M2-D
Camera Control Protocol
Ver 1.0

www.x20.org

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Table of Content

1 Overview

The document describes M2-D control protocol. The protocol is supported by the M2-D.

2 Camera Control Protocol

The camera is controlled through RS-232 interface (12V level).

2.1 RS-232

The command and control of the camera is carried over RS-232 link (12V level).

The RS-232 link configuration is depicted in the following:

Speed	19,200 bytes/sec
Start bit	1
Stop bit	1
Parity	Even

2.2 Messages

The protocol includes set of command messages to the camera and acknowledgement messages from the camera

The protocol messages have fixed length of 20 bytes.

The camera sends an acknowledgement message following the reception of a command message. The acknowledgment message can be transmitted while receiving new command message (i.e. the new command message will be processed)

Since the camera is sending a report message in response to every command message. The report rate is set by the controller. SPI Corp recommends to send a command every 50 msec (20 messages per second, complete Correlator data set is transferred within 800msec)

Little Endian ordering is used in coding the command and the report messages.

2.2.1 Camera Command

The camera command message structure is depicted in the following:

Byte	Description
0	Header1 = 0xB0
1	Header2 = 0x3B
2	**Header3 = 0x77 (independent Pan/Tilt Operation)** While in this mode, the camera acts as a 2-axis gimbal. The mode fits any camera mount.

Header3 = 0x78 (auto roll, yaw stabilize to center)

While in this mode, the camera acts like a 3-axis gimbal (pitch/roll/yaw)

The camera should be mounted parallel to the direction of movement (aka horizontal mounting)

The roll axis is internally controlled (without user intervention) to level image with the ground
The pitch axis is controlled by the user using rate commands.
The yaw axis is internally controlled (without user intervention) to compensates for rapid yaw movement. Yaw motion is limited (up to +/- 5deg). The yaw is bypassing slow movement and removes fast movement.

Header3 = 0x79 (auto roll,with yaw control)

While in this mode, the camera acts like a 3-axis gimbal (pitch/roll/yaw)

The camera should be mounted parallel to the direction of movement (aka horizontal mounting)

The roll axis is internally controlled (without user intervention) to level the image with the ground
The pitch axis is controlled by the user using rate commands.
The yaw axis should be controlled by external logic (e.g. SPI Corp controller, system controller) to synchronize with platform movement.

3

Bit	Name	Description
7	EO/IR	0 – EO (Daylight/Visible channel) 1 – IR (Thermal Channel)
6	Reserved	Reserved
5	PIP	1 = Enable Picture in Picture
[0..4]	Mode	0 – Rate (auto drift on) 1 – ***Point to Coordinate**

				2	***Hold Coordinate**		
				3	PILOT (go to Pitch=80°; Roll=0°) Un-stabilized mode		
				4	STOW (go to Pitch=0°; Roll=0°) Un-stabilized mode		
				6	Rate (auto drift off)		
				7	Dynamic Gyro Calibration (LOS should be fixed during gyro calibration)		
				8	Park (go to Pitch=0°; Roll=135°)		
				10	Static Gyro Calibration (Camera base should not move during gyro calibration) & BIT		
				11	***GRR**		
				12	**Reserved 1 for internal compass calibration**		
				13	**Reserved 2 for internal compass calibration**		
				31	Enter EXT Mode – Reserved to enter special modes TBD		
				*	**Functions marked with "*" are**		

				available only when GeoLocation accessory is used.		
4	Bit	Name	Description			
	7	Disable Stabilization	0 – Stabilization ON 1 – Stabilization OFF			
	6	Disable OSD TEXT	0 – Enable OSD TXT 1 – Disable			
	5	Disable OSD Graphics	0 – Enable OSD Graphics 1 – Disable			
	4	Disable TEC	0=TEC Enable (recommended) ***While TEC is on, IR sensor temperature is kept fixed during long period of time removing the need for recurring NUC.*** ***TEC Enabled mode is recommended for indoor operation.*** ***While using this mode an airflow is necessary to prevent over heat*** 1=TEC Disabled ***While TEC is disabled, IR Sensor Temperature Control is turned off. Camera consumes up to 50% less power and external airflow is not necessary.*** ***TEC Disabled mode is recommended for indoor operation.*** ***Thermal performance may degrade during heating or cooling and***			

				frequent NUC may become necessary	
	3	reserved			
	2	Freeze	0=normal 1= freeze		
	1..0	Rate calc	0	Rate does not depend on zoom	
			1	Rate = Rate_In / Zoom *Suitable for slow moving platforms.*	
			2	Rate = Rate_In / (func(zoom)) *Func(zoom) – is a non-linear function designed for fast moving platforms. The function expands stick displacement range while operating in narrow FOV to enhance sensitivity.* *Suitable for fast moving platforms.*	
			3	Reserved	

