Zupt's HaloCAM Overview

Zupt, LLC

Introduction

Zupt, LLC has been using Inertial Navigation Systems (INS) either as standalone sensors or coupled with other aiding sensors in the Oil and Gas industry for over 21 years. Since 2011, Zupt has invested significant resources into integrating inertial technology with imaging sensors for various offshore survey tasks.

Over the last 11 years, we have developed several "turn-key" systems, tightly coupling Inertial Measurement Units (IMUs) with imaging sensors (both cameras and LiDAR solutions). These systems are intended to replace or augment "conventional" survey methods or, in the case of HaloCAM, an alternative, more efficient method for the offshore energy installation sector.

HaloCAM is a contactless inclination monitoring sensor designed for subsea use. The current configurations of HaloCAM can utilize a navigation grade IMU tightly coupled with a single high-definition machine vision camera contained within a 4000-meter rated subsea housing, or a less expensive MEMS IMU within the same housing. HaloCAM can monitor the verticality, heading and relative position of any structure that has a Fiducial Target (April Tag similar to the common QR Code) adhered to it. HaloCAM is easily mobilized to the ROV in question as there is no precise installation required on the ROV to determine fixed offsets from the camera to an external INS/IMU. HaloCAM can also be coupled with the ROV acoustic positioning system (if available) to absolutely position structures as they are installed or can place virtual markers buoys on the seabed to mark locations for installation such as conductor casings, mud mats, manifolds, etc.

HaloCAM

In 2018 Zupt developed an affordable and compact alternative to currently available subsea AHRS/INS. This product range is known as 'Halo', the system was developed in multiple versions:

an 'affordable' version with heading accuracy of 0.3° secant latitude
a 'precise' version with heading accuracy of 0.08° secant latitude

Both system specifications are contained with an identical 4000-meter titanium housing.

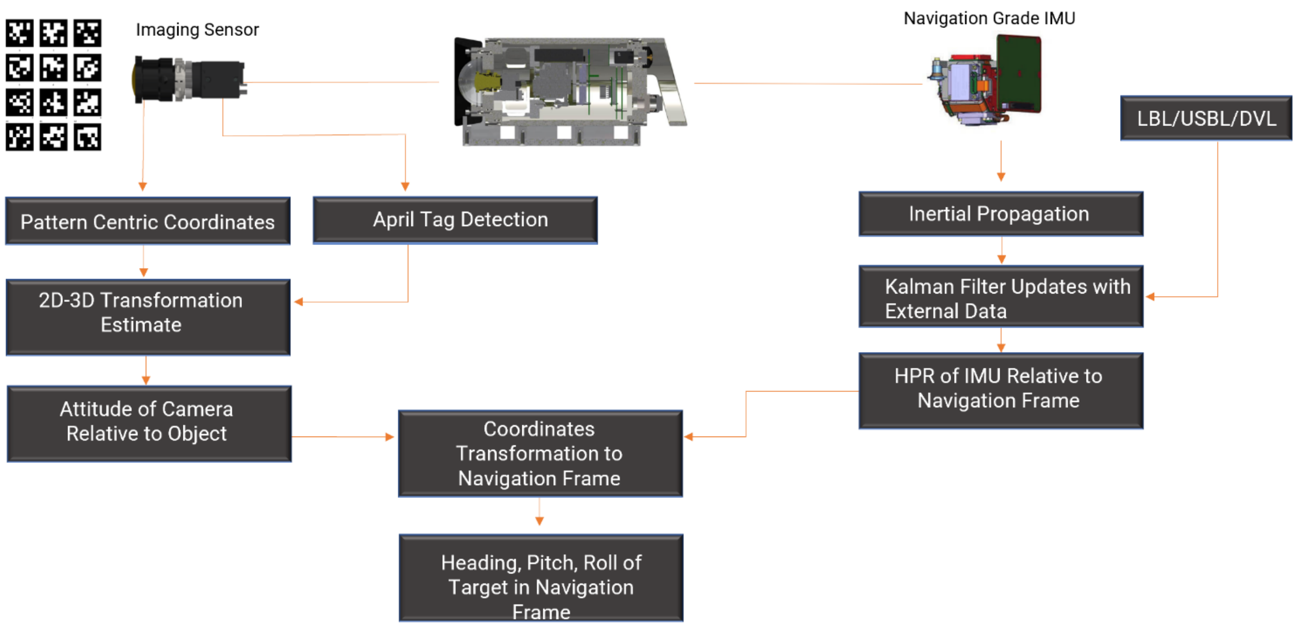
An emphasis was made to ensure that the system could be integrated with any subsea vehicle, requiring the system to be compact with relatively low power requirements and can be integrated with other positioning sensors (USBL, LBL, DVL, Depth, etc.). The "precise" system contains a highly accurate pressure transducer within the top end cap that is removable to maintain annual pressure calibrations. The "affordable system" has a strain gauge pressure transducer permanently fixed within the housing.

