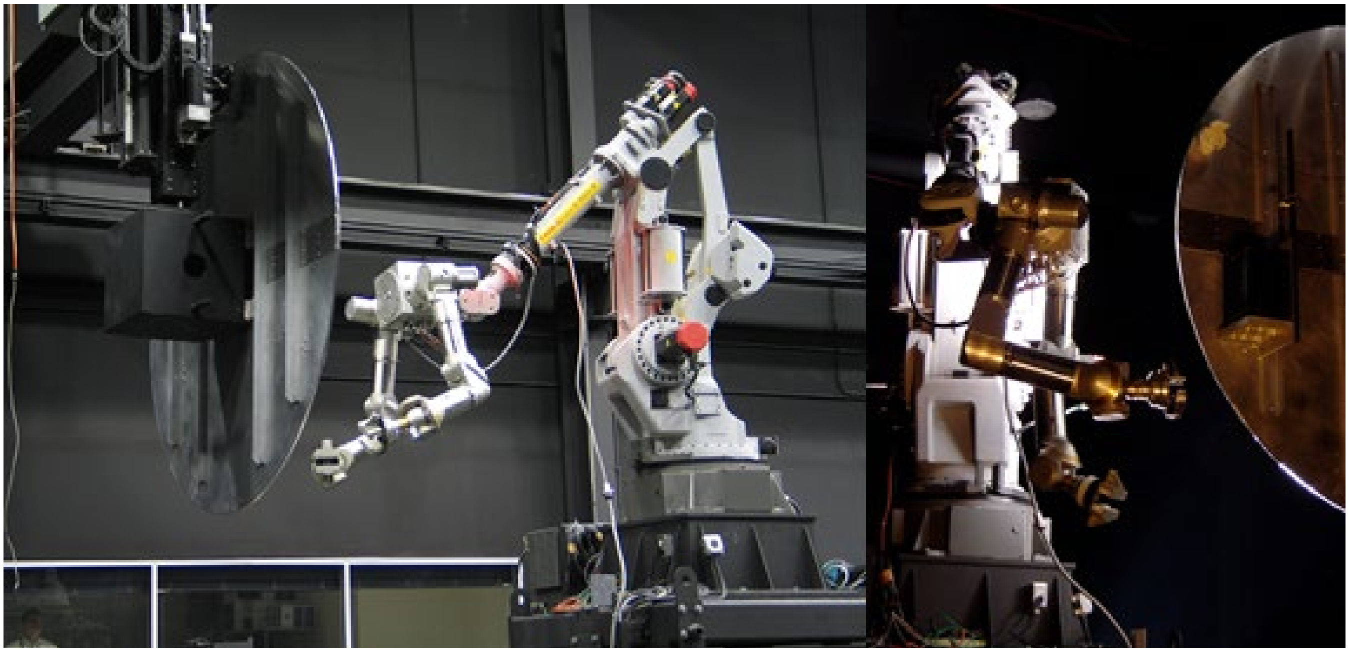
Key elements of our design are simplified kinematics, optimal redundancy, high-wrist dexterity, active compliance control, simple user interfaces, a compact and rigid tool exchange mechanism, and modularity. We have demonstrated prototype integrated manipulator modules to technology readiness level (TRL) 5 in thermal vacuum and vibration tests. Suites with multiple full arms have been exercised extensively in 1-g and neutral buoyancy simulations of spacecraft servicing operations.



Ranger Mk. 2 Manipulators at the University of Maryland demonstrate advanced technology. Credit: University of Maryland

Our expertise in space mechanism design, efficient actuator packaging, auxiliary sensors, and alignment aids support the capability to construct a complete robotic servicing system with unprecedented utility.

Advanced Manipulator Technology Features	
• Simplified kinematics	• Optimal redundancy
• High-wrist dexterity	• Active compliance control
• Simple user interfaces	• Compact and rigid tool exchange mechanism
• Modularity	



Two Ranger arms simulating satellite-servicing tasks at the Naval Research Lab. Credit: University of Maryland

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Orbital Express Capture System

Design Description

Autonomous docking operations are a critical aspect of unmanned satellite servicing missions. Tender spacecraft must be able to approach the client spacecraft, maneuver into position, and then attach to facilitate the transfer of fuel, power, and replacement parts.

