Gimbal Communications - Preliminary

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1 Introduction

TASE is a gimbaled camera system intended for use by small UAVs or any other system that needs stabilized pan and tilt functionality. This document describes the communications protocol used to talk to TASE.

2 Physical layer

TASE supports three 3-wire RS-232 serial channels, one 3-wire TTL channel, and one 3-wire CAN connection.

Table 1. Physical layer serial pin-outs and function

Port	Connector	Pins	Level	Function
Com1	39-pin	5(Gnd), 6 (Rx), 7 (Tx)	RS232	Optional Interface to Honeywell HMR2300 3-axis magnetometer.
Com2	39-pin	25(Gnd), 26 (Rx), 27 (Tx)	RS232	9600 Baud gimbal communications.
Com3	25-pin	4(Gnd), 5 (Tx), 6 (Rx)	RS232	57600 Baud gimbal communications.
KLV	25-pin	15 (Tx), 16 (Rx), 17 (Gnd)	5V TTL	9600 Baud KLV output data.
CAN	25-pin	22 (HI), 23 (LO), 9 (GND)	CAN	1Mbaud multidrop differential CAN bus for gimbal communications.

3 Gimbal communications datalink layer

3.1 General packet definition

Gimbal communications take place using packets whose general format is described Table 2 below. Note that all multi-byte values are always sent with the most significant byte first, i.e. in Big-Endian order. This document identifies the bit order of a word as starting at 0 which is the left-most or most-significant bit (MSB).

Table 2. datalink layer packet definition

Byte	Name	Meaning
0	SYNC1	Synchronization character used to signal the receiving state machine that a packet *may* be forthcoming. Must be 0x00.
1	SYNC2	Second synchronization character used to signal the receiving state machine that a packet *may* be forthcoming. Must be 0xFF.
2	SYNC3	Third synchronization character used to signal the receiving state machine that a packet *may* be forthcoming. Must be 0x5A.
3	Size	Number of data bytes in the packet, including the Group and PktType members (i.e. 2 more than the size of Data).
4	Group	The group byte identifies the category of data contained in the packet.

5	PktType	The packet type, along with the group, identifies the type of data contained in the packet.
6…Size+3	Data	Data of the packet
Size+4	Check_0	Most and least significant bytes of the checksum. The checksum is formed by unsigned summation of all bytes in the packet excluding the checksum bytes.
Size+5	Check_1	

3.2 Group types

Table 3 lists the different packet group recognized by the gimbal.

Table 3. Packet group types

Name	Group	Meaning
COMMAND_AND_CONTROL_GROUP	0x00	Gimbal input command and control packets.
DYNAMICS_INFORMATION_GROUP	0x08	Rate and attitude information input and output.
POSITION_INFORMATION_GROUP	0x10	GPS and sensor point of interest position input and output.
STATUS_INFORMATION_GROUP	0x28	Status packets.
SETUP_GROUP	0x48	Gimbal setup packets.

4 Gimbal communications packets

4.1 Command and control input packets, group 0x00

Table 4. Packet types for command and control input group 0x00

Name	PktType	Dir	Freq	Meaning
GIMBAL_CMD	0x80	In	N/A	Gimbal command packet for controlling pan, tilt, roll, and operational modes.
GYRO_ZERO_CMD	0x40	In	N/A	Gimbal command packet for zeroing the rate gyros.
CAMERA_CMD	0x41	In	N/A	Camera zoom and focus control.
LEGACY_CAMERA_CMD	0x81	In	N/A	VISCA based camera zoom and focus.
CAMERA_PASS	0x42	Both	N/A	Pass-through to directly communicate to camera
RETRACT_DEPLOY_CMD	0x43	Both	N/A	TASE third-axis command.

4.1.1 Gimbal Command Packet: 0x80

The gimbal command packet is input to the gimbal to control its position or rate, and whether stabilization is enabled or disabled.

Table 5. Gimbal command packet data contents

Byte	Name	Meaning
0	Pan(MSB)	Signed 16 bit pan position or rate command in 1/100th of deg or deg/second.
1	Pan(LSB)	
2	Tilt(MSB)	Signed 16 bit tilt position or rate command in 1/100th of

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3	Tilt(LSB)	deg or deg/second.	
4	Roll(MSB)	Signed 16 bit roll position or rate command in 1/100th of deg or deg/second. This signal is ignored by the gimbal.	
5	Roll(LSB)		
6	Flags	Flags describes how the data are interpreted:	
		0x00	Legacy rate command, stabilization off.
		0x01	Legacy position command, stabilization off.
		0x02	Legacy rate command, stabilization on.
		0x03	Legacy position command, stabilization on.
		0x10	Rate command, stabilization off
		0x90	Rate command, stabilization on.
		0x20	Position command, stabilization off.
		0xA0	Position command, stabilization on.
		0x30	Impulse command, stabilization off
		0xB0	Impulse command, stabilization on. If sensor point of interest is on than this command shifts the sensor point of interest errors.
		0xC0	SPOI error. If sensor point of interest is on than this sets the sensor point of interest error.
		0xD0	SPOI error rate. If sensor point of interest is on than this sets the rate at which the sensor point of interest error changes.
7	ImpulseTime	Unsigned 8-bit amount of time used to answer an impulse command in hundredths of a second.	

4.1.2 Gyro Zero Packet: 0x40

The gyro zero packet is a zero length input packet used to tell the gimbal to zero the rate sensors. This packet should only be sent when the gimbal is not moving.

4.1.3 Camera Command Packet: 0x41

The camera control packet provides the fields necessary to control the camera settings. This packet will change the active camera unless 0xFF is passed for the camera designator. This packet can be sent with just one byte in which case the camera settings are not changed, but instead the active camera is changed.

Table 6. Gimbal command packet data contents

Byte	Name	Meaning
0	Camera	Camera designator, 0 for camera A, 1 for camera B, 2 for camera C. 0xFF for do not change camera.
1	Reserved	Set to zero.
2	HFOV(MSB)	Signed 16 bit horizontal field of view in 1/100th of a degree. If the HFOV value is negative the value is interpreted as zoom ratio minus in -1/100ths of a zoom. 0xFFFF (-1) means do not change field of view.
3	HFOV(LSB)	
4	Focus(MSB)	Unsigned 16 bit focus position in millimeters. Note that not all cameras support focus control. Special cases: 0x0000: Auto-focus. 0xFFFD: Trigger focus on current view. 0xFFFE: Infinite focus. 0xFFFF: Do not change focus.
5	Focus{LSB)	
6	Exposure	Exposure mode. Note that not all cameras support exposure control. 0) Full auto: auto iris and gain; shutter at 1/60 s.

