

XW-4 (CAS-10) Amateur Radio Satellite User's Manual

Ver. 1.0



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The CAMSAT XW-4 (CAS-10) satellite was launched into the Chinese Space Station on November 12, 2022 aboard China's Tianzhou-5 cargo spacecraft, and was launched by the Long March-7 Y6 launch vehicle from the Wenchang Launch Center in Hainan, China. It is currently planned that the XW-4 (CAS-10) satellite will be separated from the Chinese space station and enter operational orbit at 01:30 UTC on December 18, 2022. The functions of XW-4 (CAS-10) satellite include UHF CW telemetry beacon, GMSK telemetry data transmission, V/U mode linear transponder, a visible light band space camera.



China Space Station



XW-4 (CAS-10) satellite

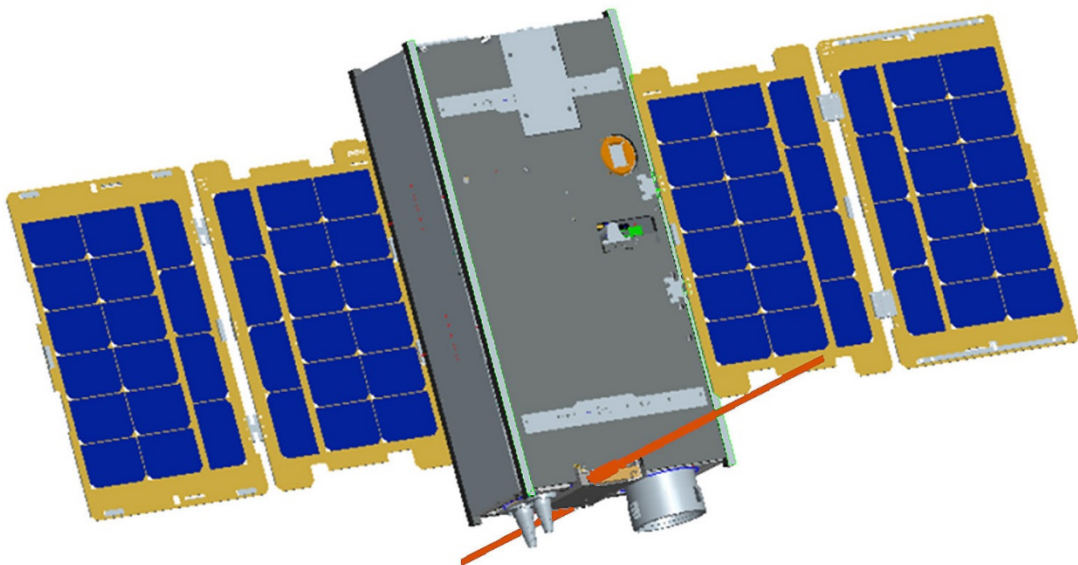
The TLE at the separation point is the same as the China Space Station:

XW-4 (CAS-10)

```
1 48274U 21035A 22349.57666509 .00020514 00000+0 25201-3 0 9994  
2 48274 41.4739 194.5783 0004074 111.0935 347.0781 15.59787538 93120
```

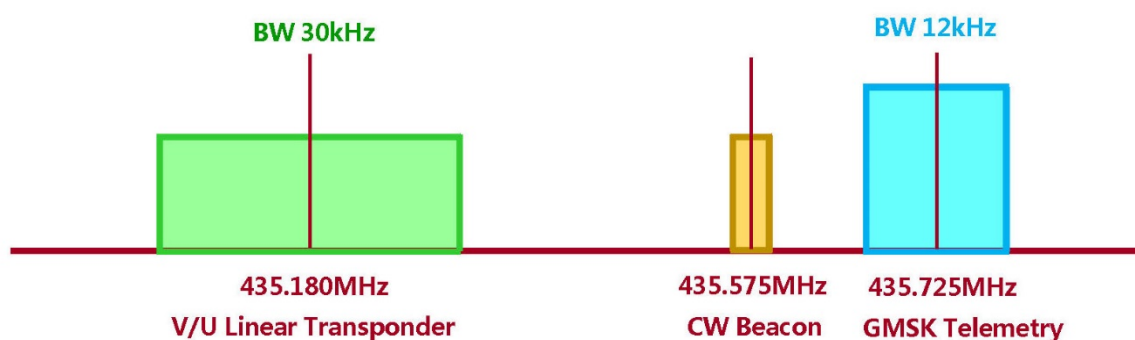
After the satellite completes the in-orbit test and works normally, the space camera photo download will be open to amateur radio enthusiasts all over the world. When the relevant remote control command is received by the satellite, the GMSK telemetry channel will be used to downlink the photo storage information and photo data, and the telemetry data will stop sending at that time.

