

## Research on Marine Navigation Sensor System

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**Abstract:** This paper reviews the development of navigation system technology and equipment, analyzes the principle, composition and function of navigation sensor system, studies the navigation data and information security strategy of navigation system, and looks forward to the next development trend of navigation system.

### 1. Introduction

Navigation system plays a very important role in the process of navigation, mainly to ensure safe navigation, to ensure the safe take-off and landing of aircraft, to align the inertial navigation system of carrier-based aircraft, and to serve as the reference information source of carrier-based intelligence information system and weapon system. The navigation systems of US Navy aircraft carriers and other main battle ships in the formation are basically the same. It is an integrated navigation system with inertial navigation system (INS) as the main part and satellite navigation system (GPS), Doppler log, echo sounder and electromagnetic log as the auxiliary part. These navigation information sources are integrated and processed through the navigation sensor system interface (NAVSSI) to obtain the optimal and unified navigation information. It also sends navigation data to various weapon combat support, command and control, computer, communication, intelligence, surveillance, reconnaissance systems and other information systems. Compared with the navigation system of other main battle ships in the formation, NAVSSI transmits navigation data to different users, and the NAVSSI on the carrier needs to send navigation information to the relevant auxiliary systems for the take-off and landing of carrier-based aircraft.

### 2. NAVSSI Development Status

NAVSSI is the core of the formation navigation system, which can integrate the data from various navigation sensors to form accurate navigation data and time data, and distribute them to the combat command system, detection system, aviation support system, navigation support system, communication system and training system of the formation ships. NAVSSI was implemented by the United States in February 1991. It is to process all kinds of navigation data between battle groups and form a unified navigation data transmission. Due to the rapid development of civil ECDIS, the United States decided to apply ECDIS to the Navy in 1998. NAVSSI not only includes the functions of ECDIS-N, but also adds many defensive mission functions. So far, NAVSSI has developed from Block 0 to Block 4, and has gone through five stages of development. Block 4.2.1 is the latest version. The design of NAVSSI is very flexible in the operation method, which can select the output data, select the inertial navigation system to recall the positioning source, and monitor the rationality of the data. The NAVSSI system adopts an open design, which can adapt to the continuous development of technology and implant new technologies. In the future, the United States plans to develop a GPS positioning, navigation and timing system (G-PNTS) to replace the NAVSSI system. Both G-PNTS and NAVSSI are embedded with next-generation GPS card receivers to ensure that ships can receive signals from improved GPS satellites.

### 3. Composition of NAVSSI system

NAVSSIBlock4 system is mainly composed of real-time subsystem (RTS), display control subsystem (DCS) and remote workstation (NRS).

The real-time subsystem is responsible for collecting, processing, and distributing positioning, navigation, and timing (PNT) data. It uses a set of navigation data source integration (NSI) algorithms to fuse data from multiple sensors, including GPS data and inertial navigation data, to form a highly accurate and effective navigation solution. All NAVSSIBlock4 system include two real-time subsystems, the two real-time subsystems exchange data through reflective memory (that is, multiple computers form a high-speed network interconnected by global shared memory, and each node regards global memory as local memory), and each real-time subsystem can share all source data. If one communication channel fails to the real-time subsystem, a real-time subsystem can also obtain information from other real-time subsystems through reflective memory.

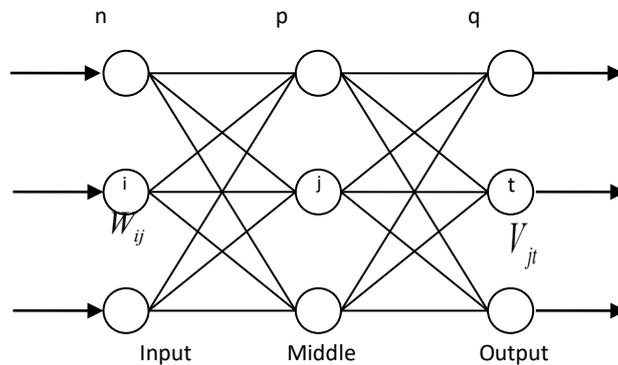


Figure 1 PNT

The display control subsystem communicates with each real-time subsystem through the local area network. The display control subsystem provides the operator interface and the electronic chart and radar interface for the real-time subsystem. The display control subsystem can use the navigation toolkit to display the sensor information, log navigation data, electronic chart and radar images of the real-time subsystem. And can control that real-time subsystem.