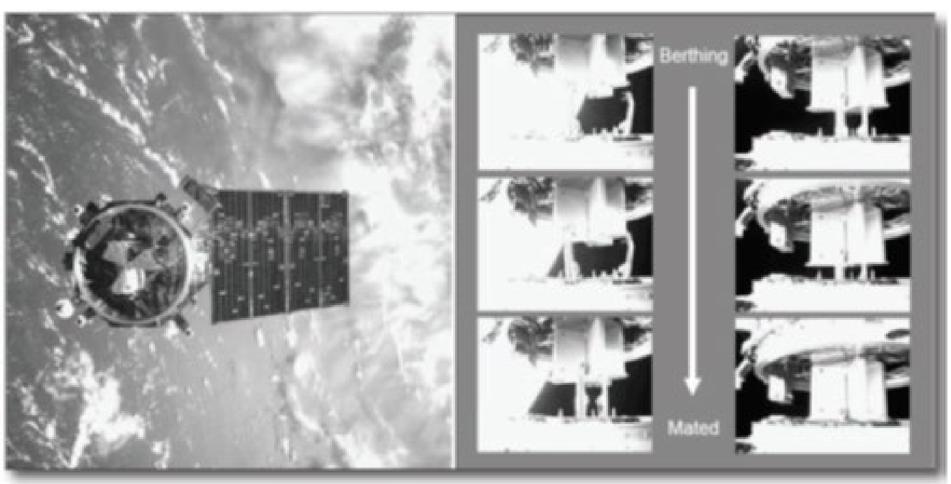
The philosophical approach to the docking system design is linked to the overall servicing mission. The docking system functionality must be compatible with the maneuverability capabilities of both spacecraft involved.

The Sierra Space Capture System was flown and operated on the Orbital Express mission. The Capture System performed as intended and has contributed to demonstrating the feasibility of autonomous docking and undocking of independent spacecraft. The Orbital Express program was intended to develop a cost-effective standard architecture for autonomous servicing. Crucial to this architecture is the effective means by which to capture, provide secure mechanical connection, and make fluid and electrical connections between two spacecraft.

The Capture System consists of an active side and a passive side. The active side contains the grappling arms and drive system; this side would normally be part of the supply spacecraft. The passive side provides capture features and a sensor to indicate proper engagement of the grappling arms; this side would normally be a part of the client spacecraft.

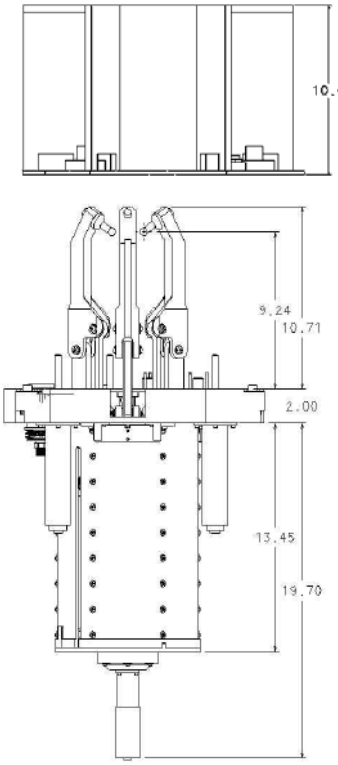
Orbital Express Docking Mechanism (image courtesy of the National Air and Space Museum – Smithsonian Institution).

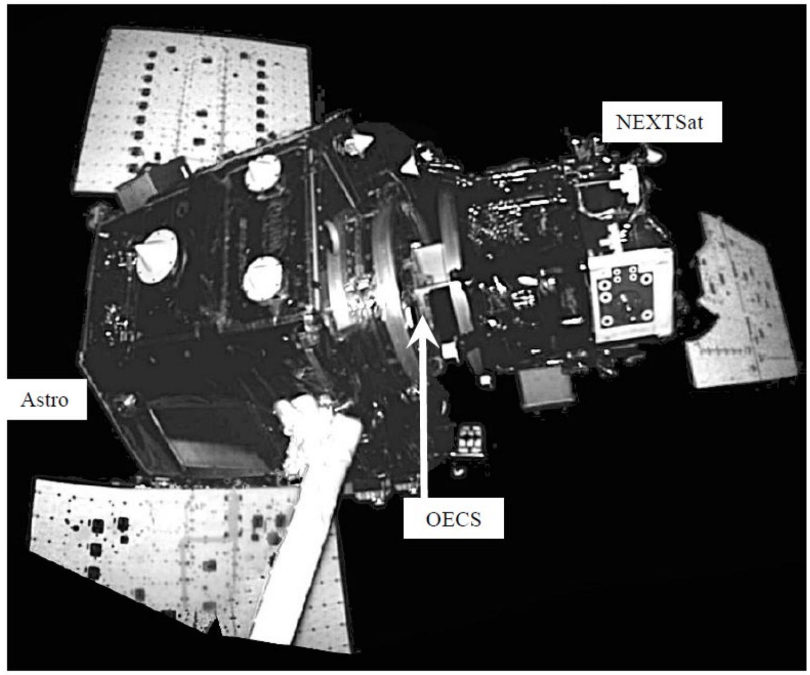
Orbital Express Capture System Features	
• Simple design with minimized part count	• Provides interface area for fluid and electrical couplings
• Single, motion force for all operations (uses single micro-stepped stepper motor with redundant windings)	• Accommodates design scalability
• Accommodates a universal interface	• Physical mating alignment features
• Proximity switch provides indication of capture	• Electrical control unit for motor with MIL-STD-1553 serial data interface included as part of the system