5 Thermal Control

Bit	Name	Description
7..6	Type	0 Gray Scale  Color1  Color2  Color3 
5	NUC	(Toggle Logic) switching 0->1 or 1->0 generates NUC
4	Polarity	"1" – Black hot "0" – White hot
3..0	Gain/Level	Bit[0] - Level DEC Bit[1] - Level INC Bit[2] - Gain DEC

			Bit[3] - Gain INC Bits[0..3] = "1111" – Reset To Default values (G=128:L=128) • **Gain/Level can also be set by correlator**	

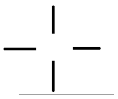
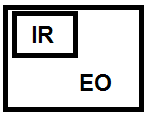
6 Tracking and Record*

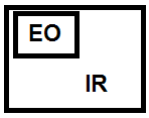
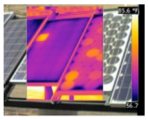
***These functions are available only when Tracking & Recorder accessories are available,**

Bit	Name	Description
[7..4]	Record	0 – Do nothing 1 – Record / Start Recording 2 – Snapshot 3 - Mark *Additional meta data (e.g. GPS location) can be added to video and still images, format TBD
[3..0]	Tracker	

BIT	Function
3..2	0 – ***Disable tracker*** 1 – ***Enable***

					A crosshair is displayed at the center of the screen (even if reticle is disabled) 2 - ***Acquire & Lock***, A target acquisition is executed while switching from either mode 1 or 3 to mode 2. When target is locked the crosshair changes to rectangular. While mode '2' is received the tracker follows the last acquired target, To be able of re-acquiring the target when tracking is lost, it is recommended to switch to mode 3 ("Keep target") when receiving tracker lock indication. 3 – ***Keep target***, While in this mode the camera follows the object automatically to maintain it at the center of the screen. When lock is lost the rectangular changes to crosshair.	
				1..0	***Tracking mode TBD***	

			OSD During tracker Tracker enabled – crosshair  ***Acquire & Lock / Keep target***  back to crosshair when tracking is lost:
7	Reserved		
8	Reserved		
9	Bit	Type	
	7..6	Bit	PIP – Picture in Picture Mode (if enabled)
		0	

<table>
<tr><td></td><td>
<table>
<tr><td></td><td>1</td><td> 
</td><td></td></tr>
<tr><td></td><td>2</td><td>  </td><td></td></tr>
<tr><td></td><td>3</td><td>Reserved</td><td></td></tr>
<tr><td>5..0</td><td colspan="2">Correlator INDEX 0-63</td><td></td></tr>
</table>
</td></tr>
<tr><td>10</td><td>Correlator_Byte_0</td></tr>
<tr><td>11</td><td>Correlator_Byte_1</td></tr>
<tr><td>12</td><td>Correlator_Byte_2</td></tr>
<tr><td>13</td><td>Correlator_Byte_3</td></tr>
<tr><td>14</td><td>
<table>
<tr><th>Bit</th><th>Description</th></tr>
<tr><td>7</td><td>Zoom IN</td></tr>
<tr><td>6</td><td>Zoom OUT</td></tr>
<tr><td>5..4</td><td>Tilt / Pitch LSB</td></tr>
<tr><td>3..2</td><td>Roll LSB</td></tr>
<tr><td>1..0</td><td>Yaw LSB</td></tr>
</table>
</td></tr>
</table>

15	Tilt / Pitch MSB (Header3 = 0x77 or 0x78 or 0x79)
16	PAN / Roll (Header3 = 0x77)
17	YAW MSB (HEADER3 = 0x79)
18	MUST BE (0x00)
19	Check SUM

Correlator = 0 (Latitude float [rad], WGS84)

Correlator = 1 (Longitude float [rad], WGS84)

Correlator = 2 (Altitude, float [m]. Height above EGM96 geoid which approximates mean sea level)

Correlator = 3 (Ground height at line of sight crossing point with ground, signed integer [m], Height above EGM96 geoid which approximates mean sea level)

