XW-3 (CAS-9) Amateur Radio Satellite

User's Manual

Ver. 1.0

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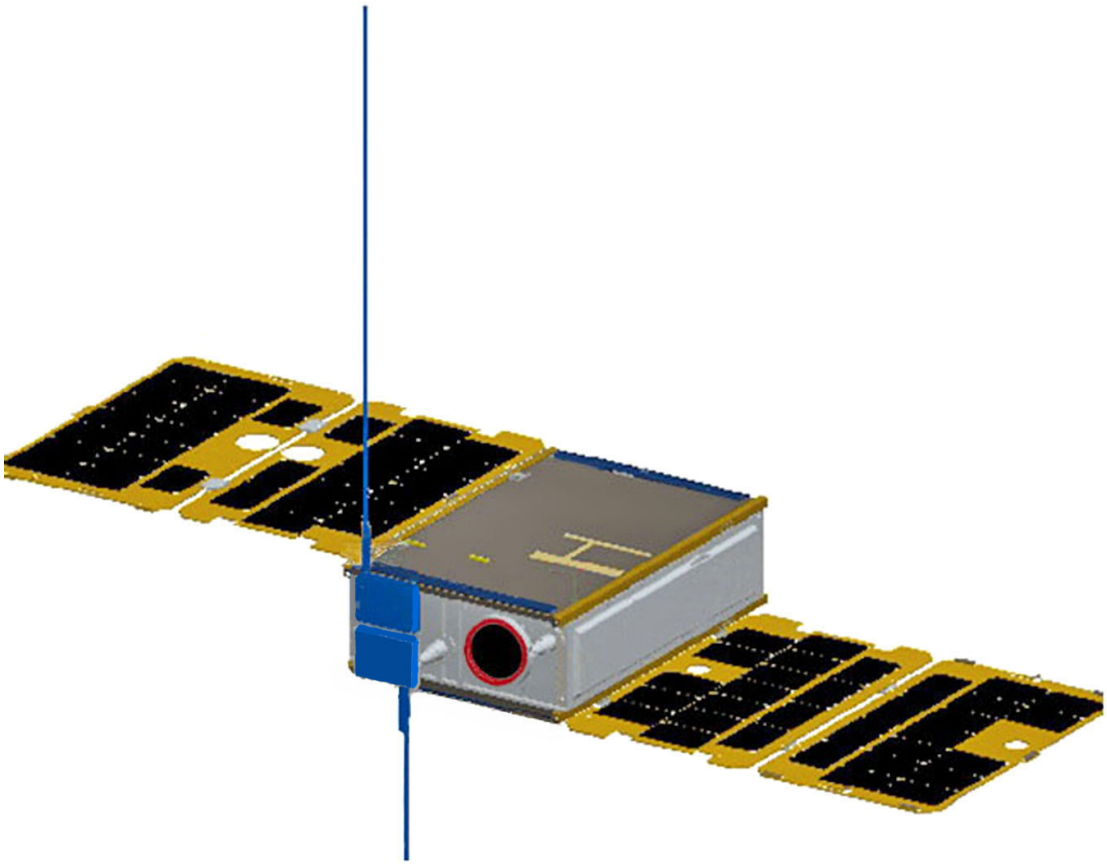
CAMSAT XW-3(CAS-9) amateur radio satellite will be launched by Chinese CZ-4C Y39 launch vehicle on December 25, 2021 from the Taiyuan Satellite Launch Center in China. XW-3(CAS-9) satellite will be piggybacked on the rocket with primary payload ZY-1(02E) satellite. The satellite orbit is a circular sun-synchronous orbit with an altitude of 770.1 kilometers and an inclination of 98.58 degrees, the running cycle is 100.14 minutes.

The functions of XW-3(CAS-9) satellite include UHF CW telemetry beacon, GMSK telemetry data transmission, V/U mode linear transponder, a visible light band space camera and an experimental thermoelectric generator for high school students.