The remote workstation is the remote display for the NAVSSI operator. The NAVSSI remote workstation provides full control and display capabilities for personnel on the bridge and in other compartments. During operation, NAVSSI continuously monitors input data from various navigation data sources to ensure data integrity.

### 4. Main functions of NAVSSI system

The main functions of NAVSSI include positioning and navigation, timing, inertial navigation system alignment, etc.

#### 4.1 Positioning and navigation

Multiple reference points are used, such as weapon systems, radars, inertial navigation systems, platform compasses, and GPS. On large ships, the difference between them can reach nearly 100 meters due to the deformation of the hull and the different reference systems used. It has become an urgent problem to establish a unified reference position data. This scheme will select an independent point on the ship. As a reference point for all systems, the OSRP. This simplifies the conversion of the ship's reference point positioning, navigation and timing data to and from other end users. Normally, the reference point of the ship should coincide with the ship's center of rotation at the waterline in the middle of the ship's centerline.

The main function of NAVSSI is to provide position and time information to the ship's weapon and combat systems, and then to provide navigation solutions to the ship's bridge, that is, to plot the

ship's position data on the electronic chart of the bridge and other on-board control sites, which can be combined with the integrated bridge to achieve collision avoidance, navigation planning and ship control automation. In order to provide effective navigation data to the user in any case, NAVSSI uses a priority approach for navigation data source selection. The data source selection scheme considers all sensors that can provide navigation data, and sets priority for each sensor, including position, speed, acceleration, heading, attitude, depth, wind speed, etc. If any sensor fails data review, transmits invalid data, or fails to transmit, NAVSSI automatically takes the next batch of data available from the sensor.

## **4.2 Timing**

To fully share track data, the time error of the time-tagged data must be small enough. GPS can provide reliable and accurate time-to-failure information for navigation systems around the world. However, GPS can be jammed in wartime and cannot meet the navigation team's need for reliable and accurate time. Therefore, NAVSSI has developed a Precision Time Service Unit (PTU).

The precise time service device comprises a frequency regulation module (FDM), a rubidium oscillator and a slow output device. Once the estimated time error (ETE) exceeds 100 ns, the precise timing unit will enter the operating mode and use the rubidium oscillator to maintain time accuracy. For most users, an accuracy of 1 ms is adequate. This means that precise timing devices can be used when GPS is not available. Meet the time needs of these users in five and a half months.

## **4.3 Inertial Navigation System Alignment**

The alignment of inertial navigation system (INS) for aircraft carrier is an important function of navigation system. The inertial navigation system needs to be aligned before the aircraft takes off, that is, the process of initialization using the attitude and position of the navigation system. The alignment of the inertial navigation system mainly uses the data of the inertial navigation system, and initially adopts a hardwired system. The data of the ship inertial navigation system goes through the carrier aircraft inertial system alignment control console (SAISAC) to the deck exit box, then through the conversion box to the relative velocity computer box, and finally to the aircraft inertial navigation system. After the introduction of NAVSSI, because NAVSSI can obtain GPS data and realize digitization, alignment can be easily realized by using LINK-4A data link. Among them, LINK-4A data link is a one-way or two-way communication system. It can send information to 100 aircraft.

## **5. NAVSSI System Information Security Policy**

Initially, NAVSSI was a stand-alone system with subsystems connected via an internal LAN and real-time subsystems connected to sensors and users via an external point-to-point interface. This independent configuration does not have information security issues, but as the number of interfaces increases, it will intersect with other network users, so information security issues need to be considered. Taking the LPD-17 class amphibious assault ship of the United States as an example, when its NAVSSI needs to communicate with the outside world through satellite communication, information security problems will arise, and at the same time, cross-border information security problems will arise when it connects with unclassified networks and classified networks.

### **5.1 Contact with the outside world through satellite communication**

The LPD-17's Unclassified Shipboard Wide Area Network (SWAN) is connected via satellite communications to the Unclassified Internet Router Network (NIPRNET), which is secured through a perimeter security approach. However, these measures are not 100% secure, so NAVSSI needs to be secured when an unclassified shipboard Wan is vulnerable. The NAVSSI security solution includes both software and hardware solutions.

