Gimbal Selection Guide

Our experience over the years has allowed us to develop a thorough selection process for the wide variety of applications we see. In reviewing application requirements and customer specifications, a common problem is the inadvertent specifying of performance requirements that ultimately become mutually exclusive. Our experience has shown that this problem often occurs for a couple of reasons. First, the inter-relationships between performance measurements are not always well understood. Second, specifications that worked perfectly well in one application were carried over into a new application where they proved to be unsuitable.

The following information is intended to supplement the product data sheets, drawings, and frequently asked questions documents that describe each product. Included is a wide variety of information and examples of how systems relate to applications, key factors to consider during the selection process, and how different performance specifications will influence other system requirements.

Our intention in writing this guide is to provide potential customers with as much information as possible, so that they can approach the gimbal specification and selection process in an organized, informed manner. To that end, this guide is divided into the following sections:

As always, the Sagebrush technical staff is available to discuss your application and requirements, further explain any of these specifications, and assist you in selecting the appropriate product. Our goal is to develop the optimal solution for your application, in the most cost-effective way.

3700 Singer Blvd NE Ste A Albuquerque, NM 87109 505-299-6623 Fax: 505-298-2072
www.sagebrushtech.com

1 Specifications Form

The Specifications Form (Specwkst.xls) is used to define the customer's payload, application, and performance requirements. With this information, Sagebrush Technology can usually determine which gimbal or gimbals are best suited to the customer's requirements.

Where a customer has a unique application that requires a custom gimbal or a modification to a standard product, complete and accurate information on the Specifications Form is essential to allow Sagebrush Technology to determine the scope and cost of the project.

2 Application Areas

The first item to consider is the intended application. For the purpose of this discussion, the application can be broken down based on where and to what the gimbal is to be mounted. The general applications categories are airborne, ground, ground mobile, marine, and robotics. Each of these has its own unique requirements and considerations that are discussed in the following paragraphs.

2.1 Airborne

Gimbals operated inside a pressurized aircraft experience a relatively benign operating environment, but may be subjected to vibration and shock loads, and may need stabilization or tracking software if they are intended to observe or follow an object outside the aircraft.

For gimbals mounted in unpressurized areas of the aircraft, the first consideration is the operating altitude. Given an altitude, the temperature and air pressure can be obtained from standards related to aircraft equipment. These values give us insight into thermal, heat transfer, and electrical aspects of the gimbal design.

Where the gimbal is subject to wind loads outside the aircraft, the operating airspeed and altitude are keys to not only the structural requirements, but also the motor torque required to overcome the wind loads and still provide acceptable performance.

Finally, the size and type of aircraft give us guidance with respect to vibration and shock loads, as well as regulatory issues. Commercial, military, and experimental aircraft, as well as Unmanned Air Vehicles (UAVs) have different rules regarding the installation and certification of payloads. When aviation authorities certify a product for use on an aircraft, the certification applies to the complete system. Because Sagebrush Technology is providing only a component of the complete system, we leave the certification process up to the system integrator. We will support an integrator's type-certification process, but the gimbals themselves are not certified for operation on any specific aircraft.

2.2 Ground

Fixed, ground based systems would not be expected to have the dynamic environment of a mobile system. However, a poor choice of mounting systems or locations can introduce problems into an otherwise well designed system. When situating a ground-based system, the mounting structure must be at least as stiff as the gimbal. For example, installing a camera-equipped pan/tilt system on top of a light pole will subject the base of the pan tilt to all of the twisting and swaying of the light pole in strong winds. This base motion will affect the camera's image quality.

Even with a firm structure to support the gimbal, wind can induce high frequency vibrations into the gimbal system. Most people are familiar with the sometimes shaky images from local weather or traffic cameras. A lack of stiffness in the mechanical drive train, a weak mounting interface between the payload and gimbal, or a high payload inertia relative to the gimbal's structural stiffness are all potential causes of resonance and vibration that can result in poor performance under certain conditions.

2.3 Ground Mobile

In many ways, the ground mobile environment is the most difficult mobile application when compared to marine or even airborne systems. A ground vehicle can be subjected to higher shock and vibration loads and the occurrence of the vibration is more random than, for example, helicopter rotors or ocean waves. The following scenarios outline Model 20 configurations for the ground mobile application, and when a Model 25 or Model 30 is a better choice.