Byte	Description
0	Ground Height above MSL (LSB) (signed short)

1	Ground Height above MSL (MSB) (signed short)
2	Reserved
3	Reserved

Correlator = 6 (Target Latitude, float [rad], WGS84)

Correlator = 7 (Target Longitude, float [rad], WGS84)

Correlator = 8 (Target Altitude, signed sort[m], Height above EGM96 geoid which approximates mean sea level)

Correlator = 16 (Thermal)

Byte	Description
0	Thermal Gain
1	Thermal Level
2	Auto NUC 0 = Disable 1 = Execute Auto NUC each 30 sec

	2 = Execute Auto NUC each 5min 3 = Execute Auto NUC each 30min 4 = Execute Auto NUC each 60min
3	DAY(EO) Bright

Correlator = 17 (thermal DBG)

Byte	Description
0	Thermal GAIN1 DBG
1	Thermal GAIN2 DBG
2	Thermal GAIN3 DBG
3	Thermal GAIN4 DBG

Correlator = 18

Byte	Description
0	DAY (EO) Bright
1	DAY (EO) Contrast
2	DAY (EO) Color

3	Reserved

Correlator = 19

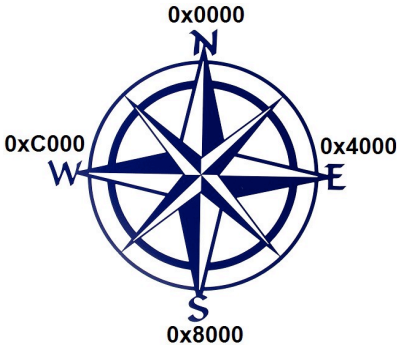
Byte	Description
0	Set Zoom (16 bit)
1	
2	
3	

Correlator = 20 (go to center speed definition)

Byte	Description
0	X to center divider If (=0) GoTo center function at X disabled
1	

2	
3	

Correlator = 21 (External Compass when external compass enabled otherwise use internal)

Byte	Description
0	Azimuth (16 bit unsigned, Clock Wise - CW)
1	
2	
3	

Correlator = 30 (OSD – On Screen Display On/OFF)

<table>
<tr><th>Byte</th><th>Description (‘1’ to enable ‘0’ to disable)</th></tr>
<tr><td>0</td><td>
<table>
<tr><th>Bit</th><th>Name</th></tr>
<tr><td>7</td><td>Pitch/Roll Text</td></tr>
<tr><td>6</td><td>Zoom/FOVText</td></tr>
<tr><td>5</td><td>LOS Azimuth Text & Graphics (---N---W---S---E---)</td></tr>
<tr><td>4</td><td>Camera Position (LAT, LON, ALT) text</td></tr>
<tr><td>3</td><td>BAT voltage text</td></tr>
<tr><td>2</td><td>Reserved</td></tr>
<tr><td>1..0</td><td>Crosshair
<table>
<tr><th>Bit</th><th>Type</th></tr>
<tr><td>0</td><td>Off</td></tr>
</table>
</td></tr>
</table>
</td></tr>
</table>

			1	Type 1	
			2	Type 2	
			3	Type 3	
1		Bit	Name		
		7	Recording indicator		
		6..5	Display measured temperature from the center of the screen 0 - Disable 1 – Display in °C 2 – Display in °F 3 – Display in °K		
		4	‘0’-Internall Compass ‘1’-External		
		3			
		2			
		1..0			

2	
3	

Correlator = 60 (Get camera type , Read Only)

Correlator = 61 (Read Only)

Byte	Description
0	Correlator Number to Read The return stream will contain the data of specified correlator
1	
2	
3	

Correlator = 62 (Main CFG)

Byte	Description		
0	Bit	Name	
	7	Camera Mirror '0' = Non Mirror (useful for horizontal & vertical-up mounting) '1' = Mirror (useful for vertical-down mount)	
	6	NTSC/PAL '0'=PAL '1'=NTSC	
	5	'1' – Force TEST Patern	
	3..0	Reserved	
1	Reserved		
2	Reserved		
3	Reserved		

Notes:

