Ins V 1.01.

BS-FN300C-M-D6EC

Product characteristics

- Gyroscope measuring range: 500 ~ 2000 °/s optional
- 2 °/H gyroscope bias stability (Allan variance)
- Acceleration range: 16g
- Zero bias stability (Allan variance) for acceleration of 0.1 mg

Field of application

UAVNavigation | hicle & Robot Navigation | / &ROV

1. Product overview

BS-FN300C-M-D6EC is a compact inertial navigation system with fiber optic gyroscope (FOG) and micro-electromechanical system (MEMS) accelerometers, which can use external GNSS accurate timing and positioning information for inertial/satellite integrated navigation. When the external GNSS information is invalid, the inertial navigation system has a high ability to maintain the accuracy of pure inertial navigation.

2. Main functions and indicators

2.1 Main functions

The inertial navigation system can receive timing and navigation information from an external GNSS. When the GNSS is valid, the inertial navigation system can perform combined navigation with the GNSS, provide the user with navigation parameters such as position, altitude, speed, attitude, course, acceleration, and angular velocity after combination, and output information such as GNSS position, altitude, and speed; When the GNSS is not available, a full set of navigation parameters can be provided in a pure inertial mode of operation.

Key features include:

A) initial alignment function: Inertial navigation needs initial alignment before integrated navigation. Initial alignment includes two modes, one is self-alignment and the other is external stapling alignment. And turning to the integrated navigation state after the alignment is finished;

B) integrated navigation function: immediately turn to the integrated navigation state after initial alignment. Inertial navigation uses external GNSS information and other information to carry out integrated navigation according to the priority of inertial/GNSS and pure inertial mode, which can solve the navigation information such as carrier speed, position and attitude;

C) the pure inertial position keeping function, course keeping function and attitude keeping function within a certain period of time after the satellite is unlocked;

D) communication function: Inertial navigation can output inertial navigation measurement information according to the protocol;

The e) has the ability to upgrade the software in situ on the aircraft: the navigation software can be upgraded through the serial port;

The f) has the function of shaking alignment;

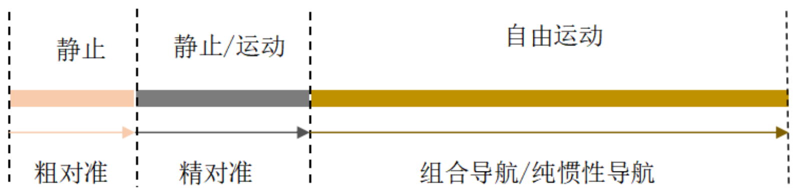


Fig. 1 Inertial Navigation Work Flow Chart

2.2 Performance indicators

Project	Test conditions	Indicators
Positioning accuracy	External GNSS Valid, Single Point	Better than external satellite positioning accuracy
	External GNSS Valid, RTK	Better than external satellite positioning accuracy
	Pure inertial horizontal positioning holding ①	100m/5min（CEP） 600m/10min（CEP） 2nm/30min（CEP）
	Airspeed combination horizontal positioning maintenance ②	1nm/30min (CEP)
Heading accuracy	Single antenna	0.1°③
	Dual antenna	0.2 °/L (L = baseline length) (RMS)
	Course holding	0.3°/30min（RMS），1°/h（RMS）
	Self-north seeking accuracy	1 ° SecL, alignment for 15 min ④
Attitude accuracy	GNSS is valid	0.02°（RMS）
	Attitude hold (GNSS failure)	0.3°/30min（RMS），1°/h（RMS）
Speed accuracy	GNSS valid, single point L1/L2	0.1m/s（RMS）
Gyroscope	Measuring range	±400°/s
	Zero bias stability	≤0.3°/h
Accelerometer	Measuring range	±20g
	Zero bias stability	≤100μg
Physical dimensions and electrical characteristics	Voltage	9-36V DC
	Power consumption	≤8W
	Interface	2-way RS 232,1 RS422, 1-way PPS (LVTTL/422 level)
	Size	111mm × 72mm × 43mm (L, W, H)
	Weight	≤450g
Environmental characteristics	Operating temperature	-40℃~+60℃
	Storage temperature	-45℃~+70℃
	Vibration	5 ~ 2000Hz, 6.06 G (with shock absorber)
	Impact	30g, 11 ms (with shock)
	Life span	> 15 years