XW-4(CAS-10) satellite adopts a 8U CubeSat structure with a mass of about 12kg, an on-orbit envelope size of 1007x790x475mm with four solar array panels and a three-axis stabilized attitude control system is used, long-term power consumption is about 18.3 Watts.



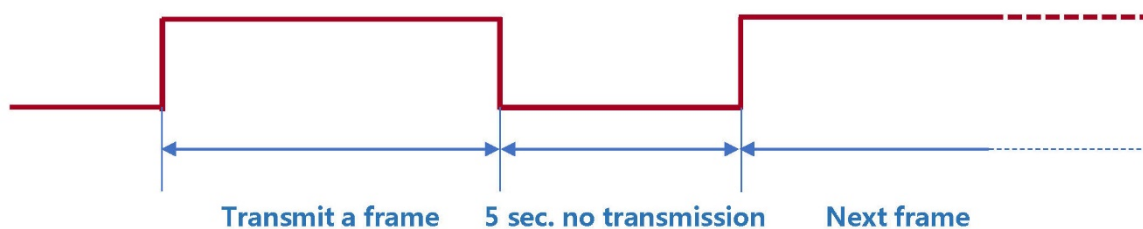
1、 Technical specifications:

- **VHF antenna:** 1/4 wavelength whip antenna
- **UHF antenna:** 1/4 wavelength whip antenna
- **CW telemetry beacon:**
 - Frequency: 435.575MHz ● RF power: 20dBm ● CW rate: 22wpm
- **GMSK telemetry:**
 - Frequency: 435.725MHz ● RF power: 23dBm ● Data rate: 4800bps
- **V/U mode linear transponder:**
 - Uplink frequency: 145.870MHz ● Downlink frequency: 435.180MHz
 - RF power: 20dBm ● Bandwidth: 30kHz ● Spectrum inverted
- **Photo download remote control:**
 - Coming soon...



2、 CW Telemetry Beacon:

(1) CW beacon sending sequence



- Send stop interval time: 5s
- CW sending rate: 22wpm

(2) CW beacon frame format

Sending order	Sending content	Description	Remarks
1	CAS10	Satellite ID	Send in standard Morse code
2	DFH	Telemetry information start identifier	
3	DFH	Telemetry information start identifier	
4	CH1~ CH30	Telemetry channel 1~Telemetry channel 30	Send this channel information, see [Digital Code Table] below
5	CAMSAT	Telemetry information end flag	Send in standard Morse code
6	CAMSAT	Telemetry information end flag	

The telemetry data (CH1 to CH30) are coded as follows:

Digital Code Table

Digital	Code
0	T
1	A
2	U
3	V
4	4
5	E



6	6
7	B
8	D
9	N

(3) CW beacon telemetry information and data analysis

Channel	Parameter name	Type	Value range		Parsing algorithm	Unit
			Mini.	Max.		
CH1	CW telemetry frame transmission counter	data	000	999	Every time a frame is sent, the CW telemetry frame counter is incremented by 1, and starts counting from 000 when it is full	Time
CH2	Remote control command receiving counter	data	000	999	Every time a remote control command is received, the counter is incremented by 1, and start counting from 000 when it is full	Time
CH3	IHU reset counter	data	000	999	Every time IHU is reset, the counter is incremented by 1, and start counting from 000 when it is full	Time
CH4	Device switch status	state	000	711	XYZ X: 0- Linear transponder is off, In-orbit mode, test mode disabled 1- Linear transponder is on, In-orbit mode, test mode disabled 2- Linear transponder is off, On-track mode, test mode is disabled 3- Linear transponder is on, On-track mode, test mode is disabled 4- Linear transponder is off, In-orbit mode, test mode enabled 5- Linear transponder is on, In-orbit mode, test mode enabled 6- Linear transponder is off, On-track mode, test mode is enabled 7- Linear transponder is on, On-track mode, test mode is enabled Y: 0- telemetry data in model 0; 1- telemetry data in mode 1 Z: 0- OBDH time calibration disabled; 1- OBDH time calibration enabled	-
CH5	Device switch status	state	000	111	XYZ X: 0- with OBDH data; 1- without OBDH data Y: Photo download enable (0- disable /1- enable)	-