1. The line of sight in Pilot mode is depicted in Figure 1:

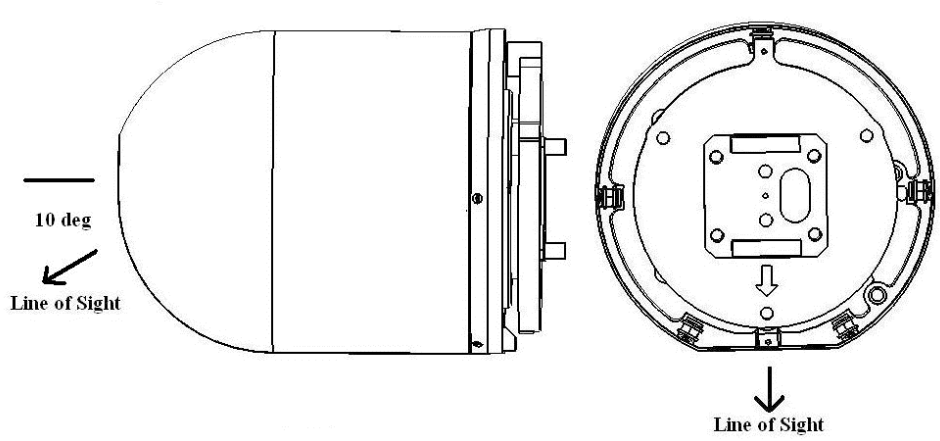


Figure 1 : Pilot Mode Line of Sight

2. The line of sight in STOW mode is depicted in Figure 2 :

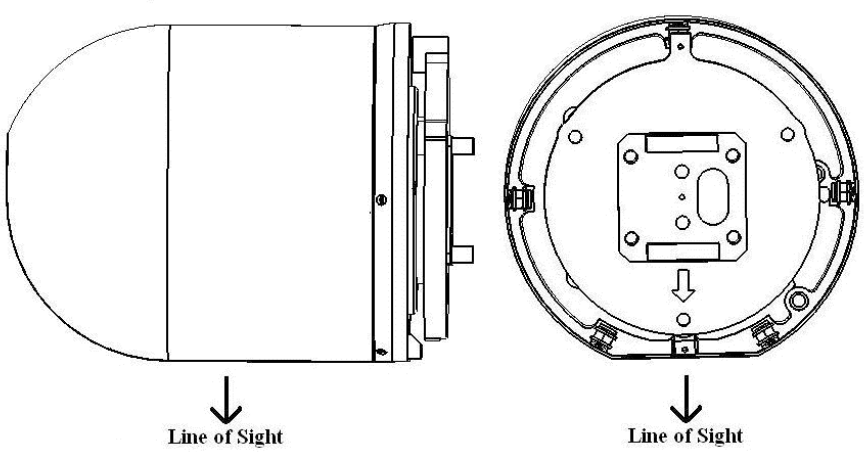


Figure 2 : STOW Mode Line of Sight

3. The line of sight in PARK mode is depicted in Figure 3:

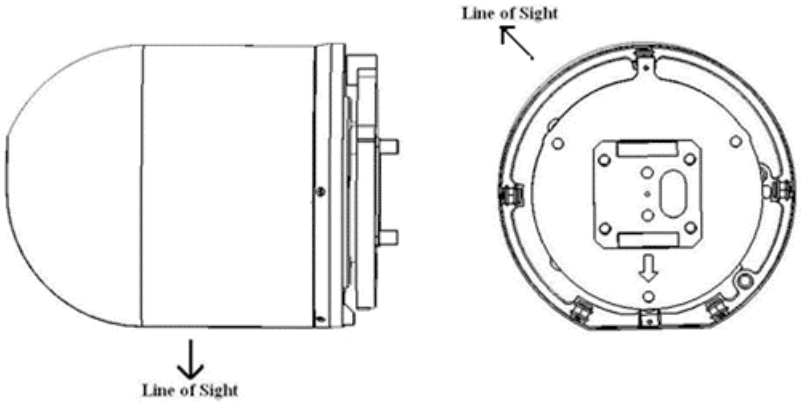


Figure 3: PARK Mode Line of Sight

4. Gyro Calibration is performed once when MODE value changes to 7 or 10. At the end of the calibration process the camera switches to rate mode.

5. When the Rate Mode (Byte 4) is set to 0, the rotation rate does **not** depend on FOV. The rotation rate equals to

   $$Roll\ Rate\ Command - 512512\ [radsec]$$

   $$12 Roll\ Rate\ Command - 512512\ [radsec]$$

   Roll Rate and Pitch Rate commands are formatted with 10 bits unsigned representation (0-1023).