	Continuous working time	>24h
Note: ① The alignment is valid; ② For airborne use, there is a turning maneuver before the airspeed combination, and the test takes the flight speed of 150km/H as an example; ③ On-board conditions, need to be mobile; ④ Two-position alignment, the heading difference between the two positions is greater than 90 degrees		

Table 1 Main technical indexes

3. Composition and working principle

3.1 System composition

Fig. 2 Physical drawing of inertial navigation system

Inertial navigation is mainly composed of fiber optic gyroscope, accelerometer combination, navigation software, DC power supply and mechanical components.

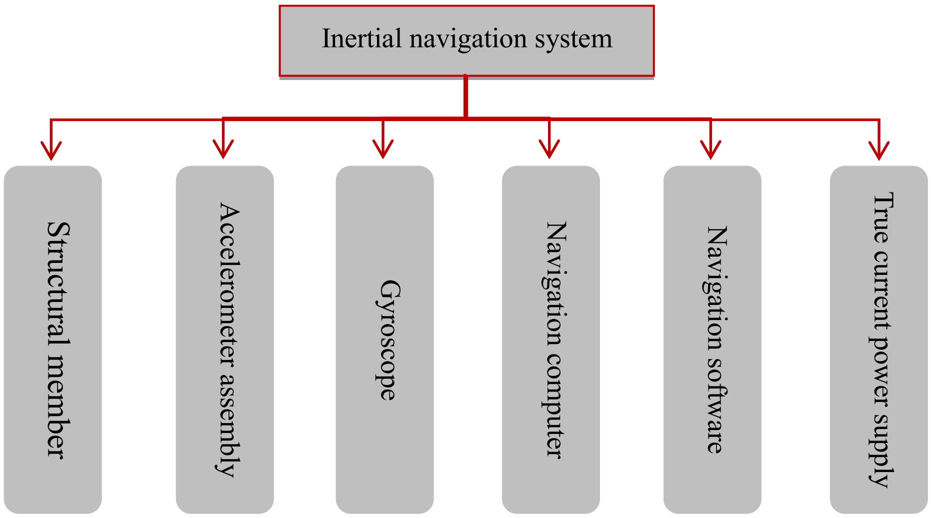


Fig. 3 Inertial Navigation System

3.2. Working principle

The inertial measurement unit (IMU) in the inertial navigation system uses three orthogonal gyroscopes to sense the angular motion of the carrier, and outputs a digital signal proportional to the angular rate of the carrier motion; three orthogonal MEMS accelerometers are used to sense the linear acceleration of the carrier.

The navigation computer completes the receiving of gyroscope, accelerometer and external GNSS data, system error compensation calculation and navigation solution, and sends real-time navigation information such as speed, position and attitude to the outside in a specified period.