		1) Shutter priority: shutter command and auto iris and gain. 2) Bright: Bright value used below with fixed shutter. 0xFF) Do not change exposure control.	
7	Shutter Speed	Unsigned 8 bit VISCA shutter speed command from 0x00 (1/1) to 0x15 (1/10000). 0xFF is do not change. This value only applies if Exposure is 1 or 2. Not all cameras support shutter speed control.	
8	Bright	Bright value used for exposure mode 2. 0x00 is darkest, 0x1F is brightest. 0xFF is do not change. This value only applies if Exposure is 2. Not all cameras support bright control.	
9	Flags	Bitfield for camera discretes.	
		0) MSB	Set for no change to flags.
		1-4) Reserved	Set to zero.
		5) Black hot	Set for black hot, else white hot.
		6) Stab on	Set to turn camera stabilization on.
		7) Title on	Set to turn title display on.

4.1.4 Legacy Camera Command Packet: 0x81

The legacy camera control packet provides the fields necessary to directly control the first camera through Sony VISCA commands.

Table 7. Gimbal command packet data contents

Byte	Name	Meaning
0	Zoom{MSB}	Unsigned 16 bit VISCA zoom command from 0x0000 (wide end) to 0x4000 (narrow end).
1	Zoom(LSB)	
2	Focus(MSB)	Unsigned 16 bit VISCA focus position command from 0x1000 (far end) to 0xC000 (near end). Special cases: 0x0000: Auto-focus at fast rate. 0x0001: Auto-focus at slow rate. 0xFFFD: Trigger focus on current view. 0xFFFE: Infinite focus. 0xFFFF: Do not change focus.
3	Focus{LSB}	
4	Auto Exposure	Automatic exposure mode: 0) Full auto: auto iris and gain; shutter at 1/60 s 1) Shutter priority: shutter command and auto iris and gain 2) Iris priority: iris command and auto gain and shutter 3) Manual: user commands
5	Shutter Speed	Unsigned 8 bit VISCA shutter speed command from 0x00 (1/1) to 0x15 (1/10000). 0xFF is do not change.
6	Iris	Unsigned 8 bit VISCA f stop setting from 0x00 (close) to 0x11 (F1.4).
7	Gain	Unsigned 8-bit VISCA gain settings from 0x00 (-3dB) to 0x0F (28 dB)

4.1.5 Camera pass through Packet: 0x42

The camera pass through packet gives the ability to directly send and receive data from the camera. Sending the camera pass through packet will disable the gimbals internal camera control functionality (i.e. the ability to respond to camera command packets). Some cameras

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(those which the gimbal does not know how to control) are automatically in camera pass through mode.

Pass through packets sent to the gimbal represent data to be sent to the camera. Pass through packets received from the gimbal represent data from the camera.

Table 8. Gimbal camera pass through packet

Byte	Name	Meaning
0	Camera	Camera designator, 0 for camera A, 1 for camera B, 2 for camera C.
1	Baud	Baud rate of the camera interface, in units of 1200. 0 means do not change. Packets from the gimbal will contain the current baud rate of the camera interface. Packets to the gimbal contain the desired baud rate. If the desired baud rate does not match the current baud rate the gimbal will change the camera interface baud rate.
2	Reserved	Set to zero
3	Reserved	Set to zero
4…	Data_0	First byte in this packet to/from the camera.
…N+3	Data_N	Last byte in this packet to/from the camera.

4.1.6 Retract Deploy Command: 0x43

The third axis command packet is used to command the retract/deploy mechanism that is an option for TASE. This system retracts or deploys the entire gimbal, hence it is not really a gimbal angle like pan or tilt, and its position does not affect the interpretation of camera orientation information in the geo-referencing packet. The gimbal will echo this packet when the retraction or deployment is complete.

Table 9. Third axis command packet

Byte	Name	Meaning
0	Deploy	Set to non-zero to command deployment, zero commands retraction.
1	Reserved	Set to zero.

4.2 Dynamics information packets, group 0x08

Table 10. Packet types for dynamics information group 0x08

Name	PktType	Dir	Freq	Meaning
GIMBAL_ANGLE	0x10	Out	10	Gimbal axis angle information.
GIMBAL_TELEMETRY	0x40	Out	10	Gimbal telemetry information.
HOST_SENSOR	0x41	In	N/A	Host sensor information.
HOST_ATTITUDE	0x42	In	N/A	Host attitude information.

4.2.1 Gimbal angle packet: 0x10

The gimbal angle packet is sent by the gimbal to report the gimbal angles relative to the gimbal mount.

Table 11. Gimbal angle packet data contents

Byte	Name	Meaning
0	Pan_0	Signed 16 bit pan position in 1/100th of degree.
1	Pan_1	
2	Tilt_0	Signed 16 bit tilt position in 1/100th of degree.
3	Tilt_1	
4	Roll_0	Signed 16 bit roll position in 1/100th of degree. The gimbal does not have a roll axis, this value will be reported zero.
5	Roll_1	

4.2.2 Gimbal rate packet: 0x40

The gimbal rate packet is sent to report the gimbal mount rate, gimbal axis rate, and mode of operation. The mount rate is measured with inertial sensors, the gimbal axis rate is the speed of the gimbal axis relative to the mount. This information can be used by video processing systems to aid video stabilization and geo-rectification.