Scenario 1: The payload(s) are small, lightweight (10 lbs or less), and do not present much cross-section to the wind. The vehicle operates only on paved roads, and the payload is only operated when the vehicle is not moving. In this case, you may be able to use a standard Model 20 gimbal with stepping motors. The standard gimbal has a six-bolt mounting circle on the bottom of the azimuth that most likely would fasten to a plate attached to the vehicle's roof.

Scenario 2: The payload is lightweight, but the vehicle may be operated on unpaved roads or off-road. Or, the payload is operating when the vehicle is in motion. In this case, we would recommend that you consider the 4-inch pan bearing option. The purpose of this option is to shift the mounting point of the gimbal from the bottom of the azimuth to the azimuth shaft just below the elevation head. This increases the structural stiffness of the system and decreases the moment and shock loads that the payload will impart to the gimbal structure. It can also be a way of reducing the profile of the gimbal above the vehicle, if the bearing plate is mounted directly to the vehicle roof.

Scenario 3: The payload is heavy (10 to 20 pounds), but does not present much of a cross-section to the wind. The 4-inch bearing option is recommended for heavier payloads, regardless of the way the vehicle is operated.

Scenario 4: The payload is a dish antenna or something that presents a large cross-section to the wind. The Model 20 gimbal may not be suitable and a Model 25 or Model 30 should be considered. Wind loading on the gimbal is the vector sum of the vehicle speed and prevailing wind. It is easy to generate torque loads of 15 to 40 foot-pounds, even at moderate vehicle speeds.

In all cases, we strongly recommend that the payload inertia be balanced as well as possible about the elevation axis. Even a small bump on a moving vehicle can generate significant G-forces on the payload. If the payload exerts moment loads on the gimbal in excess of the holding capacity of the drive, damage can result.

Stabilization should be considered if the system is intended to operate while moving. The Model 20 is the only stabilized system without brakes on the axes. This is an important consideration since an imbalanced payload can create excessive heating in the gimbal motor to maintain its position, and if power is removed the dynamic loads can backdrive the system and damage the drives.

2.4 Marine

The first aspect of selecting a pan/tilt system for a marine environment is the environment itself. External surfaces and materials must be corrosion resistant. Because the axes are designed to rotate, the system has to include seals between moving and non-moving parts. These seals are one potential source of moisture leakage. Other potential sources of leakage are connectors and access covers. Even if these penetrations are well sealed against liquid water, the system may “breath in” water vapor due to expansion and contraction of air inside the pan/tilt due to temperature changes and solar heating. Since purged or pressurized pan/tilt systems a not economical for all applications, the selection process should consider the effects of moisture inside the housings to ensure the internal parts are also corrosion protected.

Just as aircraft size and airspeed are essential components for evaluating an airborne system, the size of the ship and the operating sea states will often dictate either the choice of gimbal, or act as limiting factors in gimbal performance. For optical systems in particular, the specification of sea states should take into consideration the fact that as sea states increase, the visibility generally decreases. It is possible to over-specify the gimbal performance only to discover that due to the height of the waves relative to the ship, or due to rain and spray the desired targets are all but invisible anyway.

The shock and vibration on a ship should always be considered. On smaller ships and fast patrol boats, the pounding that the gimbal system will take during operation should not be under-estimated. In these applications, the emphasis should be on reducing the payload weight and inertia, and selecting the heaviest, stiffest, possible gimbal.

The stabilization performance will be a function of the payload, the size of the ship and the sea state. As the sea states increase relative to the size of the ship, it has to be recognized that the ship is capable of roll, pitch and yaw motions, but a two axis gimbal cannot correct all three axes. Depending on the application requirements, a three-axis system may have to be considered.

2.5 Robotics

Because of its small size and low power consumption, the Model 20 has been used in a number of robotic applications. Typically, the gimbal is carrying sensors and/or cameras that allow the operator to see or hear what is happening around the robot. One important consideration is the supply voltage on the robot. The stepping motor version of the Model 20 can operate at either 12 VDC or 24 VDC, while the servo motor version only operates at 24 VDC.

None of the Sagebrush products are recommended for use as "joints" in robotic arms, as the gimbals were not designed to carry the moment loads that are typical in this type of application. The Roto-Lok® rotary drive may be suitable for some positioning applications associated with custom robotics. Please contact Sagebrush Technology for additional information.