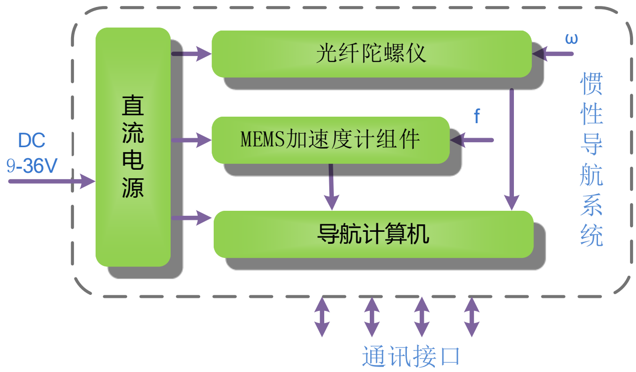


Figure 4 Working principle diagram

4. Instructions for use

4.1 Overall dimensions

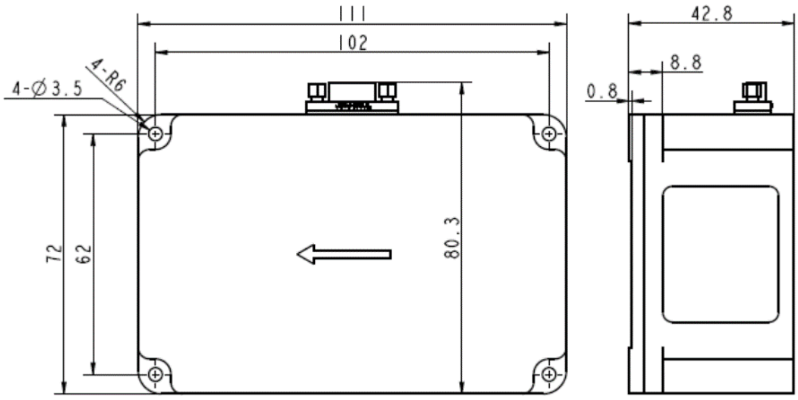


Figure 5 Dimensions of Inertial Navigation System

4.2 Weight

The main body of the inertial navigation system weighs about 450 G.

5 Power supply and electrical interface

5.1 Power supply

The power supply range of inertial navigation is 9-36 VDC, and the power is not more than 8 W.

5.2 Electrical Interface and Protocol

Definition of the 5.3 connector

The external cable plug is J30JY-15 TJL-200, and the plug size and connector point definition are shown in Schedule 1.

Electrical interface and protocol of the 5.4

The inertial navigation system has one RS422 serial port, 1,2 RS232 serial ports COM2 and COM3, and one LVTTL or 422 level PPS input signal.

Interface	Electrical form	Signal name	Source	Where to	Function	
					Data name	Refresh rate
Com1	RS422	Transmit/receive duplex	Inertial navigation	Flight control	Navigation information	200Hz
			Flight control	Inertial navigation	Flight control instructions and satellite navigation information	At least 1 Hz
Com2	RS232	Transmit/receive duplex	Satellite navigation receiver	Inertial navigation	For receiving satellite navigation information	——
Com3	RS232	Transmit/receive	Upper	Inertial	Used for receiving	——

		duplex	computer	navigation	configuration commands and sending configuration feedback information;	
			Inertial navigation	Upper computer		
PPS	LV TTL/422	—	Satellite navigation receiver	Inertial navigation	For receiving satellite navigation system PPS information	——

Table 2 Electrical Interface and Function

6 Inertial Navigation Workflow

After the inertial navigation system is powered on, the navigation software is loaded. After the loading is completed, the system self-test is performed. If the self-test fails, the self-test failure message is prompted to the outside. If the self-test is successful, enter the alignment and navigation process.

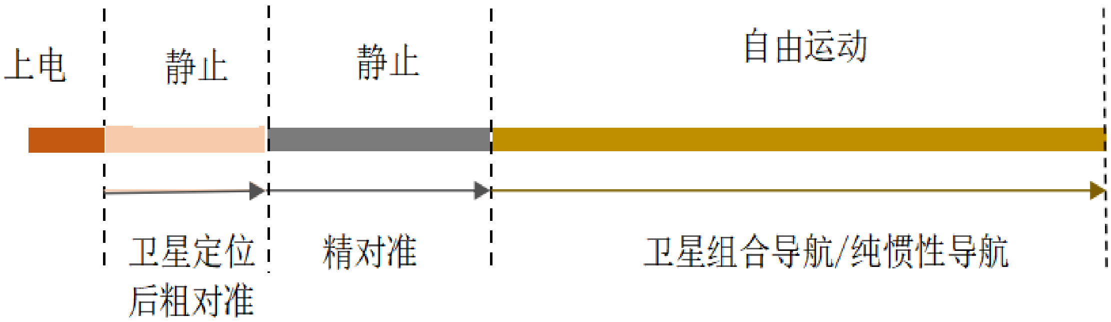


Fig. 6 Inertial Navigation Work Flow Chart

Inertial navigation waits for external valid GNSS navigation information, including longitude, latitude, altitude, speed and other information. After the binding is successful, it enters the alignment state, and the default self-alignment time is 15 min. If there is external dual-antenna information, the inertial navigation system can use the dual-antenna heading to complete the rapid alignment after the dual-antenna information is valid, and it can enter the integrated navigation state 2 min after the dual-antenna orientation is stable. The carrier is required to be stationary in the alignment state.