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-3(CAS-9) satellite adopts a 6U CubeSat structure with a mass of about 10kg, an on-orbit envelope size of 340.5x121.76x998mm with four solar array panels and a three-axis stabilized attitude control system is used, long-term power consumption is about

15.2 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:**

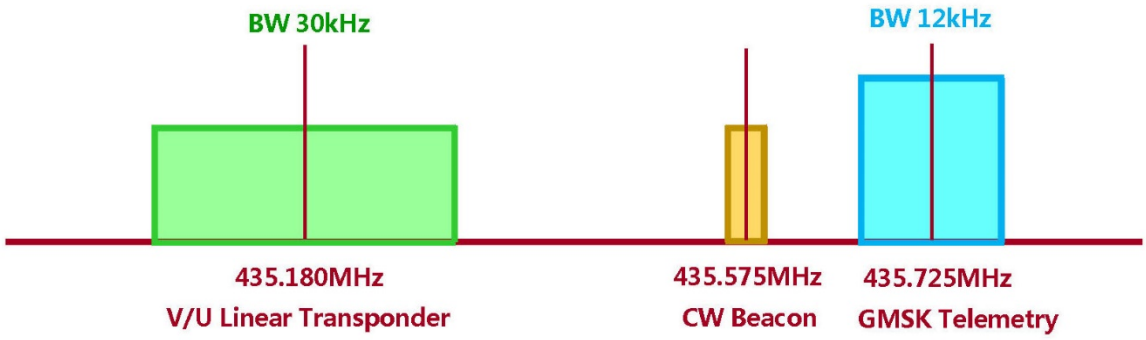
  ●Frequency: 435.725MHz ●RF power: 23dBm ●Data rate: 4800bps

- **V/U mode linear transponder:**

  ●Uplink frequency: 145.870MHz ●Downlink frequency: 435.180MHz

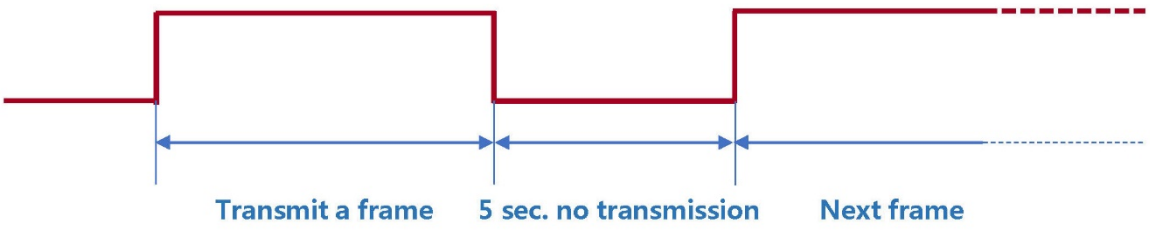
  ●RF power: 20dBm ●Bandwidth: 30kHz ●Spectrum inverted

- **Photo download remote control:**
  - **Subsequently public**



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	CAS9	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	Thermoelectric power generation voltage 1	data	000	999	V=N/100	V
CH19	Thermoelectric power generation voltage 2	data	000	999	V=N/100	V
CH20	UHF Transmitter PA temperature	data	000	999	**XYZ**	℃

Channel	Parameter name	Type	Value range		Parsing algorithm	Unit
			Mini.	Max.		
CH21	VHF Receiver temperature	data	000	999	When X is 0-2, it represents a positive temperature; X is 3-4, it represents a negative temperature. For example: 000 : 0℃ 025 : 25℃ 125 : 125℃ 301 : -1℃ 311 : -11℃ 391 : -91℃ 421 : -121℃	℃
CH22	IHU temperature	data	000	999		℃
CH23	Thermoelectric generator temperature 1	data	000	999		℃
CH24	Thermoelectric generator temperature 2	data	000	999		℃
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-3(CAS-9) 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

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				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
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

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				Range: 0 ~ 255
11	W27	1Byte	Temperature measurement software watchdog reset counter	W1 is an integer. Restart counting from 0 after counting up 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)

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				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) **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)

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
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) 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	Thermoelectric generator voltage 1	W1 is the integer part, W2 is the decimal part (1 decimal place) Range: 0 ~ 30.0(V)
29	W58	2Byte	Thermoelectric generator voltage 2	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(℃)
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(℃)
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(℃)
33	W63	1Byte	Thermoelectric generator temperature 1	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(℃)
34	W64	1Byte	Thermoelectric generator temperature 2	B7 of W1 is the sign bit, 0 is positive, 1 is negative; b6~b0 are numerical bits Range: -127 ~ +127 (℃)
35	W65	3Byte	Current delay 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	Delay 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	Delay telemetry times setting	W1W2W3 is an integer Range: 0 ~ 16777215
39	W80	2Byte	Attitude quaternion q0	W_1W_2 : Q0L Q0H q0=((Q0H<<8)|Q0L)/32768
40	W82	2Byte	Attitude quaternion q1	W_1W_2 : Q1L Q1H q1=((Q1H<<8)|Q1L)/32768
41	W84	2Byte	Attitude quaternion q2	W_1W_2 : Q2L Q2H