Positioning, navigation and timing data are meaningless if delayed, so there is no need to forward any corrupted or erroneous data or to communicate in both directions. This will allow NAVSSI to multicast data unidirectionally to an unencrypted wide area network without receiving

any data. Through the hardware implementation, the data is output by the absolutely safe unidirectional optical fiber. This software solution will become more secure. This combination of software and hardware ensures that NAVSSI can prevent any access from the unclassified ship's Wan.

## 5.2 Cross-border communication issues

LPD-17 requires NAVSSI to provide navigation information to the ship's wide area network. A similar unidirectional fiber scheme is used for this interface scheme, which ensures that classified data does not enter the NAVSSI. However, as NAVSSI provides positioning, navigation, and timing data, it creates problems with unplanned cross-border transmissions. The U.S. Navy allows unclassified positioning, navigation and timing data to be provided to classified systems. In addition, physical connections can be made.

The risk to the ship's wide area network may come from systems connected to the NAVSSI. If the system can access the ship's wide area network through a one-way communication path, it may implant a "Trojan Horse" virus or other types of malicious code. In order to prevent any possibility of cross-border channels via NAVSSI, the interface of the classified Wan is directly connected to the real-time subsystem. The real-time subsystem does not provide any authority to transfer and transmit data, or to generate data channels to other interfaces. The real-time subsystem consists of an independent executable program that is embedded in the subsystem hardware and cannot be modified or run by other programs. The real-time subsystem has no peripheral storage device and no permission to allocate memory, so it cannot store any implanted data. There is also no valid interface information. This ensures that no data can be transmitted from one interface to another. All data input to the real-time subsystem is processed in a fixed format. This data is then used to construct new output data in the appropriate output format, which also eliminates the transfer of data from one interface to another, thus creating the possibility of cross-border communication channels.

NAVSSI is a positioning, navigation and timing scheme widely used by surface warships at present, which can solve the problems of lever-arm effect at multiple positions of large warships and timing when GPS signals are interfered. The NAVSSI scheme completely unifies the positioning, navigation and timing data in the formation, which is an important guarantee for navigation.

Table 1 NAVSSI System Information Security Output

Chanell	loc ati on1	loc ati on2	loc ati on3	loc ati on4	loc ati on5	output
bz1	1	0	1	1	0	(10000000)
bz2	0	1	1	0	1	(01000000)
bz3	1	1	0	0	1	(00100000)
bg1	0	0	1	0	1	(00010000)
bg1	1	1	0	1	1	(00001000)
bg2	1	0	1	1	0	(00000100)
bg2	0	0	1	0	1	(00000010)
ysq	1	1	1	1	1	(00000001)
normal	0	1	0	1	0	(00000001)

## 6. Development trend of marine navigation system

Based on the information published over the years, the development plan of the navigation system includes: inertial navigation system (navigation error 0.1 nm/HR), hybrid inertial navigation

systems, ring laser gyroscopes (RLG), fiber optic gyroscopes (FOG), GNSS receivers (including chip-scale GPS, differential GNSS receivers, GNSS anti-jamming components and systems, GNSS jamming positioning systems, enhanced LORAN (E-LORAN) navigation systems, Doppler (radar or sonar) navigation system, hybrid navigation system (except inertial navigation system), LPI/LPD radar up to altimeter and bathymeter, star data reference navigation system and data source, topographic data reference navigation system and data source, magnetic and electric field reference navigation system, and gravity data reference guidance system.

The proportion of marine navigation equipment in the whole platform is becoming larger and larger. The application of communication and navigation equipment is becoming more and more popular. The upgrading of navigation electronic equipment will also put forward higher requirements for navigation equipment.

(1) Navigation equipment tends to be integrated

Electronic equipment integration can increase operational effectiveness, reduce equipment duplication, shorten response time, and improve reliability. The integration of navigation equipment is developing along two tracks, one is the integration of communication, navigation and identification systems, that is, the integration of various independent equipment into a fully integrated modular system; The second is the integrated electronic system, including radar warning receiver, proximity warning system, etc.

(2) Strengthening basic research of navigation equipment

The hardware foundation of navigation equipment development is microwave and millimeter wave integrated circuit, ultra-high speed integrated circuit, application specific integrated circuit, high-speed computer and digital processing technology, so as to improve the overall performance, reliability and versatility of navigation equipment and reduce costs.

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