After the alignment is completed, it will automatically turn to the integrated navigation state, the carrier can move normally, and the inertial navigation system can provide effective navigation information such as speed, position and attitude. If the satellite is invalid in the middle, it will automatically switch to the pure inertial navigation state and continuously output navigation information such as speed, position and attitude.

7 Installation and commissioning

7.1 Coordinate System and Direction Definition

Airframe coordinate system ("front-right-down"): X-axis is forward along the longitudinal axis of the airframe, Y-axis is rightward along the transverse axis of the airframe, and Z-axis is downward along the vertical axis of the airframe;

Geographic coordinate system- ("East-North-Sky"): east, north and sky directions are positive respectively;

Heading angle direction-roll angle is positive for roll right, pitch angle is positive for pitch up, and yaw angle is positive for yaw right.

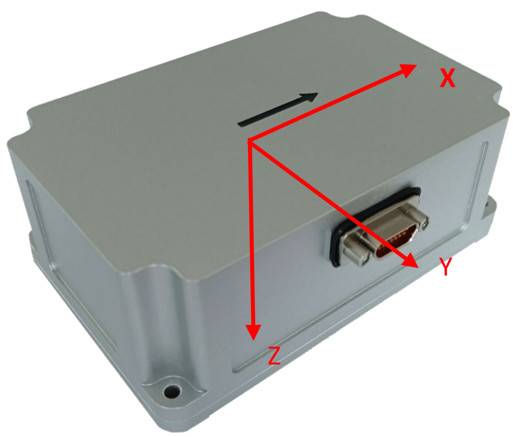


Figure 7 Definition of Coordinate System

Installation of the 7.2

The installation elements of inertial navigation system are as follows (without damping device):

The a) inertial navigation system is mounted on the carrier mounting base through four M3 screws, and the arrow direction on the inertial navigation system points forward;

The b) measures the three-dimensional size of the inertial navigation and the external receiver antenna, the inertial navigation points to the three-dimensional coordinate of the antenna in the right front upper coordinate system of the inertial navigation, and the measurement precision is better than the 0.05 m;

The bottom surface of the c) shall be firm and stable, preferably made of metal, with a thickness of not less than 5mm;

The connector outlet is installed on the side of the d) inertial navigation, and the space distance on the right side is not less than 35mm, which is convenient for the connector to be plugged and fastened.

In case of severe vibration environment, it is necessary to consider installing a shock absorber. The parameters of the shock absorber shall be selected based on the vibration magnitude and other factors, and shall be determined separately in actual use.

Debugging of 7.3

The inertial navigation debugging steps are as follows:

The inertial navigation a) is installed or placed on a stable installation table;

A b) is connecte with an inertial navigation power supply cable and a communication cable, and a com 1 port in that communication cable is connecte to a test computer so as to receive inertial navigation information in real time;

The c) checks the power supply of the inertial navigation after the circuit is connected, and configures it as the test mode. After about 20s, the com1 port can receive the data;

The d) inertial navigation system turns to the pure inertial navigation state after being aligned for 600 seconds, and the com1 port can receive effective navigation information;

The e) performs static navigation for 30 minutes, and counts the 30-minute heading attitude accuracy. If the heading attitude and horizontal position accuracy meet the 30-minute pure inertial navigation index requirements, the inertial navigation works normally;

After the f) is debugged, the inertial navigation is powered off.