Table 12. Gimbal rate packet data contents

Byte	Name	Meaning	
0	Time_0	Unsigned 32-bit gimbal time since reset in milliseconds.	
1	Time_1		
2	Time_2		
3	Time_3		
4	PanRate_0	Signed 16 bit gimbal pan axis rate in 1/100th °/s.	
5	PanRate_1		
6	TiltRate_0	Signed 16 bit gimbal tilt axis rate in 1/100th °/s.	
7	TiltRate_1		
8	RollRate_0	Signed 16 bit gimbal roll axis rate in 1/100th °/s. The gimbal does not have a roll axis, this value will be zero.	
9	RollRate_1		
10	p_0	Signed 16 bit gimbal mount body roll rate in 1/100th deg/second.	
11	p_1		
12	q_0	Signed 16 bit gimbal mount body pitch rate in 1/100th deg/second.	
13	q_1		
14	r_0	Signed 16 bit gimbal mount body yaw rate in 1/100th deg/second.	
15	r_1		
16	Reserved		
17	Mode	Operational mode of the gimbal:	
		Bit 0) MSB	Set if stabilization is on
		Bit 1)	Set if 3AX in deployed state.
		Bit 2)	Set if 3AX in retracted state.
		Bits 3-7)	The mode of the gimbal: • Rate feedback • Position feedback • Sensor point of interest • Pan initialization • Tilt initialization • Position initialization

4.2.3 Host sensor packet: 0x41

The host sensor packet is used to inform the gimbal of the host inertial information. The gimbal can use this information to perform a check against its own sensors or to perform state estimation using the host sensors. The data in this packet must be supplied in the gimbal's natural coordinate system.

Table 13. Host sensor packet data contents

<table>
<tr><th>Byte</th><th>Name</th><th colspan="2">Meaning</th></tr>
<tr><td>0</td><td>Time(MSB)</td><td colspan="2" rowspan="4">Unsigned 32-bit host time in milliseconds.</td></tr>
<tr><td>1</td><td>Time(1)</td></tr>
<tr><td>2</td><td>Time(2)</td></tr>
<tr><td>3</td><td>Time(LSB)</td></tr>
<tr><td>4</td><td>Roll(MSB)</td><td colspan="2" rowspan="2">Signed 16 bit host body roll rate in 1/100th deg/second.</td></tr>
<tr><td>5</td><td>Roll(LSB)</td></tr>
<tr><td>6</td><td>Pitch(MSB)</td><td colspan="2" rowspan="2">Signed 16 bit host body pitch rate in 1/100th deg/second.</td></tr>
<tr><td>7</td><td>Pitch(LSB)</td></tr>
<tr><td>8</td><td>Yaw(MSB)</td><td colspan="2" rowspan="2">Signed 16 bit host body yaw rate in 1/100th deg/second.</td></tr>
<tr><td>9</td><td>Yaw(LSB)</td></tr>
<tr><td rowspan="5">10</td><td rowspan="5">Flags</td><td>Bits</td><td>Meaning</td></tr>
<tr><td>0 (MSB)</td><td>Bias corrected. If set this bit indicates that the rate data have been bias corrected by the host and can be used by the gimbal to perform its own bias correction.</td></tr>
<tr><td>1</td><td>if set this bit indicates that accelerometer data are valid.</td></tr>
<tr><td>2</td><td>If set this bit indicates that TAS data is valid, else TAS data must be ignored.</td></tr>
<tr><td>3-7</td><td>Reserved. Set to zero</td></tr>
<tr><td>11</td><td>SampleRate</td><td colspan="2">Unsigned 8-bit rate at which this packet is being supplied to the gimbal in packets per second. This value is only evaluated the first time this packet is received.</td></tr>
<tr><td>12</td><td>X_Accel(MSB)</td><td colspan="2" rowspan="2">Signed 16-bit x-axis acceleration in units of 1/300th of a metet/second/second.</td></tr>
<tr><td>13</td><td>X_Accel(LSB)</td></tr>
<tr><td>14</td><td>Y_Accel(MSB)</td><td colspan="2" rowspan="2">Signed 16-bit y-axis acceleration in units of 1/300th of a metet/second/second.</td></tr>
<tr><td>15</td><td>Y_Accel(LSB)</td></tr>
<tr><td>16</td><td>Z_Accel(MSB)</td><td colspan="2" rowspan="2">Signed 16-bit z-axis acceleration in units of 1/300th of a metet/second/second.</td></tr>
<tr><td>17</td><td>Z_Accel(LSB)</td></tr>
<tr><td>18</td><td>TAS(MSB)</td><td colspan="2" rowspan="2">Unsigned 16-bit true air speed in units of 1/100th of a meter per second. 0xFFFF if this value is unavailable.</td></tr>
<tr><td>19</td><td>TAS(LSB)</td></tr>
</table>

4.2.4 Host attitude packet: 0x42

The host attitude packet is used to inform the gimbal of the host attitude information. The gimbal can use this information to aid or replaces its internal navigation solution. The data in this packet must be supplied in the gimbal's natural coordinate frame, i.e. the Euler angles of the gimbal mount relative to inertial space.

Table 14. Host attitude packet data contents

<table>
<tr><th>Byte</th><th>Name</th><th>Meaning</th></tr>
<tr><td>0</td><td>Time(MSB)</td><td rowspan="4">Unsigned 32-bit host time in milliseconds.</td></tr>
<tr><td>1</td><td>Time(1)</td></tr>
<tr><td>2</td><td>Time(2)</td></tr>
<tr><td>3</td><td>Time(LSB)</td></tr>
<tr><td>4</td><td>Roll(MSB)</td><td rowspan="2">Signed 16 bit host Euler roll angle in 1/100th deg. From –180° to 180°.</td></tr>
<tr><td>5</td><td>Roll(LSB)</td></tr>
</table>

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6	Pitch(MSB)	Signed 16 bit host Euler pitch angle in 1/100th deg. From -90° to 90°.	
7	Pitch(LSB)		
8	Yaw(MSB)	Signed 16 bit host Euler yaw angle in 1/100th deg. From -180° to 180°.	
9	Yaw(LSB)		
10	Flags	Bits	Meaning
		0-5	Reserved, set to zero.
		6	Set this bit to tell the gimbal to use the yaw information to aid the internal GPS/INS filter.
		7(lsb)	Set this bit to tell the gimbal to overwrite its internal attitude solution with the data in this packet. This can also be accomplished with the navigation source packet.
11	SampleRate	Unsigned 8-bit rate at which this packet is being supplied to the gimbal in packets per second.	

4.3 Position information packets, group 0x10

Table 15. Packet types for position information group 0x10

Name	PktType	Dir	Freq	Meaning
HOST_GPS_DATA	0x10	In	N/A	Host GPS information.
SPOI_CMD	0x40	In	N/A	Sensor point of interface command.
GEOREFERENCE_DATA	0x41	Out	4	Data needed to geo-reference the image data.