Channel	Parameter name	Type	Value range		Parsing algorithm	Unit
			Mini.	Max.		
					Z: GMSK Telemetry RF power (0- low power /- 1 high power)	
CH6	12V power supply voltage	data	000	999	V=N/10	V
CH7	VU 12V current	data	000	999	I=N	mA
CH8	VU 5V voltage	data	000	999	V=N/100	V
CH9	VU 3.8V voltage	data	000	999	I=N/100	V
CH10	VU 3.3V voltage 1	data	000	999	V=N/100	V
CH11	VU 3.3V voltage 2	data	000	999	V=N/100	V
CH12	VU 3.8V current	data	000	999	I=N	mA
CH13	Transmitter 3.8V current	data	000	999	I=N	mA
CH14	Receiver 3.8V current	data	000	999	I=N	mA
CH15	AGC voltage	data	000	999	V=N/100	V
CH16	RF transmit power	data	000	999	W=N	mW
CH17	RF reflected power	data	000	999	W=N	mW
CH18	Reserved	data	000	999	V=N/100	V
CH19	Reserved	data	000	999	V=N/100	V
CH20	UHF Transmitter PA temperature	data	000	999	XYZ When X is 0-2, it represents a positive temperature; X is 3-4, it represents a negative temperature.	°C
CH21	VHF Receiver temperature	data	000	999		°C

Channel	Parameter name	Type	Value range		Parsing algorithm	Unit
			Mini.	Max.		
CH22	IHU temperature	data	000	999	$T=N \quad (N \leq 300)$ $T=-1 \times (N-300) \quad (N > 300)$ For example: 000 : 0°C 025 : 25°C 125 : 125°C 301 : -1°C 311 : -11°C 391 : -91°C 421 : -121°C	°C
CH23	Reserved	data	000	999		°C
CH24	Reserved	data	000	999		°C
CH25	Satellite primary bus voltage	data	000	999	$V=N/10$	V
CH26	Satellite load total current	data	000	999	$I=N/100$	A
CH27	Solar array current	data	000	999	$I=N/100$	A
CH28	Battery charging current	data	000	999	$I=N/100$	A
CH29	Battery discharge current	data	000	999	$I=N/100$	A
CH30	+5.3V supply voltage	data	000	999	$V=N/100$	V

3、GMSK telemetry data:

(1) GMSK telemetry frame format and communication protocol

XW-4(CAS-10) satellite GMSK telemetry data is sent in the AX.25 UI frame format. The user data of each frame is 126 bytes, and the allocation is as follows:

Function code	Telemetry data content
7Byte	119Byte
W0~W6: 0x0100010001007E	W7~W125

(2) GMSK telemetry data format and analysis method

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
1	W7	6Byte	Satellite time	W1-Year: 00 ~ 99, representing 2000 ~ 2099 W2-Month: 01 ~ 12, representing January to December W3-Day: 01 ~ 31, representing 1st ~ 31st W4-Hour: 00 ~ 23, representing 0:00 ~ 23:00 W5-minute: 00 ~ 59, representing 0 minutes ~ 59 minutes W6-second: 00 ~ 59, representing 0 seconds ~ 59 seconds
2	W13	6Byte	48 hours reset time	W1-Year: 00 ~ 99, representing 2000 ~ 2099 W2-Month: 01 ~ 12, representing January to December W3-Day: 01 ~ 31, representing 1st ~ 31st