3 Payload

Loosely defined, the payload is whatever the positioning system is trying to point. Whether the payload is an antenna, a camera, or some sort of sensor, many of the technical aspects are similar. However, some payload requirements are so unique that they are critical to selecting the proper gimbal.

3.1 Weight

Most gimbals are rated according to the maximum payload weight that they are designed to handle. Often, the weight limit varies with how the payload is mounted relative to the gimbal axes. This is because the weight and location of the center of gravity relative to the axis of rotation are key components of the payload's inertia. In addition, weight placed away from the axis of rotation results in a moment about the axis that increases the torque required to accelerate and decelerate the payload.

3.2 Dimensions

A payload's dimensions must be considered relative to the gimbal dimensions and the range of motion to ensure that the payload does not interfere with either the gimbal or the surrounding structures. In outdoor applications, the payload dimensions also affect wind loading, which in turn affects gimbal performance. Lightweight payloads with large surface areas, such as dish antennas, often require larger positioners to overcome the torque generated by the wind.

3.3 Inertia

Inertia is an object's resistance to changing direction. High inertia payloads will require higher torque systems. For systems that require high accelerations and slew rates, or for stabilized systems, counterweights may be necessary to balance the inertia and improve performance.

The best way to optimize the payload inertia is to distribute the payload on the positioner so that the system is balanced. This is particularly true of the Model 20 and Model 25 systems where the payload is mounted on either side of the elevation head. Systems with multiple sensors can be designed so that some sensors are on either side of the positioner.

Antennas can be mounted using a U-shaped bracket attached to both ends of the elevation shaft so that they are centered in front of the positioner and rotate over the top of the elevation head. In this case, counterweights should be used behind the antenna to balance the moment loads about the elevation axis.

3.4 Field of View

Most payloads have a field of view, whether it is a camera lens, the beam width of an antenna, or the aperture of an optical system. The field of view helps determine the pointing accuracy, repeatability, and stiffness of the positioning system. Except for specific situations, such as a security camera scanning a limited area where a person is always available to adjust the view and act on the information received, the position measuring instruments typically need a resolution that is a small fraction of the field of view, and the control system must be able to consistently point the payload to within a few counts of the position instrument.

3.5 Wind Loads

When positioning dish antennas, the dish diameter and maximum operating wind speed are often the determining factors in the size and configuration of the positioning system. Wind blowing on antennas can easily generate moment loads of 40 foot-pounds or more on even a small dish. Where practical, radomes can be used to protect the antenna from the wind, and reduce the performance requirements of the positioning system.

Wind loads can also induce high frequency vibrations in the gimbal or the payload that will affect the quality of camera images. Except for low frequency motions, such as limited sway in a mast, it is usually not economical to attempt to stabilize a gimbal against wind loads. Often, the only solution is to use a heavier, stiffer positioner with a very rigid interface between the positioner and the payload in an effort to damp out the vibrations.

3.6 Wiring

Payload wiring is often overlooked, but can be a factor in the final selection of a positioning system. Most Sagebrush products are designed to allow the wiring to pass through the gimbal shafts. This results in a cleaner installation that reduces the chance of damage to the wiring over time, and eliminates the risk that the rotating wiring will be snagged on a nearby object.

In some circumstances, such as payloads with high power requirements or antennas using heavy coaxial cables, the payload wiring can influence the torque required to move the payload. Additionally, if the wiring is not routed through the gimbal, the hanging weight of the wiring becomes part of the payload and has to be factored into the performance calculations.

Due to its limited bend radius, fiber optic cable poses special installation problems and may require optical rotary joints at the gimbal axes. Similarly, antenna coax or waveguide may require rotary joints to support the desired range of motion. Unless the gimbal was designed to support rotary joints, significant mechanical changes may be necessary to accommodate the payload.

4 Positioning System Orientation

The orientation of positioning system with respect to its axes is an important structural consideration. Typically, a pan/tilt positioner is designed to be oriented with the pan axis below the tilt axis. When the pan axis moves, the payload and the tilt axis are turned.

When the tilt axis moves, only the payload is repositioned. Where the intention is to mount the system in an inverted orientation, such as from a ceiling, the bearings and structure of the pan axis must be designed to carry the weight of the elevation axis and payload even with gravity acting in the opposite direction.