4.3.1 Host GPS data

The host GPS data packet is used to inform the gimbal of the host location and velocity. The gimbal can use this information to perform sensor point of interest control or to provide metadata to downstream devices. Position data is relative to the WGS-84 ellipsoid.

Table 16. Host GPS packet data contents

Byte	Name	Meaning
0	Time_0	Unsigned 32-bit host time in milliseconds.
1	Time_1	
2	Time_2	
3	Time_3	
4	Lat_0	32-bit signed integer latitude, in milli-arcseconds.
5	Lat_1	
6	Lat_2	
7	Lat_3	
8	Lon_0	32-bit signed integer longitude, in milli-arcseconds.
9	Lon_1	
10	Lon_2	
11	Lon_3	
12	Height_0	32-bit signed integer GPS height, in centimeters above the ellipsoid.
13	Height_1	
14	Height_2	
15	Height_3	
16	Vnorth_0	16-bit signed integer North component of the groundspeed, in centimeters per second.
17	VNorth_1	
18	VEast_0	16-bit signed integer East component of the groundspeed, in

19	VEast_1	centimeters per second.
20	VDown_0	16-bit signed integer Down component of the groundspeed, in centimeters per second.
21	VDown_1	
22	Year_0	16-bit unsigned GPS year.
23	Year_1	
24	Month	GPS month, 1…12
25	Day	GPS day, 1…31
26	Hour	GPS hour, 0…23
27	Minute	GPS minutes, 0…59
28	Second	GPS seconds, 0…59
29	FracSecond	GPS fractional seconds in 0.01 seconds 0…99
30	Valid	1 if GPS data is valid, else 0
31	SampleRate	Unsigned 8-bit rate at which this packet is being supplied to the gimbal in packets per second.

4.3.2 Sensor point of interest command

The sensor point of interest (SPOI) command packet is used to command the gimbal to point at a specific location in inertial space. This packet is only useful if the gimbal is receiving regular host attitude and GPS packets. When this command is received the gimbal will switch to sensor point of interest tracking mode. The gimbal will propagate the sensor point of interest command according to the SPOI velocity. Position data is relative to the WGS-84 ellipsoid. Send this packet with zero length to request the current SPOI information.

Table 17. Sensor point of interest command packet data contents

Byte	Name	Meaning	
0	Lat_0	32-bit signed integer latitude of the sensor point of interest, in milli-arcseconds.	
1	Lat_1		
2	Lat_2		
3	Lat_3		
4	Lon_0	32-bit signed integer longitude of the sensor point of interest, in milli-arcseconds.	
5	Lon_1		
6	Lon_2		
7	Lon_3		
8	Height_0	32-bit signed integer height of the sensor point of interest, in centimeters above the ellipsoid.	
9	Height_1		
10	Height_2		
11	Height_3		
12	Vnorth_0	16-bit signed integer North component of the groundspeed of the SPOI, in centimeters per second.	
13	VNorth_1		
14	VEast_0	16-bit signed integer East component of the groundspeed of the SPOI, in centimeters per second.	
15	VEast_1		
16	VDown_0	16-bit signed integer Down component of the groundspeed of the SPOI, in centimeters per second.	
17	VDown_1		
18	Flags	Packet flags	
		0) MSB	If this packet is sent to the gimbal then set this bit to request an echo of this packet for confirmation. If this packet is received from the gimbal this bit will be set if stabilization is on.
		1-7) Mode	If this packet is received from the gimbal the mode will be recorded here.

4.3.3 Gimbal geo-referencing data: 0x41

The gimbal telemetry packet reports the gimbal position, and camera angels. The camera angels are determined from the gimbal mount orientation, and gimbal angles. The gimbal position and mount orientation may be supplied by the host system or may be determined within the gimbal itself using its own sensors. This information can be used by video processing systems to geo-reference the image information.

Table 18. Gimbal geo-referencing data

Byte	Name	Meaning
0	Time_0	Unsigned 32-bit gimbal time since reset in milliseconds.
1	Time_1	
2	Time_2	
3	Time_3	
4	Lat_0	32-bit signed integer latitude, in milli-arcseconds.
5	Lat_1	
6	Lat_2	
7	Lat_3	
8	Lon_0	32-bit signed integer longitude, in milli-arcseconds.
9	Lon_1	
10	Lon_2	
11	Lon_3	
12	Height_0	32-bit signed integer GPS height, in centimeters above the ellipsoid.
13	Height_1	
14	Height_2	
15	Height_3	
16	Vnorth_0	16-bit signed integer North component of the groundspeed, in centimeters per second.
17	VNorth_1	
18	VEast_0	16-bit signed integer East component of the groundspeed, in centimeters per second.
19	VEast_1	
20	VDown_0	16-bit signed integer Down component of the groundspeed, in centimeters per second.
21	VDown_1	
22	Year_0	16-bit unsigned GPS year.
23	Year_1	
24	Month	GPS month, 1…12.
25	Day	GPS day, 1…31.
26	Hour	GPS hour, 0…23.
27	Minute	GPS minutes, 0…59.
28	Second	GPS seconds, 0…59.
29	FracSecond	GPS fractional seconds in 0.01 seconds 0…99.
30	NumSats	Number of satellites tracked by the GPS.
31	PDOP	Position dilution of precision in units of 0.1 PDOP.
32	Status_0	16-bit GPS status word.
33	Status_1	• Bit 0-2 (msb): 111 = 3D Fix 110 = 2D Fix 101 = Propagate Mode 100 = Position Hold 011 = Acquiring Satellites 010 = Bad Geometry 001 = Reserved 000 = Reserved • Bit 3: Set if dead-reckoned • Bit 4: Set if satellite based augmentation system