From the expertise gained in developing an image-inertial based 3D Reconstruction system for subsea use (Zupt product 3D Recon), Zupt developed HaloCAM as a more efficient tool to allow accurate determination of verticality, heading, position and differential depth of subsea structures as they are installed. HaloCAM utilizes the same internal components as Zupt's Halo INS (IMU, PCBs, internal battery, etc.) but with the addition of a machine vision camera integrated in the bottom end cap of the subsea housing. The IMU used within the 'precise' version of Halo is also included in HaloCAM as the system retains the same INS capability as Halo.

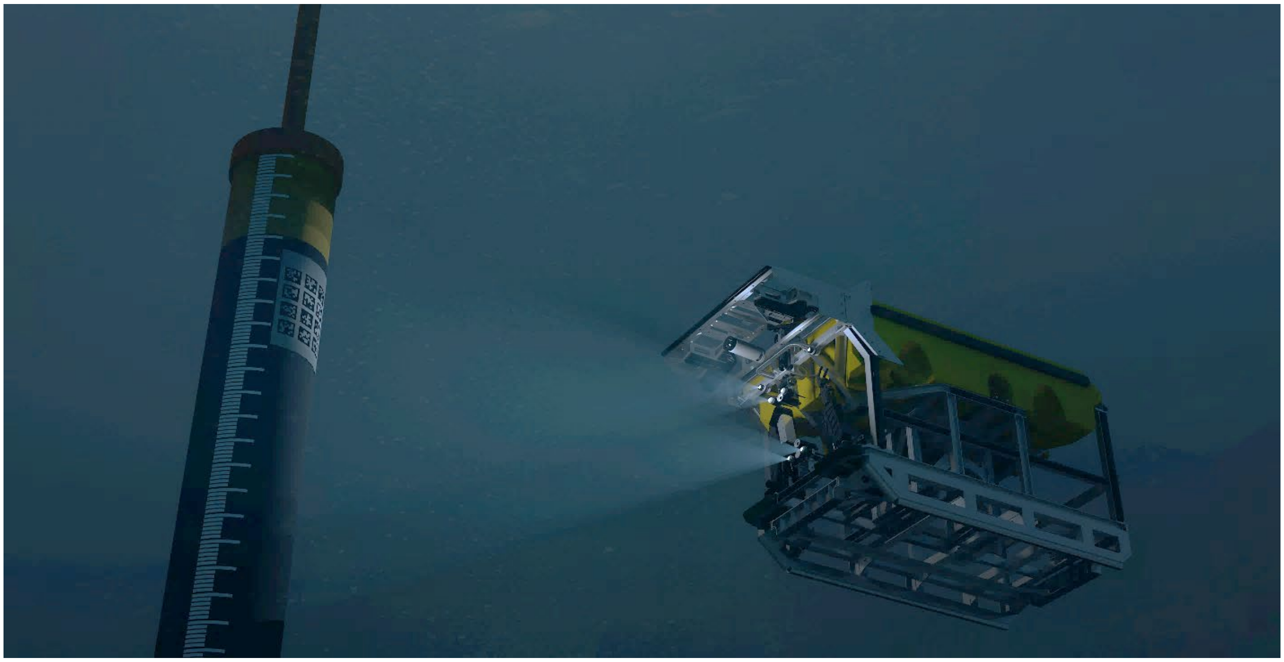
HaloCAM was specifically developed to aid drilling operations or offshore wind monopile installations with a single, contactless system for various positioning related tasks. The solution eliminates the need to physically mount sensors to conductor casings, monopiles, or other structures for the determination of verticality and stick-up height when installed into the seabed. The solution will also “place” virtual buoy markers onto the seabed to indicate the well-site touchdown point for conductor casing installation. The virtual marker buoy placement feature is enabled only when HaloCAM is integrated with a reliable USBL/LBL/Sparse LBL absolute positioning solution. In this case HaloCAM will place virtual markers onto the display screen to the same level of accuracy as the absolute ROV positioning solution.