   When the Rate Mode (Byte 4) is set to 1, the rotation rate depends on FOV. The rotation rate equals to

   $$1 zoom Roll\ Rate\ Command - 512512\ [radsec]$$

   $$1 zoom 12 Roll\ Rate\ Command - 512512\ [radsec]$$

   Where,

   $$zoom = Max\ FOV FOV$$

   The direction of camera movement due to positive and negative pitch and roll rates depends on the MIRROR on/off

configuration of the camera. When MIRROR is off the directions are depicted in Figure 4:

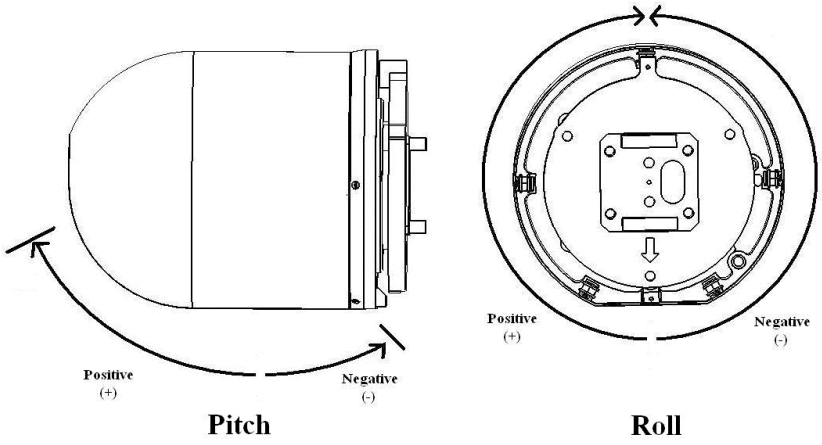


Figure 4 : MIRROR off - Pitch and roll rate command direction

When MIRROR is on the directions are depicted in Figure 5:

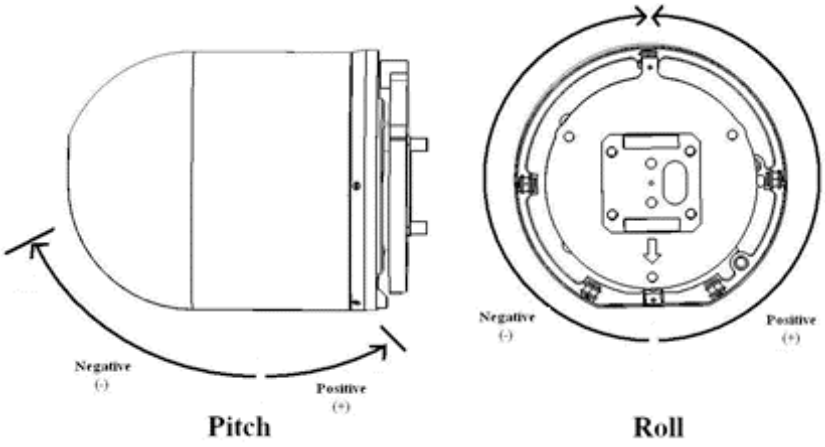


Figure 5 : MIRROR on - Pitch and roll rate command direction

Note that unlike the direction of the rate command, LOS angle report is the same for both MIRROR off and MIRROR on modes. (See section 3)

6. To restore Factory default of Gain and Level all 4 bits [0-3] in should be set to 1. Setting only 2 bits (out of the 4) to 1 will not restore to factory default.

2.2.2 Camera Acknowledgement

The camera acknowledgment message structure is depicted in the following:

<table>
<tr><th>Byte</th><th>Description</th></tr>
<tr><td>0</td><td>Header1 = 0xB0</td></tr>
<tr><td>1</td><td>Header2 = 0x3B</td></tr>
<tr><td>2</td><td>Header3 identical to last received command header 0x77; 0x78 or 0x79</td></tr>
<tr><td>3</td><td>
<table>
<tr><th>Bit</th><th>Name</th><th>Description</th></tr>
<tr><td>7</td><td>IR/EO</td><td>0 – EO (Daylight channel) 1 – IR (Thermal Channel)</td></tr>
<tr><td>6</td><td>Reserved</td><td>0</td></tr>
<tr><td>5</td><td>PIP</td><td>1 = Enable Picture in Picture</td></tr>
<tr><td>[0..4]</td><td>Mode</td><td>
<table>
<tr><td>0</td><td>Rate (auto drift on)</td></tr>
<tr><td>1</td><td>*Point to Coordinate</td></tr>
<tr><td>2</td><td>*Hold Coordinate</td></tr>
<tr><td>3</td><td>PILOT (go to Pitch=80°; Roll=0°) Un-</td></tr>
</table>
</td></tr>
</table>
</td></tr>
</table>