		• Bit 5: Reserved • Bit 6: Fast acquisition position • Bit 7: GPS data are raw (unfiltered) • Bit 8: GPS is performing cold start • Bit 9: GPS is differentially corrected • Bit 10: Position lock mode enabled • Bit 11: Auto survey mode • Bit 12: Insufficient satellites visible • Bit 13-14: 11 = No antenna power 10 = Antenna undercurrent 01 = Antenna overcurrent 00 = Antenna good • Bit 15: Reserved
34	CameraRoll_0	Signed 16 bit Euler roll angle of the camera in 1/100th deg. From -180° to 180°.
35	CameraRoll_1	
36	CameraPitch_0	Signed 16 bit Euler pitch angle of the camera in 1/100th deg. From -90° to 90°.
37	CameraPitch_1	
38	CameraYaw_0	Signed 16 bit Euler yaw angle of the camera in 1/100th deg. From -180° to 180°.
39	CameraYaw_1	
40	HFOV_0	Unsigned 16-bit horizontal field of view of the active camera in 1/100th deg.
41	HFOV_1	
42	VFOV_0	Unsigned 16-bit vertical field of view of the active camera in 1/100th deg.
43	VFOV_1	
44	Focal_0	Unsigned 16-bit focal length in 1/100th of a millimeter.
45	Focal_1	
46	Mode	Operational mode of the gimbal: Bit 0) MSB — Set if stabilization is on Bit 1) — Set if 3AX in deployed state. Bit 2) — Set if 3AX in retracted state. Bits 1-7) — The mode of the gimbal: • Rate feedback • Position feedback • Sensor point of interest • Pan initialization • Tilt initialization • Position initialization
47	SampleRate	Unsigned 8-bit rate at which this packet is being sent.
48	NavHealth_0	16 bit GPS/INS navigation health information, bit set to indicate residual error or covariance is within bounds. Bit 0: Position. Bit 1: Velocity. Bit 2: Reserved. Bit 3: Reserved. Bit 4: Reserved. Bit 5: Reserved. Bit 6: Heading. Bit 7: Attitude. Bit 8: Gyro bias. Bit 9: Accelerometer bias. Bit 10: Magnetometer bias. Bit 11: Reserved. Bit 12-15: Filter mode: init, align, ready, normal, AHRS.
49	NavHealth_1	

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50	MountRoll_0	Signed 16 bit Euler roll angle of the gimbal mount in 1/100th deg. From -180° to 180°.
51	MountRoll_1	
52	MountPitch_0	Signed 16 bit Euler pitch angle of the gimbal mount in 1/100th deg. From -90° to 90°.
53	MountPitch_1	
54	MountYaw_0	Signed 16 bit Euler yaw angle of the gimbal mount in 1/100th deg. From -180° to 180°.
55	MountYaw_1	
56	Pan_0	Signed 16 bit pan position in 1/100th deg. From -180° to 180°.
57	Pan_1	
58	Tilt_0	Signed 16 bit tilt position in 1/100th deg. From -270° to 90°.
59	Tilt_1	
60	Roll_0	Signed 16 bit roll position in 1/100th deg. From -180° to 180°.
61	Roll_1	
62	Camera	Camera designator indicating which camera is active, 0 for camera A, 1 for camera B, 2 for camera C.

4.4 Gimbal setup packets, group 0x48

The gimbal setup packets are used to configure the gimbal for custom operation. Anytime the gimbal receives one of these packets it replies by sending the packet back. Hence each of these packets can be sent as zero length in order to query the current settings. The data in these packets are stored onboard the gimbal so that they will survive a power cycle.

Table 19. Packet types for gimbal setup group 0x48

Name	PktType	Dir	Freq	Meaning
PACKET_RATE	0x00	Both	N/A	Setup and query of the rates of the various gimbal telemetry packets.
SENSOR_FILTER	0x01	Both	N/A	Setup and query the filter parameters used for stabilization.
AXIS_SETTING	0x02	Both	N/A	Setup and query the gimbal axis control data.
SYSTEM_VERSION	0x03	Both	N/A	Query of system version iformation.
NAV_SOURCE	0x04	Both	N/A	Setup of navigation sources
CAMERA_TYPE	0x05	Both	N/A	Setup of camera types
GPS_LEVER_ARM	0x06	Both	N/A	Setup of GPS lever arm
CAMERA_ALIGN	0x07	Both	N/A	Alignment of camera

4.4.1 Gimbal Packet Rate

The packet rate packet is used to specify or query the rates at which the gimbal telemetry packets are output. This packet can be used to modify the default behavior in order to reduce the telemetry bandwidth requirement or to improve time resolution (at the expense of bandwidth). A zero packet rate will disable output for that packet.

Table 20. Gimbal packet rate

Byte	Name	Meaning
0	Angle_1	GIMBAL_ANGLE Packet rate in packets per second for external

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		communications port 1. Defaults to 10.
1	Rate_1	GIMBAL_RATE Packet rate in packets per second for external communications port 1. Defaults to 10.
2	Geo-ref_1	GEO_REFERENCE Packet rate in packets per second for external communications port 1. Defaults to 4.
3	Camera_1	Reserved for camera details.
4	Reserved	Reserved byte set to zero.
5	Angle_2	GIMBAL_ANGLE Packet rate in packets per second for external communications port 2. Defaults to 10.
6	Rate_2	GIMBAL_RATE Packet rate in packets per second for external communications port 2. Defaults to 10.
7	Geo-ref_2	GEO_REFERENCE Packet rate in packets per second for external communications port 2. Defaults to 4.
8	Camera_2	Reserved for camera details.
9	Reserved	Reserved byte set to zero.
10	Angle_3	GIMBAL_ANGLE Packet rate in packets per second for external communications port 3. Defaults to 10.
11	Rate_3	GIMBAL_RATE Packet rate in packets per second for external communications port 3. Defaults to 10.
12	Geo-ref_3	GEO_REFERENCE Packet rate in packets per second for external communications port 3. Defaults to 4.
13	Camera_3	Reserved for camera details.
14	Reserved	Reserved byte set to zero.
15	Temporary	Set this to 1 to make these settings temporary (i.e. don't write them to nonvolatile storage)

4.4.2 Gimbal sensor filter

The sensor filter packet provides the ability to control the inertial sensor filters that control the bandwidth of the data used to provide stabilization.

Table 21. Gimbal sensor filter

Byte	Name	Meaning
0	Cutoff	Cutoff frequency in 0.1Hz for the 2nd order Butterworth low pass filter applied to the gyro data before being fed to the stabilization. Lower values reduce noise, higher values increase stabilization bandwidth. Default is 10Hz.
1	Decimation	Gyro rate decimation in 1/10th deg/s. If the absolute value of the gyro rate signal is less than this value the rate will be treated as zero. Increasing this value reduces the effects of gyro noise and bias error at the expense of stabilization accuracy. Default is 0.5 deg/s.