Similarly, if the requirement is for the system to mount sideways on the wall, the function of the axes reverses. The pan axis now tilts the payload up and down, while the tilt axis rotates the payload left to right. More importantly, this orientation typically creates a cantilevered system. The weight of the payload no longer passes down through the structure, but instead creates a bending moment about the base of the system. In mobile systems, this orientation is often considered so that the axes act with respect to the roll and pitch motions of the platform.

5 Performance Parameters

The performance parameters are an important part of specifying the positioning system. Because performance is a function of the payload and the operating environment, similar performance requirements often result in very different mechanical configurations. In addition, there is always the risk of over-constraining the system specifications because so many performance parameters are closely related to each other, and to other operating requirements.

5.1 Acceleration

Most standard products are designed for accelerations in the range of one to two radians per second^2. For applications with a specific acceleration requirement, the payload inertia and operating environment are factors in determining the size of the motor and the drive ratios that are most appropriate. Ideally, the payload inertia is matched to the rotor inertia of the motor to obtain the best performance.

The power supply's ability to provide current to the positioning system can be a limiting factor for payload acceleration. Where acceleration is important, the customer should be open to higher power supply requirements. Conversely, in an application with limited power supply capability, the available power should be documented and the acceleration should not be specified.

5.2 Slew Rate

Both the maximum and minimum slew rates can be important when specifying a system. For long-range surveillance systems, the minimum slew rate can be more critical, because the field of view is very narrow, and too high a rate results in the user being unable to see objects as they flash across the lens.

Depending on the selected motor and drive ratio, and the mechanism for rate control, maintaining a slow slew rate can be just as difficult as reaching a high slew rate. As a general rule, the human eye can easily track objects at up to 12 degrees per second, provided that the field of view is wide enough that the object is in view for several seconds. As the field of view narrows, the slew rate must be reduced to give a person time to recognize and follow an object. Slew rates of a fraction of a degree per second can be achieved with proper drive ratios and/or control electronics.

At the opposite end of the spectrum, the high slew rate with a heavy or unbalanced payload can become limited by the speed/torque curve of the motor, or by the power supply. For example, a system using a high drive ratio to obtain a very slow slew rate will then have the top speed limited by the maximum RPM of the motor, or by a loss of torque at high motor speeds. Similarly, motors can be voltage limited at high speeds because the power supply is inadequate to overcome the back EMF generated at the motor.

As with acceleration, high slew rates should not specified if the system is limited in its power supply or voltage.

5.3 Range of Motion

Most Sagebrush Technology products have azimuth ranges that are non-continuous, but at least +/-180 degrees. We do this for two reasons. First, non-continuous rotation usually eliminates the need for slip rings or rotary joints, which are expensive. Second, continuous rotation systems are subject to export licensing from the US Department of Commerce.

A second consideration for range of motion is the swept volume of the payload. As the payload moves through its combined motion in elevation and azimuth, it traces a volume in space. The range of motion must be limited if the motion of the payload causes it to interfere with the gimbal structures or surrounding objects.

Swept volume is particularly important with dish antennas or irregularly shaped payloads. We have seen applications where what appeared to be very reasonable ranges of motion resulted in a swept volume that covered an entire sphere; making it impossible to provide a mounting structure for the gimbal.

5.4 Accuracy and Repeatability

Pointing accuracy is a measure of the absolute error between where the gimbal actually points a payload and where it was expected to point. Accuracy is a function of the gimbal structure, the position instrument, and the location of the instrument within the structure. A position instrument on the output shaft of the gimbal gives the most accurate information on the payload position. Instruments mounted on the motor shaft or somewhere within the drive train can have very high resolution of the position, but they cannot detect mechanical deflections in the structure or drive train, and therefore are likely to be less accurate.

Repeatability is the ability of the gimbal to return to exactly the same point in space when it is commanded to a specific position. Note that a highly repeatable gimbal does not necessarily imply a high pointing accuracy. Because of the high positional resolution, an instrument on the motor shaft may produce a very repeatable system, while a less resolved instrument on an output shaft may be less repeatable.

Accuracy and repeatability are both functions of the positioning instruments, the mechanical drive train and structure, and the control electronics. There are substantial price differences between systems accurate to a few tenths of a degree and those that are accurate to a few ten-thousandths of a degree. The field of view of the payload must be carefully considered in order to not over-specify the accuracy or repeatability and therefore spend more money than necessary on the positioning system.