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				W4-Hour: 00 ~ 23, representing 0:00 ~ 23:00 W5-minute: 00 ~ 59, representing 0 minutes ~ 59 minutes W6-second: 00 ~ 59, representing 0 seconds ~ 59 seconds
3	W19	1Byte	Total reset counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
4	W20	1Byte	Telemetry Frame Transmission Counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
5	W21	1Byte	Remote control frame reception counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
6	W22	1Byte	Remote control command execution counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
7	W23	1Byte	Remote control command forwarding counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
8	W24	1Byte	Watchdog switch status	b7b6b5b4: reserved b3: VU CPU I/O acquisition watchdog (0 off/1 on) b2: ADC software watchdog (0 off/1 on) b1: Temperature measurement software watchdog (0 off/1 on) b0: Remote control software watchdog (0 off/1 on)
9	W25	1Byte	CPU I/O acquisition watchdog reset counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
10	W26	1Byte	ADC software watchdog reset counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
11	W27	1Byte	Temperature measurement software watchdog	W1 is an integer. Restart counting from 0 after counting up

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
			reset counter	Range: 0 ~ 255
12	W28	1Byte	Remote control software watchdog reset counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
13	W29	1Byte	Working status 1	b7: Allow to set to track mode (0 disable/1 enable) b6: Photo download enable (0 disable/1 enable) b5: Delayed telemetry switch status (0 off/1 on) b4: Test mode enable (0 disable/1 enable) b3: 0: Linear transponder off; 1: Linear transponder on. b2: OBDH time calibration enable (0 disable/1 enable) b1: Telemetry transmit RF power(0 low power/1 high power) b0: Program control mode enable (0-disable/1 enable)
14	W30	1Byte	Working status 2	b7: In-orbit mode (0 not In-orbit/1 In-orbit) b6: Battery discharge switch is on (0 off/1 on) b5: Program control mode switch enable (0 disable/1 enable) b4: OBDH B on A off power distribution switch status (0 off/1 on) b3: OBDH A on B off power distribution switch status (0 off/1 on) b2: VHF antenna deployed state (0 not deployed/1 deployed) b1: UHF antenna expanded state (0 not expanded/1 expanded) b0: the status of the total antenna deployment switch (0 off/1 on)
15	W31	1Byte	Working status 3	b7: Waiting for into orbit mode (0 not/1 waiting) b6: On-Track mode (0 non/1 On-track) b5: OBDH SPI state (0 normal/1 failure) b4: ADC I2C state (0 normal/1 failure)

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				b3: Temperature measurement I2C state (0 normal/1 failure) b2: Clock I2C state (0 normal/1 failure) b1: Inertial navigator serial port state (0 normal/1 failure) b0: Flash SPI state (0 normal/1 failure)
16	W32	2Byte	12V power supply voltage	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 15.0(V)
17	W34	2Byte	VU 12V power supply current	W1W2 is an integer Range: 0 ~ 1500(mA)
18	W36	2Byte	VU 5V power supply voltage	W1 is the integer part, W2 is the decimal part (2 decimal places) Range: 0 ~ 10.00(V)
19	W38	2Byte	VU 3.8V power supply voltage	W1 is the integer part, W2 is the decimal part (2 decimal places) Range: 0 ~ 5.00(V)
20	W40	2Byte	IHU 3.3V voltage 1	W1 is the integer part, W2 is the decimal part (2 decimal places) Range: 0V ~ 5.00(V)
21	W42	2Byte	IHU 3.3V voltage 2	W1 is the integer part, W2 is the decimal part (2 decimal places) Range: 0V ~ 5.00(V)
22	W44	2Byte	IHU 3.8V current	W1W2 is an integer Range: 0 ~ 500(mA)
23	W46	2Byte	UHF transmitter 3.8V current	W1W2 is an integer Range: 0 ~ 500(mA)
24	W48	2Byte	VHF receiver 3.8V current	W1W2 is an integer Range: 0 ~ 500(mA)
25	W50	2Byte	VHF AGC voltage	W1 is the integer part, W2 is the decimal part (2 decimal places)

