Halo/HaloNav Introduction

Zupt, LLC

Introduction:

The current subsea gyrocompass/inertial navigation system market is dominated by two vendors; iXblue tend to sell AHRS systems and INS solutions where complex LBL positioning is not required. Sonardyne are beginning to make market penetration were more complex aiding solutions are required - sparse LBL or tightly coupled DVL, etc. Others (Teledyne [TSS/CDL], Kongsberg, RTS, Greensea, Advanced Navigation, SBG, etc.) offer some capability into this sector. It is our belief that the customers within this market look for two different levels of system capability and associated price:

An affordable <0.3° heading sensor for basic work class ROV operations (rig support, IMR work).

A precise <0.08° sensor that delivers accurate heading, attitude and INS data for the survey market

A market may exist for a capability in between the two heading accuracies shown above.

Zupt has developed a subsea product range to be offered into this market – The "Halo" subsea INS product. This product is currently offered as a <0.3° 2 sigma Sec Lat system and a <0.08° 2 sigma Sec Lat "survey grade" system – both of these solutions have a fully capable integrated Inertial Navigation System (INS).

A significant focus has been placed on making these products far easier to integrate into a fully integrated INS solution than what is currently in the marketplace today. iXblue's and Kongsberg's current offerings are very complex to deploy as an INS, Sonardyne's requires a complete Sonardyne solution. This survey grade sensor provides Zupt with an instrument that allows us to deliver "intelligent survey services" to clients (survey contractors) to provide fully supported (long term) or mobilization support (short term) services in support of subsea aided inertial survey projects. Zupt believes that most future deep-water survey systems will include some form of inertial integration to provide operational effectiveness within the survey spread.

Zupt has sourced and negotiated access to the core component (the Inertial Measurement Unit/IMU or Inertial Sub Assembly ISA) to give us the ability to offer affordable, yet capable products. Zupt already had the required software (navigation engine) and processing hardware that took raw IMU data and processes it to heading, pitch, roll and heave as well as an integrated inertial navigation positioning solution integrating all of the required subsea sensors (USBL, LBL, DVL, Depth, etc.). This software has been operational in some form within C-PINS for the past 4 years. The version of the navigation engine deployed within Halo has been tailored to the specific IMU and application.

1. System Specification

Affordable - Rig Support Gyrocompass Specification	
Heading accuracy	~<0.3° secant latitude RMS
Pitch, Roll	<0.1°
Dynamic alignment time	<10 minutes to full accuracy
Angular rate	> 100°/s
Acceleration dynamic range	± 15 g
Operating latitude	± 80°
Operating speed	0 to 90 knots

Precise - Survey Grade Gyrocompass Specification	
Heading accuracy	<0.08° secant latitude RMS 0.01° resolution
Pitch, Roll	<0.03° with 0.01° resolution
Heave	5cm or 5% (2.5cm or 2.5%)
Dynamic alignment time	<10 minutes to full accuracy
Angular rate Rotation rate dynamic	> 100°/s range Up to 750 deg/s
Acceleration dynamic range	± 15 g
Operating latitude	± 80°
Operating speed	0 to 90 knots

Aided Inertial Navigation System Specification	
Depth Sensor – built into unit	Accuracy 0.01% FS, resolution 0.0001%
Aiding sensors supported	Extensive including: Loosely coupled - GNSS, USBL, Depth, LBL, DVL, Tightly coupled - GNSS, USBL, Depth, LBL, DVL, Additional sensors: Imagery (cameras), CTD, Altitude, velocity
Free Inertial performance (1σ) (after alignment complete)	0.5m after 30s, 50m after 5 mins, 1nm / hour
GNSS (surface application)	Loosely coupled 0.5x standard GNSS accuracy Tightly coupled <0.5x standard GNSS plus reliability
INS with DVL/Depth performance	<0.2% distance travelled
USBL Smoothing/Depth performance	Scatter reduced to 33% of USBL alone scatter
LBL/Depth performance	LBL accuracy maintained, high update rate
Sparse LBL/Depth performance	LBL accuracy, high update rate** **depends on survey deign SLAM array add-on included