For example, when pointing an antenna whose beam width is 3 degrees, a pointing accuracy of 0.25 degrees may be more than adequate. However, when pointing a camera and zoom lens with a field of view of 0.5 degrees at 2000 meters, that same pointing accuracy may result in missing the target at least half the time. In the antenna example, a positional resolution of 0.05 degrees may be more than enough to obtain the necessary pointing accuracy. However, in the camera example, the pointing accuracy may need to be 0.05 degrees. Therefore, the instrument resolution will need to be five to ten times better, say 0.005 degrees in order to obtain the desired accuracy.

5.5 Line-of-Sight Stability

In a stabilized system, the corollary to pointing accuracy is line-of-sight stability: The ability to maintain a specific pointing vector in response to base motion in the mounting platform. The instrument selection problem becomes more complex because in addition to having to resolve motions less than the specified stability, the gimbal must also be able to react quickly enough to correct for the motion before the error becomes too large. As the magnitude and frequency of the errors increases, for example as the seas get rougher or as a vehicle moves from a paved road to a dirt road, the demands on the instruments, control system, and drive trains will increase.

Factors involved in the selection of the inertial instruments include the required stability, the payload inertia, and the operating environment. The environment is a major factor because the disturbances on a ground vehicle are significantly different from a ship, which is very different from an aircraft.

Inertial sensors used to stabilize a gimbal can be influenced by the earth's motion, as well as the motion of the gimbal platform. The result can be a slow, cumulative error in pointing, commonly referred to as drift. The quality and price of the sensor is often directly related to the amount the sensor will drift over time. Automotive grade sensors often have significantly more drift than military sensors, but cost from a few hundred dollars to less than a thousand dollars. Most military grade sensors cost several thousand dollars per axis and cannot be shipped out of the United States without an export license. The drift in many inexpensive sensors is a function of temperature, so drift can be minimized using temperature compensating software, or by maintaining the sensor at a constant temperature. All of Sagebrush's stabilized products have provisions for correcting for the sensor drift. The frequency at which the drift compensation has to be adjusted will be a function of the sensor and the application.

Another factor affecting the line-of-sight stability is the number of axes in the gimbal. The high quality video images used in motion pictures and the new media are obtained with multi-axis gimbals that have been designed around specific camera payloads. Sagebrush Technology builds two axis gimbals, typically an azimuth and elevation axis, but some of the systems can also be oriented as roll and pitch axes. For our servo gimbals, we would close our position or rate loops at a rate of 10 to 20

Hz, which means that in a stabilized gimbal we can make corrections to the pointing of the payload 10 to 20 times a second.

Most manufacturers of airborne, stabilized gimbals build multi-axis gimbals to improve the stabilization performance. Four axis systems typically have two elevation and two azimuth axes. Five axis systems add a roll axis inside the azimuth and elevation axes.

The multi-axis design typically works as follows:

The elevation or azimuth drive typically consists of two independent drives nested together. The outer axis has a large range of motion, and operates at a relatively low bandwidth, similar to our gimbal axes. However, the inner axis has a more limited range of motion, possibly a few degrees in each direction. The payload is very precisely balanced about the inner axes, and the control mechanisms, such as direct drive motors or voice coils operate very quickly and at bandwidths several times that of the outer axes. The inner axes respond very quickly to the inertial instruments in order to provide a very stable image from the payload. The outer axes respond more slowly, and they are designed to keep the position the inner axes as near as possible to the center of their range of motion. For example, as the aircraft turns, the inner axis in azimuth maintains the line of sight to the target. As it moves towards its limit of range, the outer azimuth axis turns both the payload and the inner axis, causing the inner axis to simultaneously move the opposite direction, back towards the center of its range, to maintain the line of sight.

A two axis gimbal that has been designed for a “generic” payload will never have the stabilization performance of a custom, multi-axis gimbal designed around the same payload.

6 Your Budget

The budget for a positioning system is often overlooked in planning a project. Often it is assumed that the positioner will be an off-the-shelf solution or very inexpensive, regardless of the performance requirements. When developing an integrated system, there is a tendency to establish a price point based on the payload cost, only to discover that the budget no longer has room for the appropriate positioning system. When planning a project budget, the major cost drivers for positioning systems are the pointing accuracy, positional resolution, payload capacity, and, for stabilized systems, the line of sight stability.