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				Range: 0 ~ 5.00(V)
26	W52	2Byte	RF transmit power	W1W2 is an integer Range: 0 ~ 2000(mW)
27	W54	2Byte	RF reflected power	W1W2 is an integer Range: 0 ~ 1000(mW)
28	W56	2Byte	Reserved	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 30.0(V)
29	W58	2Byte	Reserved	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 30.0(V)
30	W60	1Byte	UHF Transmitter PA temperature	B7 of W1 is the sign bit, 0 is positive, 1 is negative; b6~b0 are numerical bits Range: -100 ~ +100(°C)
31	W61	1Byte	VHF Receiver temperature	B7 of W1 is the sign bit, 0 is positive, 1 is negative; b6~b0 are numerical bits Range: -100 ~ +100(°C)
32	W62	1Byte	IHU temperature	B7 of W1 is the sign bit, 0 is positive, 1 is negative; b6~b0 are numerical bits Range: -100 ~ +100(°C)
33	W63	1Byte	Reserved	B7 of W1 is the sign bit, 0 is positive, 1 is negative; b6~b0 are numerical bits Range: -127 ~ +127(°C)
34	W64	1Byte	Reserved	B7 of W1 is the sign bit, 0 is positive, 1 is negative; b6~b0 are numerical bits

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				Range: -127 ~ +127 (°C)
35	W65	3Byte	Current delayed telemetry interval	W1-Hour: 00 ~ 23, representing 0:00 ~ 23:00 W2-Minute: 00 ~ 59, representing 0 minute ~ 59 minutes W3-second: 00 ~ 59, representing 0 second ~ 59 seconds
36	W68	6Byte	Delay telemetry start time setting	W1-Year: 0 ~ 99, representing 2000 ~ 2099 W2-Month: 01 ~ 12, representing January to December W3-Day: 01 ~ 31, representing 1st ~ 31st W4-Hour: 00 ~ 23, representing 0:00 ~ 23:00 W5-minute: 00 ~ 59, representing 0 minute ~ 59 minutes W6-second: 00 ~ 59, representing 0 second ~ 59 seconds
37	W74	3Byte	Delayed telemetry interval setting	W1-Hour: 00 ~ 23, representing 0:00 ~ 23:00 W2-Minute: 00 ~ 59, representing 0 minutes ~ 59 minutes W3-second: 00 ~ 59, representing 0 seconds ~ 59 seconds
38	W77	3Byte	Delayed telemetry times setting	W1W2W3 is an integer Range: 0 ~ 16777215
39	W80	2Byte	Attitude quaternion q0	W1W2: Q0L Q0H $q0 = ((Q0H < 8) Q0L) / 32768$
40	W82	2Byte	Attitude quaternion q1	W1W2: Q1L Q1H $q1 = ((Q1H < 8) Q1L) / 32768$
41	W84	2Byte	Attitude quaternion q2	W1W2: Q2L Q2H $q2 = ((Q2H < 8) Q2L) / 32768$
42	W86	2Byte	Attitude quaternion q3	W1W2: Q3L Q3H $q3 = ((Q3H < 8) Q3L) / 32768$

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm	
43	W88	2Byte	X-axis angular speed	W ₁ W ₂ : WxL WxH Wx=((WxH<<8) WxL)/32768*2000(°/s)	
44	W90	2Byte	Y axis angular speed	W ₁ W ₂ : WyL WyH Wy=((WyH<<8) WyL)/32768*2000(°/s)	
45	W92	2Byte	Z-axis angular speed	W ₁ W ₂ : WzL WzH Wz=((WzH<<8) WzL)/32768*2000(°/s)	
46	W94	4Byte	Satellite time seconds	W1 second highest byte	The four bytes are the accumulated value of the whole second of UTC since 0:00:00:00 UTC on January 1, 2009 (0:00 after the jumped second).
				W2 second high byte	
				W3 second low byte	
				W4 second lowest byte	
47	W98	2Byte	Satellite time milliseconds	W1W2 is an integer	
48	W100	2Byte	Satellite primary bus voltage	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 30.0(V)	
49	W102	2Byte	Satellite load total current	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 10.0(A)	
50	W104	2Byte	Solar array current	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 10.0(A)	
51	W106	2Byte	Battery charging current	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ -10.0(A)	
52	W108	2Byte	Battery discharge current	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 10.0(A)	