8 Use and operation

The use steps are as follows:

The a) shall correctly install the inertial navigation system according to the requirements in the "Installation" section;

The b) is connected to the cables among the inertial navigation, flight control, external GNSS board (in the case of direct connection to the external receiver board) and PPS. Each cable is correctly connected to the user equipment and can communicate with the external flight control in both directions; the DC power supply is 9 V ~ 36 V, and the power supply current is not less than 3A;

The c) checks the power supply of the inertial navigation system after the circuit is connected, and waits for about 20s before the inertial navigation system sends navigation information to the outside;

The d) inertial navigation system waits for effective external satellite information, if the satellite information is effective, the alignment is started; if the external dual-antenna directional information cannot be provided, the self-alignment is carried out for 10 minutes; if the external dual-antenna information exists, the rapid alignment is carried out for 3 minutes after the external effective dual-antenna information is received; after the alignment, the navigation state is switched to, and the navigation information is sent; When the external satellite is invalid, the inertial navigation system automatically switches to pure inertial navigation and continuously outputs navigation information;

Power off after the inertial navigation system of the e) is used.

9 Maintenance and service

9.1 Maintenance content

It is recommended to power on the inertial navigation system once a quarter for more than 30 minutes each time. In case of any fault, it is necessary to record the fault status accurately and report to the manufacturer for maintenance or repair in time.

In order to ensure that the inertial navigation accuracy meets the use requirements, the parameter calibration shall be carried out every 2a (tentative), and the tentative calibration shall be returned to the factory.

9.2 Requirements for testing and using personnel

The personnel engaged in inertial navigation test and use shall carefully read the technical documents and operation instructions, master the operation essentials of the specialty, and use the equipment and tools related to the operation of the specialty.

9.3 Precautions for use of inertial navigation

Attention shall be paid to the following items during the use of inertial navigation:

The power supply interval of a) inertial navigation should not be less than 30 s to avoid repeated power supply in a short time, otherwise the internal inertial devices may be burned out;

B) inertial navigation is a precision instrument, which should avoid falling, collision and extrusion;

10 Fault analysis and troubleshooting

The possible faults, fault causes and troubleshooting methods of inertial navigation are shown in the following table.

Serial number	**Fault symptom**	**Possible causes of failure**	**Exclusion method**
1	Startup fault: the inertial navigation system does not start after being powered on, and there is	Inertial navigation power supply or communication cable is not connected properly; The power supply voltage or starting current does not meet the inertial navigation requirements; Inertial navigation circuit failure;	Check whether the cable connection is loose or missing; Check whether the power supply parameters of power supply meet the requirements; After eliminating A) and B), it still does not start after being

	no output;		powered on for many times, and it needs to be returned to the factory for maintenance;
2	Long-term preparation state without entering the alignment state	The satellite signal of the location is poor, and the location is not determined; The external satellite information is not normally input to the inertial navigation system;	A good satellite receive place is selected; Check whether the external satellite information input is connected correctly; After troubleshooting A) and B), the fault still occurs after being powered on for many times, and it needs to be returned to the factory for maintenance.
3	Alignment failed	In the process of alignment, the inertial navigation system is in a non-static state and changes its position obviously. Inertial device failure;	Ensure that the inertial navigation system is in a static state during alignment; After elimination of A), the alignment still fails after several times of power-on, and it shall be returned to the factory for repair;
4	Gyroscope and accelerometer failure, navigation aborted	Gyroscopes and accelerometers are faulty;	Return to the factory for repair

Table 3 Fault Analysis and Troubleshooting

11 Transportation and storage

The inertial navigation system is equipped with a special packing box. Inertial navigation must be packed in a packing case during separate transportation. It shall be handled with care during disassembly and handling to avoid collision, turnover, knocking and rain. It is strictly prohibited to transport the inertial navigation with acid, alkali and other corrosive substances, volatile substances, flammable and explosive substances. The well-packed inertial navigation system can be suitable for highway, railway, waterway, aviation and other transportation.