Shown to the left: NEXTSat is 14 m away during a departure. Shown to the right: Progressive side view configurations of the "Berthing" to "Mated" states.
Images courtesy of NASA.

Dimensions





Orbital Express Astro and NEXTSat spacecraft shown mated by Orbital Express Capture System (OECS) during flight. Image courtesy of NASA.

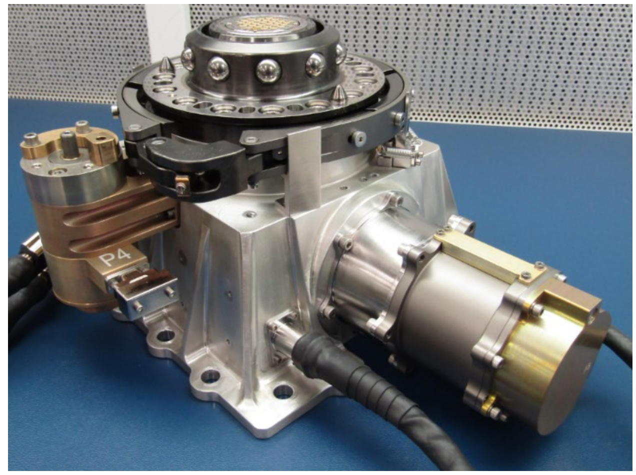
Note: All dimensions above are in inches.

Product Specifications	Active		Passive	
	U.S.	**SI**	**US**	**SI**
Mechanical				
Envelope dimensions	33 in H x Ø18 in	838 mm x Ø457 mm	10 in H x Ø18 in	254 mm x Ø457 mm
Mass (including cables)	<50 lb	<22.7 kg	<25 lb	<11.3 kg
Axial Capture Distance	6 in			
Angular Capture Misalignment Tolerance	Pitch/Yaw = ±5 deg, Roll = ±5 deg			
Lateral Misalignment Tolerance	±2 in			
Linear Contact Velocity Tolerance	3 cm/sec			
Capture Time	<10 seconds			
Capture and Latch Time	<300 seconds			
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.				

Structural, Power, and Data Port (SPDP)

Design Description

Designed as a tool holder for a robotic servicing satellite, the SPDP consists of an active unit and passive unit that can be mated and locked together or unlocked and demated. The active unit consists of 1) a launch-restraint system; 2) electrical pass-through cables; 3) a payload locking mechanism; and 4) a stepper gear motor to actuate the mechanism. The passive unit itself has no moving parts and is integrated structurally and electrically to the payload. The active unit contains onboard telemetry to indicate a ready-to-lock state, locked vs. unlocked, and excessive locking force fault.



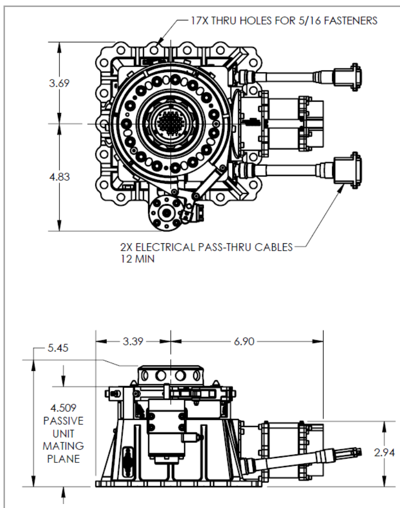
Structural, Power and Data Port.