4.4.3 Axis settings

The axis settings packet provides the ability to control the settings used to drive the gimbal axis actuators. It can be used to adjust the actuator to account for camera mass and rotation limitations due to cabling or physical interference issues. When sending this packet use 0xFF (or 0xFFFF for 16-bit values) to indicate that you don't want to change a parameter.

Table 22. Gimbal axis settings

Byte	Name	Meaning

0	Pan_NoGo_Center_0	16-bit signed center of the pan no go range in 1/100th deg from -180° to 180°. The no go range defines a region in which the system cannot go because of physical limitations. Default is zero.
1	Pan_NoGo_Center_1	
2	Pan_NoGo_Range_0	16-bit unsigned range of the pan no go area in 1/100th deg from 0° to 360°. If the no go range is zero then the axis is free running. Default is zero.
3	Pan_NoGo_Range_1	
4	Tilt_NoGo_Center_0	16-bit signed center of the Tilt no go range in 1/100th deg from -270° to 90°. Default is 90°.
5	Tilt_NoGo_Center_1	
6	Tilt_NoGo_Range_0	16-bit unsigned range of the Tilt no go area in 1/100th deg from 0° to 360°. Default is 60°.
7	Tilt_NoGo_Range_1	
8	Roll_NoGo_Center_0	16-bit signed center of the Roll no go range in 1/100th deg from -180° to 180°. Ignored.
9	Roll_NoGo_Center_1	
10	Roll_NoGo_Range_0	16-bit unsigned range of the Roll no go area in 1/100th deg from 0° to 360°. Ignored.
11	Roll_NoGo_Range_1	
12	Pan_MaxRate	Max pan rate in units of 5°/s. Default is 300°/s.
14	Tilt_MaxRate	Max tilt rate in units of 5°/s. Default is 300°/s.
15	Roll_MaxRate	Max roll rate in units of 5°/s. Ignored.
16	Pan_MaxAccel	Max pan acceleration in units of 200°/s/s. Default is 10,000°/s/s
17	Tilt_MaxAccel	Max tilt acceleration in units of 200°/s/s. Default is 10,000°/s/s
18	Roll_MaxAccel	Max roll acceleration in units of 200°/s/s. Ignored.
19	Pan_PosGain	Pan position feedback gain in units of 0.1 °/s commanded rate per degree of position error. Default is 4[(°/s)/°]
20	Tilt_PosGain	Tilt position feedback gain in units of 0.1 °/s commanded rate per degree of position error. Default is 4[(°/s)/°]
21	Roll_PosGain	Roll position feedback gain in units of 0.1 °/s commanded rate per degree of position error. Ignored
22	Temporary	Set this to 1 to make these settings temporary (i.e. don't write them to nonvolatile storage)

4.4.4 Gimbal System Version

The system version packet is used to request version information from the gimbal. The version information includes both hardware and software versions and camera information. Send this packet as zero length to request the version information.

Table 23. Gimbal system version packet

Byte	Name	Meaning
0	Major	Major version number of the gimbal software.
1	Minor	Minor version number of the gimbal software.
2	Sub	Sub version number of the gimbal software.
3	Released	One if software is released, else test version.
4	SoftYear_0	16-bit unsigned year of the software release.
5	SoftYear_1	
6	SoftMonth	Month of the software release, 1-12.
7	SoftDay	Day of the software release, 1-31.

8	BoardSN_0	Unsigned 32-bit board serial number.
9	BoardSN_1	
10	BoardSN_2	
11	BoardSN_3	
12	BoardRev_0	Unsigned 32-bit board revision number.
13	BoardRev_1	
14	BoardRev_2	
15	BoardRev_3	
16	BoardConfig_0	Unsigned 32-bit board configuration code.
17	BoardConfig_1	
18	BoardConfig_2	
19	BoardConfig_3	
20	BoardYear_0	16-bit unsigned year of the board fabrication
21	BoardYear_1	
22	BoardMonth	Month of the board fabrication, 1-12
23	BoardDay	Day of the board fabrication, 1-31
24	Camera A	Identifier for the first camera, See Table 28.
25	Reserved	
26	MaxHFOV_A_0	Unsigned 16 bit maximum horizontal field of view in $1/100^{th}$ of a degree for camera A.
27	MaxHFOV_A_1	
28	MinHFOV_A_0	Unsigned 16 bit minimum horizontal field of view in $1/100^{th}$ of a degree for camera A.
29	MinHFOV_A_1	
30	Camera B	Identifier for the second camera, 0xFF if none. See Table 28.
31	Reserved	
32	MaxHFOV_B_0	Unsigned 16 bit maximum horizontal field of view in $1/100^{th}$ of a degree for camera B.
33	MaxHFOV_B_1	
34	MinHFOV_B_0	Unsigned 16 bit minimum horizontal field of view in $1/100^{th}$ of a degree for camera B.
35	MinHFOV_B_1	
36	Camera C	Identifier for the third camera, 0xFF if none. See Table 28.
37	Reserved	
38	MaxHFOV_C_0	Unsigned 16 bit maximum horizontal field of view in $1/100^{th}$ of a degree for camera C.
39	MaxHFOV_C_1	
40	MinHFOV_C_0	Unsigned 16 bit minimum horizontal field of view in $1/100^{th}$ of a degree for camera C.
41	MinHFOV_C_1	

4.4.5 Gimbal Navigation Source

The gimbal has its own set of inertial sensors and its own GPS. By default it runs its own GPS/INS solution to generate the high rate position, velocity, and attitude information needed to perform sensor point of interest (SPOI) calculations. However external systems can supply their own data by sending this packet to change the navigation source information. Send this packet with zero length to query the navigation source settings.

Table 24. Gimbal navigation source packet

Byte	Name	Meaning
0	ExternalAttitude	If this byte is nonzero then the attitude solution used for SPOI calculations will be taken from the Host Attitude packet. In addition the gyro biases will be estimated by comparing the locally measured angular rates with the rates arriving in the Host Body Rates packet. If this field is clear the host data are not

		used and attitude and gyro bias estimates are done using a GPS/INS filter.
1	ExternalGPS	If this byte is set then the system will default to using the GPS data from the Host GPS packet. If the external attitude byte is clear the host GPS will be fed into the GPS/INS filter and its output will be used for SPOI. If the external attitude byte is set then the position and velocity will be taken directly from the host GPS.