The tightly integrated IMU contained within the same subsea housing as the camera significantly increases the deployment efficiency and capability of system. IMU integration eliminates the need for an external subsea INS and the need to dimensionally control and calculate lever arm offsets from the ROV INS to the camera after each installation onto the ROV. The system can be installed on the ROV without concern for precise leveling or heading as the IMU/camera are calibrated within the same housing.

Two versions of HaloCAM are available a navigation grade IMU (expensive) version and a MEMS IMU based solution. If the solution only needs to deliver pitch, roll and stick-up height the less expensive version is all that is needed.



Structure Installation

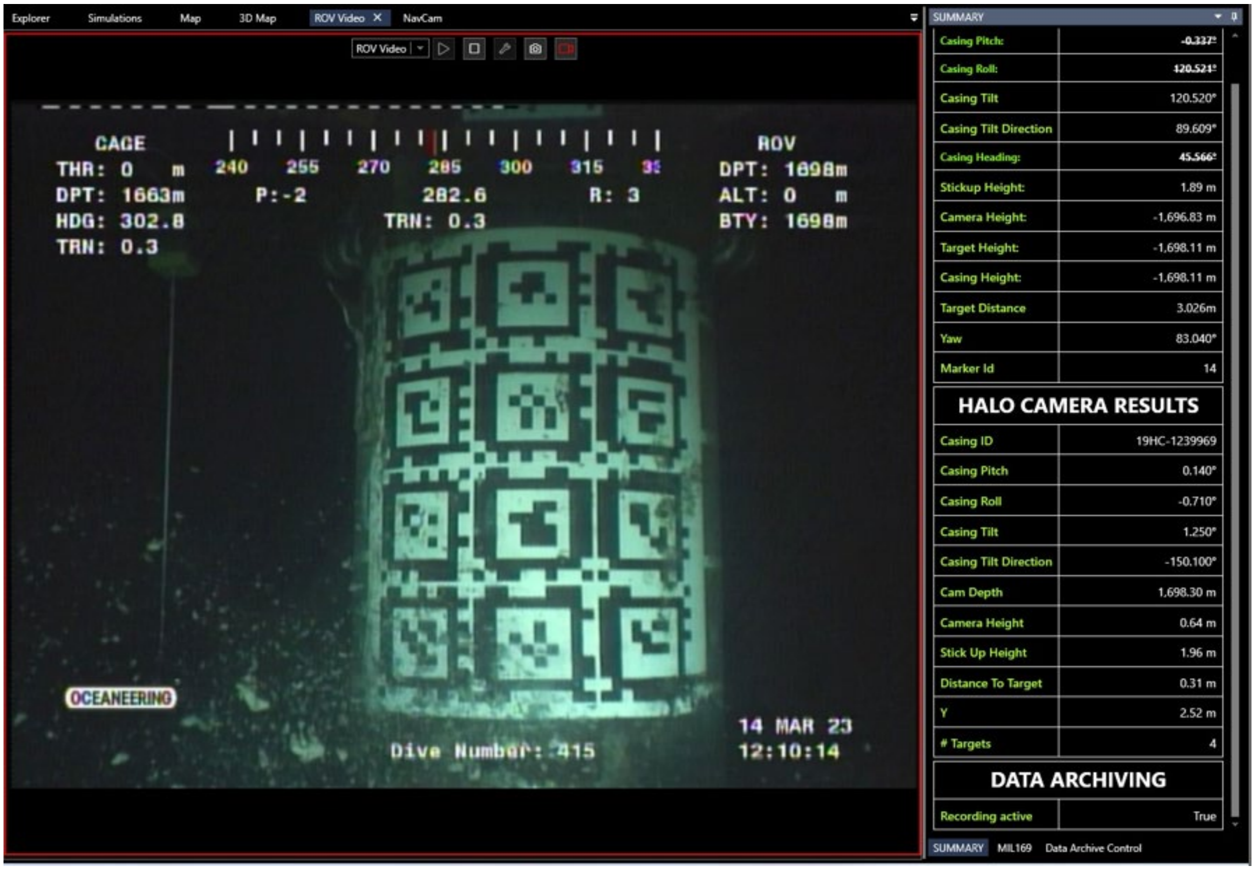


For the determination of verticality and position of structures as they are installed subsea, the solution requires Dimensionally Controlled (DC) waterproof markers to be placed on the structure. These markers are available as flexible, adhesive targets or rigid targets. Multiple conventional 'fiducial tags' (April Targets or similar) are included within each target to provide multiple sets of observations to provide redundant position, attitude, heading and depth data as well as a quality metric for this data (rms is displayed). Targets can be placed on any structure and DC can be completed during structure fabrication or offshore, just prior to deployment. The placement of the target requires a flat or gradually curved surface (such as a 36" conductor casing or monopile).

HaloCAM is interfaced to the ROV via a single RS 232 serial communication connector. As the structure approaches the seabed the ROV will position itself in a manner that sets HaloCAM at an approximately 2-meter offset from the target on the structure. Areas of poor visibility of camera-to-target offsets greater than 2 meters will reduce the positioning and attitude accuracy of the