The SPDP can support an 8.25 kg[1] payload through the launch environment with a first mode frequency above 200 Hz. The SPDP is designed to capture and release the payload repeatedly, up to 400 times on-orbit, and up to 1,600 times in ground testing. The port also supports the transfer of more than 2 dozen electrical power and data connections across the locked active-passive interface.

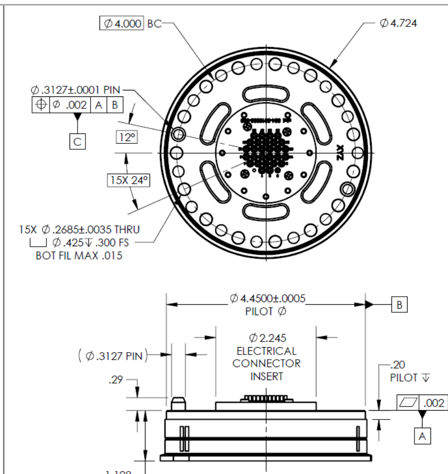
Note: The SPDP is export controlled under Export Administration Regulations (EAR). Export to foreign entities may require U.S. Government authorization. Approved for Public Release, Distribution Unlimited.

Structural, Power and Data Port Features	
• Defined capture envelope	• Driven by heritage stepper gear motor
• Mating and locking telemetry feedback	• Designed for GEO radiation and low electromagnetic interference (EMI)
• Active (spacecraft-side) and passive (tool-side) components	• Physical mating alignment features
• Lock fault protection	• Visual alignment and state indicators

Dimensions



Active Unit



Passive Unit

[1] *8.25 kg payload with a CG offset of 125.4 mm (4.9 in) from the passive unit to payload-mating interface.*

Note: All dimensions above are in inches.

Applications	
• Deployment mechanisms	• Satellite docking
• Robotics applications	• Launch restraint
• On-orbit upgrade	

Heritage Programs (Motor only)	
• Geosynchronous Space Situational Awareness Program (GSSAP)	• Space-Based Infrared System (SBIRS)

Product Specifications	Active		Passive	
	U.S.	**SI**	**US**	**SI**
Mechanical				
Envelope Dimensions	10.3 in x 8.6 in x 5.5 in	261 mm x 217 mm x 139 mm	1.42 in x Ø4.8 in	36.1 mm x Ø121 mm
Mass (including cables)	13.56 lb	6.15 kg	1.27 lb	0.575 kg
Capture Envelope/Load Capability	Available Upon Request			
Time to Lock/Unlock	15 seconds Lock/15 seconds Unlock			
Life	1,600 cycles in air, 400 cycles in vacuum: 8 years in GEO			
Electrical				
Gearmotor Type	2-phase, 1.8-deg stepper + 42.8:1 reduction gearbox			
Voltage	29.5 to 33.0 Vdc			
Resistance	34.5 Ω			
Power, Nominal	15 W			
Sensor, Temperature	Platinum RTD 2,000 Ω @ 0 °C			
Pass-through Harness	29 connections, including 6 power pairs, 4 digital signal pairs, 3 analog signal pairs			
Thermal				
Operating Temperatures	-13 °F to + 140 °F	-25 °C to +60 °C	-76 °F to +185 °F	-60 °C to +85 °C
Nonoperating Temperatures	-58 °F to +158 °F	-50 °C to +70 °C	-76 °F to +185 °F	-60 °C to +85 °C
Note: These specifications can be modified to meet the customer's requirements. Contact Sierra Space regarding design options to fit specific customer needs.				

ACRONYM LIST

Acronyms	
Acronym/Symbol	**Definition**
%	Percent
~	Approximately
°C	Degrees Celsius
°F	Degrees Fahrenheit
µ	micro sign or 'Mu' symbol (metric prefix: 0.000001, one millionth)
µa	Microamperes
σ	Sigma
Ω	Ohms
328SSG	328 Support Services GmbH
3D	Three Dimensional
A	Amp/Amperage/Amperes (An SI unit of electric current)
ABEC	Annular Bearing Engineering Committee (ABEC scale is an industry accepted standard for the tolerances of a ball bearing)
ABS	Asia Broadcast Satellite
ACBM	Active Common Berthing Mechanism
ACE	Atmospheric Chemistry Experiment
ACFM	Actual Cubic Feet per Minute
ADC	Analog-to-Digital Converter
AEHF	Advanced Extremely High Frequency
AFRL	Air Force Research Laboratory
AI&T	Assembly, Integration, and Test
AIRS	Atmospheric Infrared Sounder (AIRS) Earth Shield
AIS	Automatic Identification System
AL	Alabama
Al	Aluminum
AM0	Air Mass Zero
AMC	Americom Communications Satellite
APM	Antenna Pointing Mechanism
ARS	Air Revitalization System
ATCS	Active Thermal Control System
atm	Atmosphere
AU	Astronomical Unit (Unit of length approximately equal to the mean distance between the Earth and Sun)
AWG	American Wire Gauge (A standardized wire gauge system used for diameters of round, solid, nonferrous, electrically conducting wire)
BCD	Bolt Circle Diameter
BEAM	Bigelow Expandable Activity Module
BLDC	Brushless DC (direct current)
BPMS	Brushless Permanent Magnet Synchronous
BSAT	Broadcasting Satellite System
BTU	British Thermal Unit
CA	California
CAD	Computer-aided Design
CAN	Controller Area Network
CAPS	Cassini Plasma Spectrometer