In single unit quantities, Model 20 configurations typically fall between $6,800 and $18,000. The Model 25 products start at around $20,000 and the Model 30 at around $30,000. Special purpose systems, such as Model 2 and Aero 20 are significantly more expensive, with the Model 2 prices starting at $40,000 and the Aero 20 at $70,000.

When developing custom systems, or customizing a standard product, Sagebrush Technology typically charges a one-time fee for non-recurring engineering services in addition to the price of the initial positioning system. Subsequent production runs are priced only on the cost of producing the products. System Integrators and resellers may be eligible for additional discounts based on their sales volume.

7 Gimbal Options for all Models

Many of the standard gimbal products include options that have been developed for specific customer requirements. The options discussed in this section are available on all or most Sagebrush Technology products. Subsequent sections discuss the product-specific options that are available on Model 2, Model 20, Model 25 and Model 30 gimbals.

7.1 Gyro-Stabilization

The servo motor versions of the Model 20, Model 25 and Model 30 Roto-Lok® systems are available as stabilized gimbals using rate sensors in each axis. The standard sensors are exportable without a license. Stabilization performance will be a function of the gimbal, payload, vehicle, and application. Higher performance sensors may be available for US Government customers or customers who can demonstrate a performance need and are able to obtain an export license. Please contact Sagebrush Technology for additional information.

7.2 Optional Finish Color

The standard finish on all gimbals other than the Aero 20 is a white powder coat. The standard finish color on the Aero 20 is black. We will customize gimbals with different anodize, paint, or powder coat finishes based upon customer requirements.

7.3 Payload Cable Installed

For customers placing a camera or other sensor on the payload shelf, we can install power, communications, and/or coax cable from the payload shelf, through the elevation head, down through the internal cable path, and exiting at the base. This cable installation eliminates problems with cable wrap that might interfere with gimbal motion or cause wear on the cables. For the customer that requires this option, the cable is installed during the gimbal assembly. There may be additional charges for special connectors or wire types, if required.

8 Specific Model 2 Options

8.1 Waveguide Rotary Joints

Because the Model 2 was designed to support radar antennas, a provision for small rotary joints was included. The rotary joints allow the use of small diameter semi-rigid waveguide in place of coaxial cable for payload communications.

8.2 Elevation Yoke System

A custom version of the Model 2 has now been produced to allow the mounting of small cameras and optical hardware in a yoke-style elevation drive.

9 Specific Model 20 Options

9.1 Increased Resolution Stepping Motors

The increased resolution motors provide a step increment that is 1/2 the standard motor step. This allows a gimbal resolution of one half the standard motor, or .005 degrees per motor step. The increased resolution motor has the same torque capability and therefore the same payload capacity as the standard motor. However, the electronics limit the maximum slew speed of the gimbal to half the standard motor speed, or 30 degrees/second. This option is recommended for applications requiring increased positional resolution where decreased slew speeds are acceptable.

9.2 5:1 Gear Reduction Stepping Motor

The Gear Reduction Motor option has an extra gear reduction stage in both axes of motion for the gimbal. This option implements a sealed gearbox attached directly to the motor providing a 5:1 reduction ratio. It provides twice the torque of the standard motor. A smaller motor is used to minimize the motor-gear head assembly size, weight and power, thus the increase in torque of 2:1 versus 5:1. The positional resolution of the gimbal on this option increases to 7.5 arc-seconds per motor step, but the maximum slew rate is reduced to 12 degrees/second. This option is recommended for applications requiring high positional resolution and/or payloads exceeding 20 lbs. where a slower slew rate is acceptable.

9.3 Optical Encoders: 25.9 and 6.48 arc-second resolution

Note: This option is only available on Model 20 gimbals with stepping motors.

Optical encoders are mounted on the output shaft for both the azimuth and elevation drives. Encoders are available in two resolutions, 25.9 and 6.48 arc-seconds. Both encoders have an absolute zero reference. Communications with the encoders is via the two RS-232 auxiliary ports on the circuit board located in the elevation drive assembly. Communication is shared via the gimbal RS-232 line. The encoders are queried by addressing the auxiliary ports in the elevation head. The stepper gimbal control electronics are not set up for closed-loop control to command positions based on encoder counts. The closed-loop programming would need to be provided by the user computer, if desired. Closed-loop control is standard on the Model 20 Servo gimbals.