					stabilized mode		
				4	STOW (go to Pitch=0°; Roll=0°) Un-stabilized mode		
				6	Rate (auto drift off)		
				7	Dynamic Gyro Calibration (LOS should be fixed during gyro calibration)		
				8	Park (go to Pitch=0°; Roll=135°)		
				10	Static Gyro Calibration (Camera base should not move during gyro calibration) & BIT		
				11	***GRR**		
				12	**Reserved 1 for internal compass calibration**		
				13	**Reserved 2 for internal compass calibration**		
				31	Enter EXT Mode – Reserved to enter special modes TBD		

4 Record & Tracker status

Bit	Name	Description

	[7..4]	Record	0 – Paused 1 – Recording 14 - Error 15 – Memory Full	
	[3..0]	Tracker	0 – Disabled 1 – Enabled 2 - Acquire & Lock 3 – Keep Target 14 - Error 15 – Lock is lost	
5	FOV (Zoom) Report FOV = 100/1.03^report			
6	Reserved			
7	Pitch/Tilt Report MSB			
8	Roll / Pan Report MSB			
9	**Bits**	**Function**		

<table>
<tr><td></td><td><table>
<tr><td>7..4</td><td>Pitch/Tilt Report LSB</td></tr>
<tr><td>3..0</td><td>Roll / Pan Report LSB</td></tr>
</table></td></tr>
<tr><td>10</td><td>X Report MSB (Internal Gimbal only)</td></tr>
<tr><td>11</td><td>Y Report MSB (Internal Gimbal only)</td></tr>
<tr><td>12</td><td><table>
<tr><th>Bits</th><th>Function</th></tr>
<tr><td>7..4</td><td>X Report LSB (Internal Gimbal only)</td></tr>
<tr><td>3..0</td><td>Y Report LSB (Internal Gimbal only)</td></tr>
</table></td></tr>
<tr><td>13</td><td><table>
<tr><th>Bit</th><th>Type</th></tr>
<tr><td>5..0</td><td>Returned Correlator INDEX 0-63</td></tr>
</table></td></tr>
<tr><td>14</td><td>Correlator_Byte_0</td></tr>
<tr><td>15</td><td>Correlator_Byte_1</td></tr>
<tr><td>16</td><td>Correlator_Byte_2</td></tr>
<tr><td>17</td><td>Correlator_Byte_3</td></tr>
<tr><td>18</td><td>0x00</td></tr>
<tr><td>19</td><td>Check SUM</td></tr>
</table>

Notes

1 The mode field returns value in the mode field of the last camera command.

2 Report of camera HFOV. Report is according to power law in the range 0-255

$$HFOV = 1001.03^{Report\ [deg]}$$

3 Pitch and roll reports are formatted with 12 bits 2's complement representation. The angular report equals to

$$\frac{360}{4096} \times angular\ report \quad [\text{degrees}]$$

The angular report range is -180 to +180 degrees.

The axis for angular report is depicted in Figure 6.

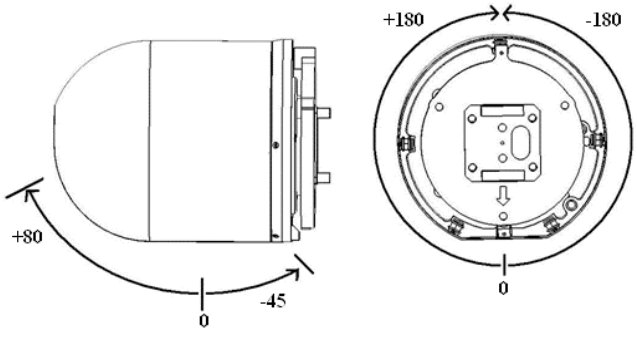


Figure 6 : Range of Rotation

Note that unlike the direction of the rate command, LOS angle report is the same for both MIRROR off and MIRROR on modes. (See section 5)