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Acronyms	
Acronym/Symbol	**Definition**
CASSIOPE	Cascade SmallSat and Ionospheric Polar Explorer
CBOD	Clamp Band Opening Devices
CCDev	Commercial Crew Development
CCW	Counterclockwise
CEO	Chief Executive Officer
CFA	Computational Fluid Analysis
CFA	Cabin Fan Assembly
CFM	Cubic Feet per Meter
CFR	Code of Federal Regulations
CG	Center of Gravity
CH_4	Methane
CM	Cargo Module
cm	Centimeter
cm^2	Square Centimeter
cm^3	Cubic Centimeter
CNC	Computer Numeric Controlled
CNOFS	Communications/Navigation Outage Forecasting System
CO	Colorado
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_3	Carbon Trioxide
CoNNeCT	Communications, Navigation, and Networking re-Configurable Testbed
CONOPS	Concept of Operations
COPV	Composite Overwrapped Pressure Vessels
COTS	Commercial-Off-the-Shelf
CP3	Cold Plate
CRES	Corrosion-Resistant Steel
CrIS	Cross-track Infrared Sounder
CRS	Cargo Resupply Service
CRS2	Commercial Resupply Services 2
CW	Clockwise
CYGNSS	Cyclone Global Navigation Satellite System
DANDE	Drag and Atmospheric Neutral Density Explorer
DB	Duplex Bearings
dB	Decibel
DC	direct current
deg	Degree (angle)
Delta V	Change in Velocity
dia	Diameter
DMAU	Deployment Module Avionics Unit
DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense
DOF	Degrees of Freedom
dP	Delta Pressure

Acronyms	
Acronym/Symbol	**Definition**
DSCOVR	Deep Space Climate Observatory
DSPSE	Deep Space Program Science Experiment
DSX	Demonstration and Science Experiment
EAR	Export Administration Regulations
EASA	European Aviation Safety Agency
ECLSS	Environmental Control and Life Support System
ECS	Environmental Control System
ECU	Electronic Control Unit
EDU	Engineering Development Unit
EEE	Electrical, Electronic, and Electromechanical
EELV	Evolved Expendable Launch Vehicle
EH (1)	External Heater (in reference to high output paraffin (HOP) actuator products)
EH (2)	Enhanced Hybrid (in reference to gimbals/actuators)
EMC/EMI	Electromagnetic Compatibility/Electromagnetic Interference
eMotor	Electronic Motor
EO	Earth Observation
EOM	End-of-Mission
EOS	Earth Observing System
EPIC	Earth Polychromatic Imaging Camera
EPS	Electrical Power Systems
ESD	Electrostatic Discharge
ESPA	EELV Secondary Payload Adapter
ETA	Engineering Test Article
EVA	Extra Vehicular Activity
EW	Electronic Warfare
F	Fahrenheit (temperature)
FAA	Federal Aviation Administration
FASSN	Fast-Acting Shockless Separation Nut
FASTSAT	Fast, Affordable, Science and Technology Satellite
FCS	Flight Control Systems
FL	Florida
FORMOSAT-2	Formerly known as ROCSat-2 (Republic of China Satellite-2) is a National Space Program (NSPO) of Taiwan Earth imaging satellite
FPGA	Field Programmable Gate Array
FSO	Full Scale Output
ft	Foot or Feet
ft/s	Feet per Second
ft^3	Cubic Feet
g (1)	gram
G (2)	Gauge
g (3)	Standard Acceleration of Gravity (acceleration of Earth's gravity is written as gs for gravity-force acceleration)
G (4)	Gravitational constant
G (5)	giga (metric prefix: 1000000000)
GaAs	Gallium Arsenide