In order to maintain higher accuracy and longer service life of the inertial navigation system as far as possible, a better storage environment shall be selected as far as possible. In general, the storage environment shall meet the following requirements: the temperature shall be 5 ℃ ~ 40 ℃, the relative humidity shall not be greater than 80%, and there shall be no corrosive substances in the warehouse.

APPENDIX 1 CONNECTOR POINT DEFINITIONS AND RELATED DIMENSIONS

Product end socket: J30JY-15ZPK37;

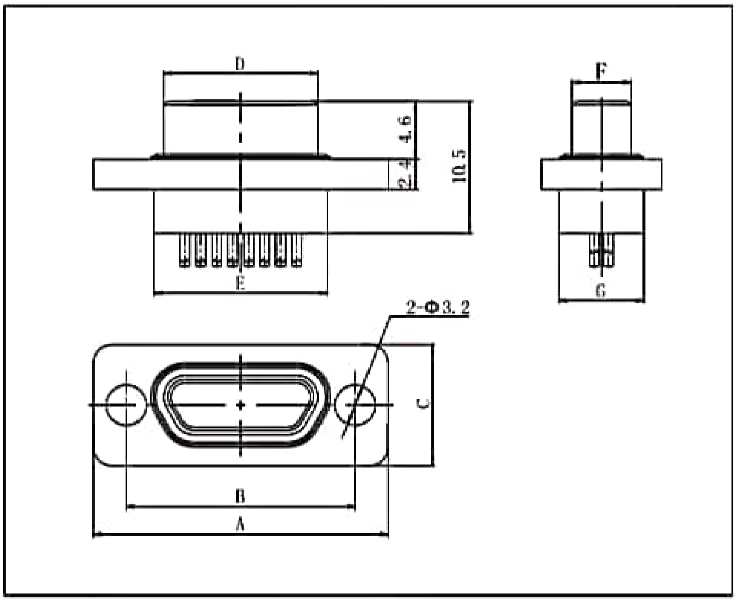
Cable end plug: J30JY-15TJL-200.

Connection point 1		Connection Point 2		Terminal number definition (connection point 1)	Cable model, Specification and color	Cable handling method	Length
Plug wire code	Terminal number	Plug wire Mark Code	Terminal number				
X1	1	DB9 Female head	3	COM1_ RS422T+	AF 0.15 cable	Twisted pair	1.5 meters
X1	2		4	COM1_ RS422T-	AF 0.15 cable		1.5 meters
X1	3		2	COM1_ RS422R-	AF 0.15 cable	Twisted pair	1.5 meters
X1	4		1	COM1_ RS422R+	AF 0.15 cable		1.5 meters
X1	8		5	GND	AF 0.15 cable		1.5 meters
X1	5	DB9 Female head	2	COM2_ 232T	AF 0.15 cable	Twisted pair	1.5 meters
X1	6		3	COM2_ 232R	AF 0.15 cable		1.5 meters
X1	12		5	GND	AF 0.15 cable		1.5 meters
X1	13	DB9 Female head	2	COM3_ 232T	AF 0.15 cable	Twisted pair	1.5 meters
X1	14		3	COM3_ 232R	AF 0.15 cable		1.5 meters
X1	15		5	GND	AF 0.15 cable		1.5 meters
X1	11	PPS	Throw the line	PPS	AF 0.15 cable		1.5 meters
X1	7		Throw the line	PPS_ GND	AF 0.15 cable		1.5 meters
X1	10	Red Alligator clip	24V	24V	AF 0.15 cable	Twisted pair	1.5 meters

X1	9	Black Alligator clip	24V_GND	24VGND	AF 0.15 cable		

Schedule 1 Connector Point Definition and Standard Test Cable Definition Table

The dimensions of the plug are shown in the figure below.



J30JY-□TJ

J30JY 压接基本型 J30JY-TJ

订货标志	A	B	C	D	E	F	G
J30JY-9TJ	19.6	14.3	9.6	8.3	9.9	4.7	6.8
J30JY-15TJ	23.5	18.2	9.6	12.3	13.8	4.7	6.8

Appendix 2 Protocol Format between Flight Control and Inertial Navigation System

The integrated navigation system interacts with the flight control through the com1 port (flight control port), and the input and output are in the frame format as shown in the figure.