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
53	W110	2Byte	+5.3V supply voltage	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 30.0(V)
54	W112	1Byte	Satellite attitude control mode	b7~b0 (the following are hexadecimal representations, where b7~b4 correspond to the main operating mode, and b3~b0 correspond to the sub-mode): 0x00--Active segment mode 0x11—Full attitude capture mode: Rate damping 0x12—Full attitude capture mode: Sun search 0x13—Full attitude capture mode: Orientation to sun 0x14—Full attitude capture mode: Orientation to the ground 0x15—Full attitude capture mode: Maneuvering to the sun 0x20—Attitude maneuver mode 0x23—Attitude maneuver mode: Switch to cruise to the sun 0x24—Attitude maneuver mode: Switch to normal operation 0x25—Attitude maneuver mode: Switch to offset flight 0x26—Attitude maneuver mode: Switch to a fixed point to stare 0x27—Attitude maneuver mode: Switch to inertial space pointing 0x30—Cruising mode to the sun 0x40—Normal operating mode 0x50-Biased flight mode 0x60—Fixed-point staring mode 0x70—Inertial space pointing mode 0xB0—Track control mode

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				0xC0—Stop control mode 0xD0-Reset mode Other: Invalid mode
55	W113	1Byte	Satellite longitude	B7 of W1 is a character bit, 0 is positive, 1 is negative; b6~b0 are numeric bits Range: $N*2$, $(-180^{\circ} \sim 180^{\circ})$
56	W114	1Byte	Satellite latitude	B7 of W1 is a character bit, 0 is positive, 1 is negative; b6~b0 are numeric bits Range: $N*2$, $(-90^{\circ} \sim 90^{\circ})$
57	W115	1Byte	Rolling angle estimation	B7 of W1 is a character bit, 0 is positive, 1 is negative; b6~b0 are numeric bits Range: $-125 \sim +125^{\circ}$
58	W116	1Byte	Pitch angle estimation	B7 of W1 is a character bit, 0 is positive, 1 is negative; b6~b0 are numeric bits Range: $-125 \sim +125^{\circ}$
59	W117	1Byte	Yaw angle estimation	B7 of W1 is a character bit, 0 is positive, 1 is negative; b6~b0 are numeric bits Range: $-125 \sim +125^{\circ}$
60	W118	2Byte	Uplink remote control data block counter	W1 is the high byte, W2 is the low byte Range: $0 \sim 65535$
61	W120	1Byte	X-band transceiver working status	b7 : X-band transceiver transmitter switch status 1: On; 0: Off b6 : X-band transceiver position synchronization lock indication 1: locked; 0: lost lock

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				b5: X-band transceiver remote control carrier lock indication 1: locked; 0: lost lock b4: X-band transceiver remote control pseudo code lock indication 1: locked; 0: lost lock b3: CRC check status of X-band transceiver remote control data 1: CRC is correct; 0: CRC is wrong b2: X-band transceiver remote control channel status self-check 1: valid; 0: invalid b1b0: X-band transceiver remote control code group status 01: Code group 1; 10: Code group 2
62	W121	2Byte	X-band transceiver AGC voltage	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 6.6(V)
63	W123	2Byte	X-band transceiver transmit power level	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 6.6(V)
64	W125	1Byte	X-band transceiver SPI interface status	b7~b4: X-band transceiver baseband execution counter 0 ~ 15 b3b2: X-band transceiver SPI interface empty flag 01: valid; 10: invalid b1: X-band transceiver SPI-MISO data with or without monitoring 1: with data; 0: without data b0: X-band transceiver SPI-MOSI data with or without monitoring 1: with data; 0: without data

4、Space camera photo data:

Coming soon...

5、Test mode telemetry data format:

CAMSAT XW-4 (CAS-10) satellite test mode is used for in-orbit engineering monitoring, diagnosis and maintenance of the satellite. The test mode is only used when the satellite passes over China. In the test mode, the telemetry data is sent using AX.25 UI frames, with 128 bytes of valid data per frame, including: frame synchronization code (2 bytes) + satellite telemetry data (12 bytes) + total frame counter (1 byte) + Frame counter (1 byte) + Engineering test and diagnostic data (112 bytes). Every 4 frames form a cycle, the frame count value of the first frame is a multiple of 4, and 4 frames are downloaded to the ground every second, with a total of 512 bytes in each cycle.