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm	
				q2=((Q2H<<8)|Q2L)/32768	
42	W86	2Byte	Attitude quaternion q3	W_1W_2 : Q3L Q3H q3=((Q3H<<8)|Q3L)/32768	
43	W88	2Byte	X-axis angular speed	W_1W_2 : WxL WxH Wx=((WxH<<8)|WxL)/32768*2000(°/s)	
44	W90	2Byte	Y axis angular speed	W_1W_2 : WyL WyH Wy=((WyH<<8)|WyL)/32768*2000(°/s)	
45	W92	2Byte	Z-axis angular speed	W_1W_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)	

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				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)
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

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
				0x60—Fixed-point staring mode 0x70—Inertial space pointing mode 0xB0—Track control mode 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 º ~180 º)
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 º ~90 º)
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 ~ +125 º
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 ~ +125 º
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 ~ +125 º
60	W118	2Byte	Uplink remote control data block counter	W1 is the high byte, W2 is the low byte Range: 0 ~ 65535

Sending order	Starting position	Data length	Telemetry data function description	Telemetry data parsing algorithm
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 **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：

XW-3 (CAS-9) satellite can store up to 10 photos taken by the space camera. The newly taken photo data will overwrite the old photo data, first in, first out. There are two photo resolutions, one is 256x256 pixels, and the data size of each photo is 64k bytes; the other is 512x512 pixels, and the data size of each photo is 256k bytes. Users can download the photo storage information to learn about the photos stored on the satellite, and select the photos to download.

(1) Photo storage information

XW-3 (CAS-9) satellite photo storage information is stored in the solid-state memory on the satellite in the following format.

Function code	Photo storage information content
7Byte	80Byte
W0~W6：0x02000100010057	W7~W86

Photo storage information content			
Article 1 Photo storage information	Article 2 Photo storage information	.....	Article 10 Photo storage information
8Byte	8Byte	.....	8Byte

The format of each photo storage information is shown in the following table:

1Byte	1Byte	1Byte	1Byte	1Byte	1Byte	1Byte		1Byte
Year	Month	Day	Hour	Minute	Second	bit7~Bit3	Bit2~Bit0	1Byte
Photograph time						Camera number	Photo counter	

1) Year, month, day, hour, minute, and second: the time when the photo data

starts to be stored.

2) Camera number: fixed value 1

3) Photograph counter: start counting from 1, and restart counting from 1 when it is full. 0 is the initial state, which means that no photo has been taken yet. 1~999 is the photo count value.

(2) Photo data

The format of the photo data is shown in the table below:

Function code	Photo data content
7Byte	≤249Byte
W0~W6 : 0x03xxxx xxxx xxxx	W7~Wn (n≤255)

Photo data content									
Photo information									Photo data
W7	W8	W9	W10	W11	W12	W13		W14	W15	W16~Wn (n≤255)
Year	Month	Day	Hour	Minute	Second	bit7~Bit3	Bit2~Bit0	1Byte	1Byte	≤240Byte
Photograph time						Camera number	Photo counter		Photo specifications	Photo data

1) Photo information

Including photo time, camera number and photo counter. For detailed description, please refer to this article (instructions related to photo storage information).

2) Photo data

Fill the data of a certain photo, except for the last frame, the photo data of each photo frame is 240 bytes, and the photo data of the last frame is the actual number

of remaining bytes. The total number of frames in the photo frame is the total number of frames of all the photo data, and the frame number is the frame number of the photo data in all the photo data.

3） W15 photo specifications

Photo specifications	Width (pixels)	High (pixels)	Note
1	--	--	Reserve
2	--	--	Reserve
3	256	256	64K bytes
4	512	512	256K bytes
5	--	--	Reserve

After downloading the photo data frame, the 240 bytes of "photo data" (the last frame is less than 240 bytes) in the above description of each frame of data are combined in a file in order, the file is saved with the raw extension, and then you can Use the photo browsing tool that can open raw format pictures to view the photos.

(3) Photo data download remote command

Subsequently public.