Interfaces and Connectors - **INS version**	
Interfaces	5 x configurable bi-directional RS-232 / RS-422 1 x Ethernet 100 Mbits TCP client / TCP server / web server (GUI)
Connectors	Seacon MIN-CON or Burton Series 55 TBA
Trigger inputs/outputs	1 PPS Input/Output*** *** subsea tuned/locked to surface 1PPS Pulse port 3 inputs / 2 outputs
Data formats	Extensive Industry standard and Zupt proprietary NMEA 0183, IEC61162, ASCII, BINARY
Data output rate	0.1 Hz to 100 Hz

Operating Environment	
Water Depth Rating	4,000m Titanium (safety factor 1.5)
Power supply	8Vd.c. to 36Vd.c. Internal battery backup – 45 mins
Power consumption	< 10W Nominal 15W Peak Note: Peak when battery is charging
Dimensions	H 266mm x Dia 150mm
Weight	Air 10kg, Water 6.5kg
Environmental	Meets or exceeds IEC60945
Operating/Storage temperature	-20°C to +70°C /-30°C to +80°C
MTBF (computed / observed)	40 000 hours / 80 000 hours
Compliance Standards	EU Marine Equipment Directive, US Coast Guard recognized, IMO Resolutions, IEC 60945, IEC61162, IEC62288, ISO8728, ISO16328
Warranty	12 months international warranty including parts and labor
Export Control	ECCN 7A003 (EAR re-export regulations do not apply outside of the USA)

System Size

General Design Parameters:

Material for main housing components:
Zupt prefers Titanium housings as we believe they have a better subsea life compared to anodized aluminum housings. It is also easier to maintain high tolerances/repeatability during manufacture. Titanium housings wear better in normal offshore use.

Common parts for all variants:

Significant effort has been expended to design a system that will be cost effective to manufacture and support in volume. We intend to minimize the stockholding of parts to support the various versions of the product that will be sold.

Multiple sensors will need to be interfaced to this subsea unit for the INS application and this requires multiple connectors to interface to these external sensors into the housing. To accommodate these multiple connectors, we have an additional external housing (very similar to our MicroTTU product) that combines all aiding sensors into a single string connected to the Halo housing. The price differentiation from AHRS/HPR to INS will be the additional cost of this external instrument.

The ***primary configuration connector*** is a 24-way combined use connector. This connector enables Ethernet (up to 100Mbps). The standard connectors selected are Seacon MINI-CON connectors. The primary connector being a MINL size connector. The primary MINL connector configuration is:

Function	Conductors/Pins
Power 0vdc/24Vdc	2
Serial Port Master	3
Ethernet	4
Serial One	3
Serial Two RS422	5
Trigger/1PPS in	2

An annual calibration requirement exists for all survey sensors that are specified to be "calibrated". The pressure transducer within Halo is one such sensor that requires annual calibration. To facilitate this, we have designed the top end cap so that the pressure transducer and associated PCB can be easily removed from the top end cap without opening the pressure housing.

Pressure sensors change or "age" over time from their calibration values foremost because of contamination on their pressure port and abuse, or operators "touching" the pressure port face. We have included within this design a sintered metal filter port from the water column to the face of the pressure transducer. This inexpensive sintered metal filter ensures that the pore size is too small for larger contaminants to enter the pressure orifice and seawater based micro-organisms find the metal toxic and do not establish a habitat on the top of the pressure membrane.

Housing Tube

The housing tube is a simple tube accommodating the sealing face for the end caps and providing the height for contents of Halo. A "North" lubber line is machined onto the outside of the housing tube and end caps as we have on the C-PINS housings.