Acronyms	
Acronym/Symbol	**Definition**
GALEX	Galaxy Evolution Explorer
GCH_4	Gaseous Methane
GCU	Gimbal Control Unit
GDA	Gas Delivery Assembly
GEO	Geosynchronous Earth Orbit
GEVS	General Environmental Verification Specification
GH_2	Gaseous Hydrogen
GHe	Gaseous Helium
GHz	Giga Hertz
GmbH	Abbreviation of German phrase “Gesellschaft mit beschräkter Haftung,” which means “company with limited liability”
GOES-R	Geostationary Operational Environmental Satellite R-Series
GOX	Gaseous Oxygen
GP	Government-provided
GPM	Global Precipitation Measurement
GPS	Global Positioning Satellite
Grms	Gravity Root-Mean-Square (acceleration)
GSFC	Goddard Space Flight Center
GSSAP	Geosynchronous Space Situational Awareness Program
GTCR	Gaseous Trace Contaminant Removal
GTO	Geosynchronous/Geostationary Transfer Orbit
H	Height
H_2	Hydrogen
HDRM	Hold Down Release Mechanism
He	Helium
HED	Hall Effect Devices
HEO	Highly Elliptical Orbit
HGAS	High Gain Antenna System
HOP	High Output Paraffin
hr	Hour
HRP	Humidity Removal Package
HTP	High-test Peroxide
HTPB	Hydroxyl Terminated Polybutadiene
HTV	H2 Transfer Vehicle
HX	Heat Exchange
Hz	Hertz
I/O	Input/Output
ID	Inside Diameter
IH	Internal Heaters
IKONOS	Space Imaging Remote Sensing System
in	Inch
in^2	Square Inch
in^3	Cubic Inch
inH_2O	Inch of Water

SIERRA SPACE

Acronyms	
Acronym/Symbol	**Definition**
in-lb/rad	Inch pound per radian (rotary stiffness)
Intelsat	International Telecommunications Satellite Organization
inwc	Inches Water Column
IPC	Institute of Printed Circuits
IR	Infrared
ISDLA-1 and 2	International Telecommunications Satellite (Intelsate)
ISO	International Organization for Standardization
ISR	Intelligence, Surveillance and Reconnaissance
ISS	International Space Station
JCSAT	Japanese Communications Satellite
JPL	Jet Propulsion Laboratory's
JPSS-1	Joint Polar Satellite System
J-STD	Joint-Industry Standard
k	kilo (one-thousand or 10^3)
K	Monetary symbol for one thousand (1,000)
kg	Kilogram
kHz	Kilohertz
kN	Kilonewton
KOMPSAT	Korean Multi-Purpose Satellite
kPa	Kilopascal
kPaD	Kilopascal Differential
krad	Kilorad
ksi	Kilopound per Square Inch
K-truss	A deployable boom arranged in a unique K-type configuration that provides a predictable and orderly folding dynamic as from a stowed to a deployed state.
kW	Kilowatt (1,000 Watts)
kΩ	kilo-ohm (1,000 ohms)
L	Length
l/s	Liters per Second
L2	2,000 lbf
LAPSS	Large Area Pulsed Solar Simulator
lb(s)	Pound(s)
lb/in	Pounds per inch (lineal stiffness)
lbf	Pound Force (A pound-force is equal to the gravitational force exerted on a mass of one pound on Earth's surface)
lbm	Pound Mass
lbs	Pounds
LDPE	Long Duration Propulsive ESPA
LEO	Low Earth Orbit
LH_2	Liquid Hydrogen
Li_2CO_3	Lithium Salt of Carbonic Acid (inorganic compound)
LiOH	Lithium Hydroxide
LLHX	Liquid-to-Liquid Heat Exchanger
LNG	Liquid Natural Gas