1	2	3	4	5～(N-2)	N-1	N
A		B	C	D	E	

A) a frame header, A1 = 0xEB, A2 = 0x90;

B) B frame length N, total length of all bytes from frame header A to checksum E;

C) C frame recognition word;

D) D valid data, N-6 bytes in total;

Check sum of e) E, the sum of all bytes from a to D is the lower two bytes, with the lower byte in the front and the higher byte in the back.

The inertial navigation system receives the air pressure altitude and airspeed data forwarded by the flight control system through the flight control port, and sends the navigation data regularly. After the inertial navigation system is powered on and initialized, it will automatically output navigation data according to the set frequency of 200Hz and baud rate of 460800bps. The output frame format is shown in the following table.

<table>
<tr><th>Serial number</th><th>Data content</th><th>Description of use</th><th>Remark</th><th>Type</th></tr>
<tr><td>Data[0]</td><td>0xEB</td><td rowspan="2">Frame header</td><td rowspan="2"></td><td>U8</td></tr>
<tr><td>Data[1]</td><td>0x90</td><td>U8</td></tr>
<tr><td>Data[2]</td><td>0x7A</td><td>Frame length N</td><td>Number of all data bytes from frame header to checksum</td><td>U8</td></tr>
<tr><td>Data[3]</td><td>0xD1</td><td>Frame ID</td><td>Navigation data</td><td>U8</td></tr>
<tr><td>Data[4]</td><td colspan="3" rowspan="11">U32 counter; //frame counter
U8 state;
//Lower 3 bits: AHRS. 0 Initialization 1 OK 2 Error
//bit3 Whether the compass needs to be calibrated 0 Normal 1 Needs to be calibrated
//High 4 health status
//bit4 Compass 0 OK 1 Fault
//bit5 Gyroscope 0 normal 1 fault
//bit 6 add 0 normal 1 fault
//bit7 Barometer 0 OK 1 Fault
F32 pitch; //unit: rad, AHRS +
F32 roll; //unit: rad, AHRS right roll positive
F32 yaw; //unit:rad,ahrs N 0d E 90d W -90d S +-180d
F32 yaw_gps; //GPS track direction
//unit:d, gps N 0 E 90d W -90d S +-180d
F32 pitch_rate; //unit: rad/s, AHRS +
F32 roll_rate; //unit: rad/s, AHRS right roll positive
F32 yaw_rate; //unit: rad/s, AHRS positive clockwise
S32 lon; //unit:0.0000001d, INS
S32 lat; //unit:0.0000001d, INS
S32 alt_baro; //unit: 0.01 m, barometer original barometric altitude
S32 alt_gps; //unit: 0.01 m, GPS original GPS altitude</td><td rowspan="11">Data structure</td></tr>
<tr><td>Data[5]</td></tr>
<tr><td>Data[6]</td></tr>
<tr><td>Data[7]</td></tr>
<tr><td>Data[8]</td></tr>
<tr><td>Data[9]</td></tr>
<tr><td>Data[10]</td></tr>
<tr><td>…</td></tr>
<tr><td>…</td></tr>
<tr><td>…</td></tr>
<tr><td>Data[N-3]</td></tr>
</table>

	S32 alt; //unit: 0.01 m, INS EKF filter height No GPS starts from zero, with GPS Initialize according to GPS height
	F32 velocity_n; //unit: m/s, NED, INS N northbound speed
	F32 velocity_e; //unit: m/s, NED, INS E due east speed
	F32 velocity_d; //unit: m/s, NED, INS D normal velocity
	F32 velocity_air; //m/s, airspeed
	
	F32 accel_n; //unit: m/s ^ 2, NED, AHRS N Positive Northward Acceleration
	F32 accel_e; //unit: m/s ^ 2, NED, AHRS E due east acceleration
	F32 accel_d; //unit: m/s ^ 2, NED, AHRS D positive earth acceleration
	