(1) Test mode telemetry frame data format

Byte No. W	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	...	127
Frame F0	EB	90	##	##	##	##	##	##	Sat. time seconds				Millisec.		M	FE	##	##	##	##
Frame F1	EB	90	##	##	##	##	##	##	##	##	##	##	##	##	M+1	FF	##	##	##	##
Frame F2	EB	90	##	##	##	##	##	##	##	##	##	##	##	##	M+2	00	##	##	##	##
Frame F3	EB	90	##	##	##	##	##	##	##	##	##	##	##	##	M+4	02	##	##	##	##
Instruction	Frame synchronization code		Satellite telemetry data												Total frame counter (Molded 256)	Frame counter	Engineering test and diagnostic data			
Total byte	2		12												1	1	112			

(2) Test mode GMSK telemetry data analysis method

F0 frame (frame count is 4n)

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
1	F0W2	1Byte	Total reset counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
2	F0W3	1Byte	Telemetry Frame Transmission Counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
3	F0W4	1Byte	Remote control command execution counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
4	F0W5	1Byte	Remote control command forwarding counter	W1 is an integer. Restart counting from 0 after counting up Range: 0 ~ 255
5	F0W6	1Byte	Working status 1	b7: Allow to set to track mode (0 disable/1 enable) b6: Photo download enable (0 disable/1 enable) b5: Delayed telemetry switch status (0 off/1 on) b4: Test mode enable (0 disable/1 enable) b3: 0: Linear transponder off; 1: Linear transponder on. b2: OBDH time calibration enable (0 disable/1 enable) b1: Telemetry transmit RF power(0 low power/1 high power) b0: Program control mode enable (0-disable/1 enable)
6	F0W7	1Byte	Working status 2	b7: In-orbit mode (0 not In-orbit/1 In-orbit) b6: Battery discharge switch is on (0 off/1 on)

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm	
				b5: Program control mode switch enable (0 disable/1 enable) b4: OBDH B on A off power distribution switch status (0 off/1 on) b3: OBDH A on B off power distribution switch status (0 off/1 on) b2: VHF antenna deployed state (0 not deployed/1 deployed) b1: UHF antenna expanded state (0 not expanded/1 expanded) b0: the status of the total antenna deployment switch (0 off/1 on)	
7	F0W8~F0W11	4Byte	Satellite time seconds	W1 second highest byte W2 second high byte W3 second low byte W4 second lowest byte	The four bytes are the accumulated value of the whole second of UTC since 0:00:00:00 UTC on January 1, 2009 (0:00 after the jumped second).
8	F0 W12W13	2Byte	Satellite time milliseconds	W1W2 is an integer	

F1 frame (frame count is 4n+1)

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm	
1	F1W2W3	2Byte	VU 5V power supply voltage	W1 is the integer part, W2 is the decimal part (2 decimal places) Range: 0 ~ 10.00(V)	
2	F1W4W5	2Byte	VU 3.8V power supply voltage	W1 is the integer part, W2 is the decimal part (2 decimal places) Range: 0 ~ 5.00(V)	
3	F1W6W7	2Byte	IHU 3.3V voltage 1	W1 is the integer part, W2 is the decimal part (2 decimal places)	

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				Range: 0V ~ 5.00(V)
4	F1W8	1Byte	Satellite primary bus voltage	$Y = 0.0882 * X - 1.0558$
5	F1W9	1Byte	Satellite load total current	$Y = 0.0244 * X - 0.3927$
6	F1W10	1Byte	Solar array current	$Y = 0.0239 * X - 0.2696$
7	F1W11	1Byte	Battery charging current	$Y = -0.0833 * X + 13.127$
8	F1W12	1Byte	Battery discharge current	$Y = 0.0833 * X - 13.127$
9	F1W13	1Byte	Solar array voltage	$Y = 0.0873 * X - 0.9338$

F2 frame (frame count is 4n+2)

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
1	F2W2W3	2Byte	Reserved	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 30.0(V)
2	F2W4W5	2Byte	Reserved	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 30.0(V)
3	F2W6W7	2Byte	UHF transmitter 3.8V current	W1W2 is an integer Range: 0 ~ 500(mA)
4	F2W8	1Byte	Satellite attitude control mode	b7~b0 (the following are hexadecimal representations, where b7~b4 correspond to the main operating mode, and b3~b0 correspond to the sub-mode):