4.4.6 *Camera Type*

The camera type packet is used to request or change the camera type. The gimbal uses the camera type to determine how to communicate to a camera. This packet is typically only used during manufacturing setup.

Table 25. Gimbal system version packet

Byte	Name	Meaning
0	Camera A	Type of the first camera, 0x0 is do not change, 0xFF is no camera. See Table 28.
1	Camera B	Type of the second camera, 0x0 is do not change, 0xFF is no camera. See Table 28.
2	Camera C	Type of the third camera, 0x0 is do not change, 0xFF is no camera. See Table 28.

4.4.7 *GPS Lever Arm*

The GPS lever arm gives the distance from the IMU of the gimbal to the GPS antenna. This data are used in the GPS/INS navigation filter. On the TASE gimbal the IMU is located at the top front of the man electronics housing (the side furthest from the connectors). When traveling from the IMU to the GPS, if the motion goes in a positive direction with respect to gimbal coordinates, than the lever arm is positive.

Table 26. GPS lever arm

Byte	Name	Meaning
0 1	X ant	16-bit signed X distance from the avionics IMU to the GPS antenna in millimeters.
2 3	Y ant	16-bit signed Y distance from the avionics IMU to the GPS antenna in millimeters.
4 5	Z ant	16-bit signed Z distance from the avionics IMU to the GPS antenna in millimeters.

4.4.8 *Camera alignment*

The camera alignment gives the error between the cameras boresight axis and the gimbal position as measured by the encoders. The camera alignment can vary as a function of camera optical zoom and hence is measured in two different locations. The sign convention on the alignment is confusing. Assuming the gimbal is mounted such that zero pan and zero tilt should provide a centered image, than if the image is to the right of center the pan error is positive; and

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if the image is above center the tilt error is positive. (i.e. if you center the image the current pan and tilt reading will be the error).

Table 27. Camera alignment

Byte	Name	Meaning
0 1	Zoom_1	Unsigned 16-bit zoom ratio at which the first alignment measurement was taken, in units of 1/100th.
2 3	PanErr_1	Signed 16-bit pan error at the first zoom ratio in 1/100th of degree.
4 5	TiltErr_1	Signed 16-bit tilt error at the first zoom ratio in 1/100th of degree.
6 7	RollErr_1	Signed 16-bit roll error at the first zoom ration in 1/100th of a degree.
8 9	Zoom_2	Zoom ratio at which the second alignment measurement was taken, in units of 1/100th.
10 11	PanErr_2	Signed 16-bit Pan error at the second zoom ratio in 1/100th of degree.
12 13	TiltErr_2	Signed 16-bit Tilt error at the second zoom ratio in 1/100th of degree.
14 15	RollErr_2	Signed 16-bit Roll error at the second zoom ration in 1/100th of a degree.

4.5 Camera Type

The camera types supported by the gimbal are given below

Table 28. Gimbal camera types

Type	Name	Meaning
36	SONY_FCB_EX480B	Sony 480B block camera, 18x optical zoom, NTSC
37	SONY_FCB_EX480BP	Sony 480B block camera, 18x optical zoom, PAL
38	SONY_FCB_EX48B	Sony 48B block camera, 18x optical zoom, NTSC
39	SONY_FCB_EX48BP	Sony 48B block camera, 18x optical zoom, PAL
48	SONY_FCB_EX980	Sony 980 block camera, 26x optical zoom, NTSC
49	SONY_FCB_EX980P	Sony 980 block camera, 26x optical zoom, PAL
50	SONY_FCB_EX980S	Sony 980 block camera, 26x optical zoom, NTSC, with built-in stabilizer
51	SONY_FCB_EX980SP	Sony 980 block camera, 26x optical zoom, PAL, with built-in stabilizer
52	SONY_FCB_EX480C	Sony 480C block camera, 18x optical zoom, NTSC
53	SONY_FCB_EX480CP	Sony 480C block camera, 18x optical zoom, PAL
68	SONY_FCB_EX1010	Sony 1010 block camera, 36x optical zoom, NTSC
69	SONY_FCB_EX1010P	Sony 1010 block camera, 36x optical zoom, PAL

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95	FLIR_320_PHOTON_14	FLIR Indigo Photon IR camera with 14° FOV lens
96	FLIR_320_PHOTON_20	FLIR Indigo Photon IR camera with 20° FOV lens
97	FLIR_320_PHOTON_23	FLIR Indigo Photon IR camera with 23° FOV lens
98	FLIR_320_PHOTON_36	FLIR Indigo Photon IR camera with 36° FOV lens
99	FLIR_320_PHOTON_50	FLIR Indigo Photon IR camera with 50° FOV lens
112	THERMOTEKNIX_MIRICLE_110_41	Thermoteknix miracle 110 IR camera with 40.9° FOV lens
113	THERMOTEKNIX_MIRICLE_110_24	Thermoteknix miracle 110 IR camera with 23.7° FOV lens
114	THERMOTEKNIX_MIRICLE_110_15	Thermoteknix miracle 110 IR camera with 15.3° FOV lens
115	THERMOTEKNIX_MIRICLE_110_10	Thermoteknix miracle 110 IR camera with 10.2° FOV lens
120	THERMOTEKNIX_MIRICLE_307_48	Thermoteknix miracle 307 IR camera with 47.9° FOV lens
121	THERMOTEKNIX_MIRICLE_307_28	Thermoteknix miracle 307 IR camera with 28.1° FOV lens
122	THERMOTEKNIX_MIRICLE_307_18	Thermoteknix miracle 307 IR camera with 18.2° FOV lens
123	THERMOTEKNIX_MIRICLE_307_13	Thermoteknix miracle 307 IR camera with 12.2° FOV lens

5 CAN interface

The gimbal can be interfaced over a CAN connection. The datalink layer remains exactly the same, and the bytes of each packet are simply encapsulated within consecutive CAN frames. Note that this requires that the time order of CAN frames be preserved on the bus. The CAN bus runs at 1Mbaud

5.1 Gimbal input CAN frames

CAN frames with an ID value of 0x11000000 are input frames that are interpreted as data going to the gimbal. The frame length can be from 1 to 8 bytes as needed.