Acronyms	
Acronym/Symbol	**Definition**
LOX	Liquid Oxygen
LPM	Liters per Minute
LPSS	Low-Profile Separation System
LRO	Lunar Reconnaissance Orbiter
LSRM	Low-Shock Release Mechanism
LVDS	Low-Voltage Differential Signaling
M	mega (Metric prefix: 1,000,000)
m	milli (Metric prefix: 0.001, one-thousandth)
m	Meter
m^2	Meters Squared
M2M	Machine-to-Machine
m^3	Cubic Meter
mA	milliampere
MAC	Multiply Alkylated Cyclopentane
MASPEX	Mass Spectrometer for Planetary Exploration (Europa Mission)
MATLAB	Matrix Laboratory (A numerical computing environment and fourth generation programming language, developed by MathWorks)
max	maximum
MDM	Motor Drive Module
MDP	Maximum Design Pressure
MEO	Medium Earth Orbit
MER	Mars Exploration Rover
MexSat	Mexico's next-generation mobile satellite system (English translation)
mH	Millihenry
MIB	Minimum Impulse Bit
MIL	Military
MIL-STD	Military Standard
min	Metric abbreviation for minute (no periods)
min	minimum
MIP	Mars 2001 In-situ-Propellant-Production Precursor
MiSER	Miniature Satellite Energy-Regulating Radiator
MIV	Motorized Isolation Valve
MLI	Multi-Layer Insulation
mm	Millimeter
MMC	Multi-Motion Controller
MMD	Mass Measurement Device
MMH	Monomethyl Hydrazine
mNm	Milli-Newton Meter
MON	Mixed Oxides of Nitrogen
MON-3	Nitrogen Tetroxide
MPa	Megapascal
mrad	Milliradian
ms or msec	millisecond (one-thousandth of a second)
MSG	Meteosat Second Generation

Acronyms	
Acronym/Symbol	**Definition**
mT	Metric Ton
MUOS	Mobile User Objective System
MUSES	Multi-User System for Earth Sensing
mV	Millivolt
MVF	Modular Ventilation Fan
MWT	Metallized Wrap Through
N	Newton
N/A	Not Applicable
N_2H_4	Hydrazine
NASA	National Aeronautics and Space Administration
NBN	National Broadband Network
NC	North Carolina
NDI	Nondestructive Inspection
NDIR	Non-Dispersive Infrared
NEXTSat	Next Generation Satellite
NH_4	Ammonia
Nm	A newton meter (A unit of torque, in the SI system; one newton meter of torque is equivalent to one joule per radian.)
Nm	Nanometer (An SI unit of length, equal to 10^{-9} m or a billionth of a meter)
Nm	Newton meter
N-m	Newton meter
Nm/rad	Newton meter per radian
NPOESS	National Polar-orbiting Environmental Satellite System
NPP	NPOESS Preparatory Project
NPRV	Negative Pressure Relief Valve
NRE	Nonrecurring Engineering
NSI	NASA Standard Initiator
Ø	Diameter
O/F	Oxidizer to Fuel Ratio
O_2	Oxygen
OAP	Orbital Average Power
OD	Outside Diameter
OD/L	Outside Diameter x Length
OECS	Orbital Express Capture System
OG2	ORBCOMM Generation 2
OH	Ohio
OISL	Optical Inter-Satellite Link
OMS	Orbital Missions and Services
ORBITEC	Orbital Technologies Corporation
OSIRIS-REx	Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer
oz	Ounce
Pa	Pascal (unit), an SI derived unit of pressure
pA	picoampere, an SI unit of electric current, symbol, pA
PAN	Palladium at Night

Acronyms	
Acronym/Symbol	**Definition**
PBN	Powered Bolt Nut
PbNp	An extreme-pressure lubricant additive where lead naphthenate has been used
PCB	Printed Circuit Board
PCBM	Passive Common Berthing Mechanism
PCS	Pressure Control System
PFPE	Perfluoropolyether
PGW	Propylene Glycol/Water
PN	Part Number
PPM	Pivot Platform Mechanism
ppm	Parts per Million
P-POD	Poly Picosatellite Orbital Deployer
PPRV	Positive Pressure Relief Valve
pps	Pulse per Second
PRT	Platinum Resistance Thermometer
psi	Pounds per Square Inch
psia	Pounds per Square Inch (absolute)
psid	Pounds per Square Inch Differential
psig	Pounds-Force per Square Inch Gauge
PSP	Parker Solar Probe
PTFE	Polytetrafluoroethylene (Teflon)
PWA	Printed Wire Assembly
PWB	Printed Wire Board
PWM	Pulse Width Modulated
QD	Quick Disconnect
QwkSep®	Quick Separation (Sierra Space release device product)
RA	Rotary Actuator
rad	Radians
rad (1)	radian (the SI standard unit of angular measurement)
rad (2)	A metric unit measuring radiation dose
RCRA	Regenerable Carbon Dioxide Removal Assembly
RCS	Reaction Control System
RDA	Rotary Drive Assembly
RDC	Resolver-to-Digital Converter
RDE	Rotary Drive Electronics
RF	Radio Frequency
RFI	Radio Frequency Interference
RH	Relative Humidity
ROCSAT-2	Republic of China Satellite (Renamed FORMOSAT-2, an Earth observation satellite operated by the National Space Organization [NSPO] of the Republic of China [Taiwan])
rpm	Revolutions per Minute
RTD	Resistive Temperature Detector (A temperature sensor that accurately measures temperature changes)
s/sec	Second (The second (symbol: s) (abbreviated s or sec) is the base unit of time in the International System of Units (SI); prefer the symbol s)
SADA	Solar Array Drive Assembly