Bottom End Cap

The ease of alignment and re-alignment of the bottom end cap to the vehicle/vessel will define the repeatability of the system as used in the field. Alignment keys (reamed blind holes) located on the

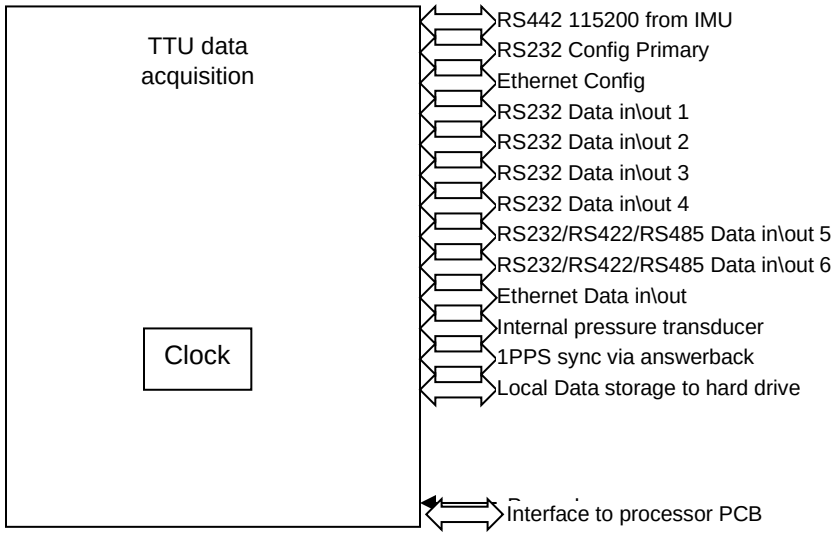
underside of the bottom end cap allow the system to be aligned (realigned) accurately into the mounting onto the vehicle/vessel.

Adaptor plates are also offered to allow this system to be "bolt in compatible" with Octans, ROVINS and Sprint and as such we ensure the heading, pitch and roll accuracy is maintained through these adaptor plates. Additionally, when removed from a vehicle/vessel or systems are swapped out and then returned to the mounting location, the alignment will be maintained with these alignment keys.

In the design shown to the right we have 4 blind threated holes on the bottom of the end cap to allow the unit to be bolted from the underside onto a structure. For bolting down onto a structure, we will use one of our adaptor flanges.

TTU PCB

Within all Zupt products and systems he core is our Time Tag Unit (TTU) PCB. The Halo TTU is new generation of our current TTU board running within our C-PINS system. The TTU has the following capability.



For INS operation of Halo all data ports are precisely time tagged into the processing board. The external data is brought in and time tagged on our TTU boards.

External data import/export – Qty 6 RS232, Qty 2 configurable RS422, RS485 ports, Ethernet
Configuration Ports fixed for config use – Config RS232 or Config Ethernet
ISA comms interface (RS422, 8 data, 1 start, 1 stop, no parity, 115200baud, data at 100Hz)
Precise time capability via an oven controlled oscillator 1ppb – (86.4us/day, 2.6ms per month)
Time sync capability 1PPS with loop back testing with surface
Precise time used for data time tag (enabled via the processor board)
Galvanic isolation
All comms driver components

Power Supply/Battery charger PCB

The power supply/battery charger PCB will have the following capabilities:

Protection	15W DC:DC
Input voltage range	9Vdc to 36Vdc
Power capability	15W for Halo battery charging
ISA power supply	5V 4A max (2ms at power up), 1.2A operational
Halo power load	Processor 5W

The battery charging capability (I^2C bus) is the same as we currently have within our backpack system and has seen many years of field use (B-PINS).

Battery

We have included a small battery to ensure alignment is not lost during power outages and to manage general power supply issues often seen on ROV's. We are very familiar with charging and connecting to these packs as we have used a variant of them in our backpacks and C-PINS for the past 10 years. They are certified and tested by a third-party assembler, so very easy to integrate. The connectors for these packs are a known reliable AMP knife connector.

DVL Options

HaloNAV has been designed to primarily interface to the Nortek DVL DVL1000 (4,000m rated). This unit has one of the smaller footprints of the various sensors available on the market currently. We have also conceptual designs for fitting into our housing for any of the other sensors in the marketplace. We have specifically looked at Teledyne RDI Pathfinder, Rowe, LinkQuest and we have just started the conversation with Water Linked.