5.2 Gimbal output CAN frames

CAN frames with an ID value of 0x10000000 are output frames that are interpreted as data coming from the gimbal. The frame length can be from 1 to 8 bytes as needed.

5.3 3AX axis control

The 3AX is a gimbal mounting drive system to deploy and retract TASE gimbals. A small microprocessor on the 3AX performs the actual motor control for retract and deploy operation. The TASE and the 3AX communicate over CAN using the following frames:

5.3.1 Move command, 0x12010000

This two byte message is sent by the TASE gimbal to command the 3AX to perform a retraction or deployment

Table 29. Move command CAN frame ID 0x12010000

Byte	Name	Meaning
0	Position	0 for deploy, else retract commanded
1	Reserved	Set to zero.

5.3.2 Moving command, 0x12020000

This two byte message is sent by the 3AX periodically to indicate the position and movement status of the retract deploy mechanism.

Table 30. Move command CAN frame ID 0x12010000

Byte	Name	Meaning
0	Position	From 0 (completely deployed) to 0xFE (completely retracted). 0xFF is reserved to indicate that the position is unknown.
1	Speed	Signed 8 bit number indicating the speed of deployment in units of 5 deg/sec. The speed is positive if the system is retracting, else negative.

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6 KLV format

The gimbal supports a KLV output (Key, Length, Value) output packet. The packet is output at 9600 baud as fast as the serial port can accept it, about every 900 milliseconds. The packet format is given in Table 31.

Table 31. KLV output packet format.

Byte	Name	Value/Meaning
0	Master key	0x06
1		0x0E
2		0x2B
3		0x34
4		0x02
5		0x03
6		0x01
7		0x01
8		0x00
9		0x00
10		0x00
11		0x00
12		0x00
13		0x00
14		0x00
15		0x00
16	Key length	69
17	UTC key	1
18	Key length	8
19	Value_0	Unsigned 64-bit number of microseconds since Midnight Jan 1 1970.
20	Value_1	
21	Value_2	
22	Value_3	
23	Value_4	
24	Value_5	
25	Value_6	
26	Value_7	
27	Lat key	2
28	Key length	4
29	Value_0	Signed 32-bit latitude of the sensor as half circle over 2^32: Latitude_deg = Value*4294967296.0/180.0 Latitude_rad = Value*4294967296.0/Π
30	Value_1	
31	Value_2	
32	Value_3	
33	Lon key	3
34	Key length	4
35	Value_0	Signed 32-bit longitude of the sensor as full circle over 2^32: Longitude_deg = Value*4294967296.0/360.0 Longitude_rad = Value*4294967296.0/2Π
36	Value_1	
37	Value_2	
38	Value_3	
39	Alt key	4
40	Key length	2
41	Value_0	Unsigned 16-bit altitude[m] of the sensor from -900 to 10000: Altitude = Value*65536/10900 - 900
42	Value_1	
43	Pan key	5

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44	Key length	2
45	Value_0	Unsigned 16-bit sensor relative azimuth (i.e. Pan) from 0.0 to 360.0 deg: Azimuth_deg = Value*65536/360.0 Azimuth_rad = Value*65536/2Π
46	Value_1	
47	Tilt key	6
48	Key length	2
49	Value_0	Signed 16-bit sensor relative elevation (i.e. Tilt): Elevation_deg = Value*65536/360.0 Elevation_rad = Value*65536/2Π
50	Value_1	
51	Heading key	7
52	Key length	2
53	Value_0	Unsigned 16-bit platform heading from 0.0 to 360.0 deg: Heading_deg = Value*65536/360.0 Heading_rad = Value*65536/2Π
54	Value_1	
55	Pitch key	8
56	Key length	2
57	Value_0	Signed 16-bit platform pitch angle from -20.0 to 20.0 deg: Pitch_deg = Value*65536/40.0 Pitch_rad = Value*65536/(40.0Π /180.0)
58	Value_1	
59	Roll key	9
60	Key length	2
60	Value_0	Signed 16-bit platform roll angle from -50.0 to 50.0 deg: Roll_deg = Value*65536/100.0 Roll_rad = Value*65536/(100.0Π /180.0)
61	Value_1	
62	VNorth key	10
63	Key length	2
64	Value_0	Signed 16-bit North velocity[m/s] of the sensor: VNorth = Value*65536/510.0
65	Value_1	
66	VEast key	11
67	Key length	2
68	Value_0	Signed 16-bit East velocity[m/s] of the sensor: VEast = Value*65536/510.0
69	Value_1	
70	HFOV key	12
71	Key length	2
72	Value_0	Unsigned 16-bit horizontal field of view as half circle over 2^16: HFOV_deg = Value*65536/180.0 HFOV_rad = Value*65536/Π
73	Value_1	
74	VFOV key	13
75	Key length	2
76	Value_0	Unsigned 16-bit vertical field of view as half circle over 2^16: VFOV_deg = Value*65536/180.0 VFOV_rad = Value*65536/Π
77	Value_1	
78	GPS status key	14
79	Key length	2
80	Value_0	16-bit GPS status word. • Bit 0-2 (msb): 111 = 3D Fix 110 = 2D Fix 101 = Propagate Mode 100 = Position Hold 011 = Acquiring Satellites 010 = Bad Geometry 001 = Reserved
81	Value_1	

		000 = Reserved • Bit 3: Set if dead-reckoned • Bit 4: Set if satellite based augmentation system • Bit 5: Reserved • Bit 6: Fast acquisition position • Bit 7: GPS data are raw (unfiltered) • Bit 8: GPS is performing cold start • Bit 9: GPS is differentially corrected • Bit 10: Position lock mode enabled • Bit 11: Auto survey mode • Bit 12: Insufficient satellites visible • Bit 13-14: 11 = No antenna power 10 = Antenna undercurrent 01 = Antenna overcurrent 00 = Antenna good • Bit 15: Reserved
82	Checksum key	15
83	Key length	2
84	Value_0	16-bit unsigned summation of bytes 17 through 81.
85	Value_1	