Acronyms	
Acronym/Symbol	**Definition**
SADE	Solar Array Drive Electronics
SAGE	Stratospheric Aerosol and Gas Experiment
SAR	Synthetic Aperture Radar
SBIRS	Space-Based Infrared System
SCaN	Space Communications and Navigation (SCaN)—aka, Communications, Navigation, and Networking re-Configurable Testbed (CoNNeCT)
scc/s	Standard Cubic Centimeter per Second
sccm	Standard Cubic Centimeters per Minute
SCFM	Standard Cubic Feet per Minute
SCISAT	Scientific Satellite
SDO	Solar Dynamics Observatory
SEE	Single Event Effects
SES	Society of European Satellites (English translation)
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SHARC	Satellite for High Accuracy Radar Calibration
SI	International System of Units
SINDA	Systems Improved Numerical Differencing Analyzer
SMA	Shape Memory Alloy (An alloy that remembers its original, cold-forged shape, returning to pre-deformed shape when heated)
SMAC	Spacecraft Maximum Allowable Concentrations
SMART-1	Small Missions for Advanced Research in Technology
SMC/AD	Space and Missile Systems Center/Advanced Systems and Development Directorate
SMT	Surface Mount Technology
SNC	Sierra Nevada Corporation
SOHO	Solar and Heliospheric Observatory
SP	Shut-off Pin Puller
SPDP	Structural, Power and Data Port
SSD	Simple Stepper Driver
SSP	Space Station Program
STC	Supplemental Type Certificates
STD	Standard
STEREO	Solar Terrestrial Relations Observatory
STP	Space Test Program
STPSat-1	Space Test Program Satellite-1
STPSat-5	Space Test Program Satellite-5
SVM	Space Vector Modulation
T	tera (metric prefix: 1,000,000,000,000 or 10^{12}; or one trillion)
T25	T-cup type transmission
TacSat	Tactical Satellite
TBC	To Be Confirmed
TBR	To Be Resolved
TCPS	Trash Compaction and Processing System
TCS	Thermal Control Systems
TCV	Temperature Control Valve

Acronyms	
Acronym/Symbol	**Definition**
TES	Thermal Emission Spectrometer
TID	Total Ionizing Dose
TIROS	Television Infrared Observation Satellite
Torr (metric symbol) torr (unit's name)	Unit of Pressure (A unit of pressure equal to $\frac{1}{760}$ of an atmosphere–about 133.3 pascals or 1 mm of Hg)
TPS	Thermal Protection System
TRL	Technology Readiness Level
TTI	Thermospheric Temperature Imager
TVC	Thrust Vector Control
TX	Texas
typ	typical on construction documents
U.S.	United States
UAS	Unmanned Aircraft Systems
UDC	Uncrewed Dream Chaser
UMCD	Universal Microstepping Control Driver
UNF	Unified National Fine - Thread Standard (Fine threads)
UNS	Unified National Screw - Thread Standard (Screw threads)
UTS	Universal Technical Systems (Integrated Gear Analysis Software)
UVOT	Ultraviolet/Optical Telescope
V	Volt
Vcm	Vector Current Meter
Vd	Voltage Drop
Vdc	Volts Direct Current
VEGGIE	Vegetable Production Unit
VIIRS	Visible Infrared Imaging Radiometer Suite
VINASAT	Vietnam Satellite (National Satellite Program for Vietnam)
VIPER	Volatiles Investigating Polar Exploration rover
VOC	Volatile Organic Compounds
VSWR	Voltage Standing Wave Ratio
W	Watt
W/K	Watt per Kelvin
W/m^2	Watt per Square Meter
WCD	Water Capture Device
WI	Wisconsin
XRT	X-ray Telescope
XSS-10	eXperimental Small Satellite 10

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