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				0x00--Active segment mode 0x11—Full attitude capture mode: Rate damping 0x12—Full attitude capture mode: Sun search 0x13—Full attitude capture mode: Orientation to sun 0x14—Full attitude capture mode: Orientation to the ground 0x15—Full attitude capture mode: Maneuvering to the sun 0x20—Attitude maneuver mode 0x23—Attitude maneuver mode: Switch to cruise to the sun 0x24—Attitude maneuver mode: Switch to normal operation 0x25—Attitude maneuver mode: Switch to offset flight 0x26—Attitude maneuver mode: Switch to a fixed point to stare 0x27—Attitude maneuver mode: Switch to inertial space pointing 0x30—Cruising mode to the sun 0x40—Normal operating mode 0x50-Biased flight mode 0x60—Fixed-point staring mode 0x70—Inertial space pointing mode 0xB0—Track control mode 0xC0—Stop control mode 0xD0-Reset mode Other: Invalid mode
5	F2W9	1Byte	Satellite longitude	B7 of W1 is a character bit, 0 is positive, 1 is negative; b6~b0 are numeric bits

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				Range: $N \times 2$, $(-180^\circ \sim 180^\circ)$
6	F2W10	1Byte	Satellite latitude	B7 of W1 is a character bit, 0 is positive, 1 is negative; b6~b0 are numeric bits Range: $N \times 2$, $(-90^\circ \sim 90^\circ)$
7	F2W11	1Byte	Rolling angle estimation	B7 of W1 is a character bit, 0 is positive, 1 is negative; b6~b0 are numeric bits Range: $-125 \sim +125^\circ$
8	F2W12	1Byte	Pitch angle estimation	B7 of W1 is a character bit, 0 is positive, 1 is negative; b6~b0 are numeric bits Range: $-125 \sim +125^\circ$
9	F2W13	1Byte	Yaw angle estimation	B7 of W1 is a character bit, 0 is positive, 1 is negative; b6~b0 are numeric bits Range: $-125 \sim +125^\circ$

F3 frame (frame count is $4n+3$)

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
1	F3W2W3	2Byte	VHF receiver 3.8V current	W1W2 is an integer Range: $0 \sim 500(\text{mA})$
2	F3W4W5	2Byte	RF transmit power	W1W2 is an integer Range: $0 \sim 2000(\text{mW})$

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
3	F3W6	1Byte	UHF Transmitter PA temperature	B7 of W1 is the sign bit, 0 is positive, 1 is negative; b6~b0 are numerical bits Range: -100 ~ +100(°C)
4	F3W7	1Byte	Reserved	B7 of W1 is the sign bit, 0 is positive, 1 is negative; b6~b0 are numerical bits Range: -127 ~ +127(°C)
5	F3W8W9	2Byte	Uplink remote control data block counter	W1 is the high byte, W2 is the low byte Range: 0 ~ 65535
6	F3W10	1Byte	X-band transceiver working status	b7: X-band transceiver transmitter switch status 1: On; 0: Off b6: X-band transceiver position synchronization lock indication 1: locked; 0: lost lock b5: X-band transceiver remote control carrier lock indication 1: locked; 0: lost lock b4: X-band transceiver remote control pseudo code lock indication 1: locked; 0: lost lock b3: CRC check status of X-band transceiver remote control data 1: CRC is correct; 0: CRC is wrong b2: X-band transceiver remote control channel status self-check 1: valid; 0: invalid b1b0: X-band transceiver remote control code group status 01: Code group 1; 10: Code group 2
7	F3W11	1Byte	X-band transceiver AGC voltage	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 6.6(V)

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
8	F3W12	1Byte	X-band transceiver transmit power level	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 6.6(V)
9	F3W13	1Byte	X-band transceiver SPI interface status	b7~b4: X-band transceiver baseband execution counter 0 ~ 15 b3b2: X-band transceiver SPI interface empty flag 01: valid; 10: invalid b1: X-band transceiver SPI-MISO data with or without monitoring 1: with data; 0: without data b0: X-band transceiver SPI-MOSI data with or without monitoring 1: with data; 0: without data