	U8 satellite_num; //Number of satellites
	U16 hdop; //0.01 m horizontal precision factor
	U16 vdop; //0.01 m vertical precision factor
	
	U8 gps_status;
	//NO _ GPS = 0, no GPS data
	//NO _ FIX = 1, GPS signal unlocked
	//GPS _ OK _ FIX _2 D = 2, 2D positioning
	//GPS _ OK _ FIX _3 D = 3, 3D positioning
	//GPS_OK_FIX_3D_DGPS = 4, 3D_DGPS
	//GPS_OK_FIX_3D_RTK_FLOAT = 5, 3D RTK Float
	//GPS_OK_FIX_3D_RTK_FIXED = 6, 3D RTK Fixed
	U8 gps_hh; //GPS hour
	U8 gps_mm; //GPS minute
	U8 gps_ss; //GPS seconds
	
	S8 temperature; //d deg C
	S16 HDT; //d dual antenna heading 0 ~ 360 degrees unit 0.1 degree
	S16 HDG_Dev; //d antenna course standard deviation 0 ~ 360 degrees unit 0.1 degree
	U8 redundancy; //Use status of each sensor
	//bit01 Add bit23 Gyro bit45 Compass bit67 GPS
	//add & gyro: 0 external 1 internal 1 2 internal 2
	//Compass: 0 external 1 internal
	//GPS: 0 internal 1 external
	U8 GPS 0_ DT;//Internal GPS Sampling Interval Unit 100ms Range 0-255	

	U8 GPS 1_ DT;//External GPS Sampling Interval Unit 100ms Range 0-255
	F32 GPS_vn; //unit: m/s, NED, GPS N True North Speed
	F32 GPS_ve; //unit: m/s, NED, GPS E due east speed
	F32 GPS_vd; //unit: m/s, NED, GPS D normal velocity
	//GPS system time
	U16 gps_ms; //milliseconds in GPS seconds, range 0-999
	U8 gps_day; //GPS days of the week, range: 0-6
	U16 gps_week; //GPS week, range: 0-1023
	//AHRS status
	U8 ahrs_state; //AHRS status, for factory testing only			

Data[N-2]	Low byte	Checksum	Data [0] ~ Data [N-3]'s accumulated sum is the lower two bytes	U8
Data[N-1]	High byte			U8

Table 2 Format of Inertial Navigation Output Protocol Frame

The airspeed data and air pressure data protocol format requirements are as follows, and the transmission cycle is 0.2 s.

Serial number	**Data content**	**Description of use**	**Remark**	**Type**
Data[0]	0xEB	Frame header		U8
Data[1]	0x90			U8
Data[2]	0x13	Frame length N	Number of all data bytes from frame header to checksum	U8
Data[3]	0xA1	Frame ID	Navigation data	U8

Data[4]	U32 counter; //frame counter
	U8 state;
	//bit0 Pitot tube 0 normal 1 fault
	//bit1 Barometer 0 OK 1 Fault
	//bit3-7 standby
	S32 alt_baro; //unit: 0.01 m, barometric altitude
	F32 velocity_air; //m/s, airspeed
	Satellite navigation information may be added (expanded based on user receiver information)
				Data structure

Data[5]				
Data[6]				
Data[7]				
Data[8]				
Data[9]				
Data[10]				
…				
…				
…				
Data[N-3]				
Data[N-2]	Low byte	Checksum	Data [0] ~ Data [N-3]'s accumulated sum is the lower two bytes	U8
Data[N-1]	High byte			U8

Schedule 3 Format of Agreement from Flight Control to Inertial

Navigation

In addition, the inertial navigation system can also receive satellite navigation data through the com2 port (either com1 or com2 can receive satellite information), the baud rate is set to 460800bps, and the satellite navigation data can be configured with the following protocols:

Serial number	**Protocol name**	**Cycle**
1	bestposb	0.2
2	headingb	0.2
3	bestvelb	0.2
4	psrdopb	1
5	timeb	0.2

Schedule 4 Satellite Guide Output Agreement