The encoders are recommended in applications with precise position requirements. This position indication can then be used for closed loop feedback to position the gimbal, or for readout of the gimbal's position. High repeatability and/or accuracy requirements dictate the use of optical encoders.

9.4 Offset Bracket

The offset bracket allows for placing the payload at the center of both the azimuth and elevation axis.

This is accomplished by mounting a bracket between the azimuth and elevation sections. This mounting shifts the elevation drum off the azimuth axis to allow the payload shelf to sit directly over the azimuth axis of rotation. The offset option comes in two different lengths. The shorter arm of 5.6 inches allows for centering a 5-inch diameter payload on the center of axis. The longer arm of 7.4 inches allows positioning an 8-inch diameter payload on the center of the azimuth axis.

This option is recommended for applications where on-axis rotation of the payload is desired. An example is raster scanning of a room using a laser range finder. Another application is in the use of mirrors where the gimbal provides two-axis rotation of a mirror mounted at the intersection of both axes.

There is a structural trade-off when using an offset arm. In high shock or vibration environments, the offset arm may actually decrease the stiffness of system, resulting in additional jitter or increased settling times.

9.5 Azimuth Mounting Plate (Tabletop mounting bracket)

An azimuth base plate provides four mounting bolt holes in a pattern outside the radius of the azimuth base, to provide alternate gimbal mounting options. This configuration allows the gimbal to be easily fastened to a tabletop. This mounting configuration is not as strong as the standard bolt circle and should not be used in high vibration environments.

9.6 4-Inch Pan Bearing

The 4-inch pan bearing is recommended for use in applications where the gimbal will be subjected to high mechanical loading, such as a moving vehicle. It was an option originally designed for a Model 20 application where the unit was required to track artillery shells throughout their flight, and was subjected to ballistic shock.

This option is also recommended for applications where the Model 20 is used as a roll/pitch system, because it reduces the bending moments on the gimbal structure.

9.7 Video Connector

The standard weatherproof connector can support video (coax) wiring from a BNC connector at the payload into the spare pins on the connector. For customers who prefer to keep the video signals separate, up to two BNC connectors can be installed on the azimuth base. These connectors are mounted 90-degrees to one side of the power/data connector.

9.8 Camera Control Module

The Model 20 Stepper electronics include lens drivers for zoom and focus control of a single camera as part of the standard electronics. This option, which is available on the Model 20 Servo gimbal at no additional cost, provides analog inputs and outputs that implement the lens zoom and focus commands that are part of the standard protocol. Digital outputs are also available to turn camera power on and off, or to support accessories such as a camera housing wiper or washer.

10 Specific Model 25 Options

10.1 Continuous Rotation

A continuous rotation azimuth has been developed for the Model 25 using a belt drive. The rotation is accomplished through the addition of slip rings in the base housing. At additional cost, provisions can be made for rotary joints in addition to the slip rings. Please contact Sagebrush Technology for technical support when configuring a gimbal with continuous rotation. Please note that continuous rotation gimbals are export controlled and will require an export license for foreign customers.

11 Specific Model 30 Options

11.1 Zero Backlash Worm Drive

This option is available on the azimuth of the Model 30 Worm Drive system. The zero backlash drive eliminates the backlash normally associated with the worm gears. This option is recommended for applications where unidirectional pointing is impractical and the pointing error due to backlash is unacceptable.

The option is only available on the azimuth drive. Sagebrush Technology recommends the use of counterweights on the payload to drive out the backlash in the elevation drive.

11.2 Continuous Rotation

Continuous azimuth rotation is available only on the Worm Drive version of the Model 30. The rotation is accomplished through the addition of slip rings in the base housing. At additional cost, provisions can be made for rotary joints in addition to the slip rings. Please contact Sagebrush Technology for technical support when configuring a gimbal with continuous rotation. Please note that continuous rotation gimbals are export controlled and will require an export license for foreign customers.

11.3 AC/DC Power Supply

This option is available on the on the Worm Drive version of the Model 30. The standard power input is 48 to 75 Volts DC. As an option, Sagebrush Technology can install an AC to DC power supply in the base of the gimbal. The customer must specify either 120 V AC or 230 V AC input power with the purchase order.