system. This reduction in accuracy is based on the pixel resolution of the camera at increasingly larger offsets from the target; as the system is further away from the structure, the pixel resolution becomes larger and larger. At an optimal 2-meter offset the pixel size is approximately 0.9mm. HaloCAM will automatically detect the tags on the structure target and determine whether the individual tag is able to provide orientation data for the solution. Tags that are not accepted by the solution may be hidden from view. The offshore user is provided quality data in real time confirming that enough tags can be clearly viewed by the system and RMS of the attitude, depth or position data.

During final installation, HaloCAM will determine the heading (relative if MEMS IMU, G or T with a navigation grade IMU), pitch, and roll of the structure in real time. HaloCAM combines the machine vision camera data with the ROV positioning solution to also determine the absolute position of the structure to the same level of positional accuracy as the subsea vehicle (USBL or LBL). If stick up height is required, a depth fix is taken at the seabed at the desired location. Then the vertical point of reference offset from the target will be published with respect to this seabed "set depth" point.

The data from HaloCAM is provided to the topside user in a simple user interface that displays the real-time HPR and position and the standard deviation of each data output. The top side user will indicate whether the structure is within verticality and position tolerances as the structure is being installed. Note – to operate HaloCAM over a simple serial link no video or image data is sent to the surface, just the measurements and quality data. If a 10/100MB Ethernet connection is available via the ROV's mux system, then image data (frame rate will be slowed to fit within the available bandwidth) will be available at the surface.



Virtual Marker Buoy Positioning

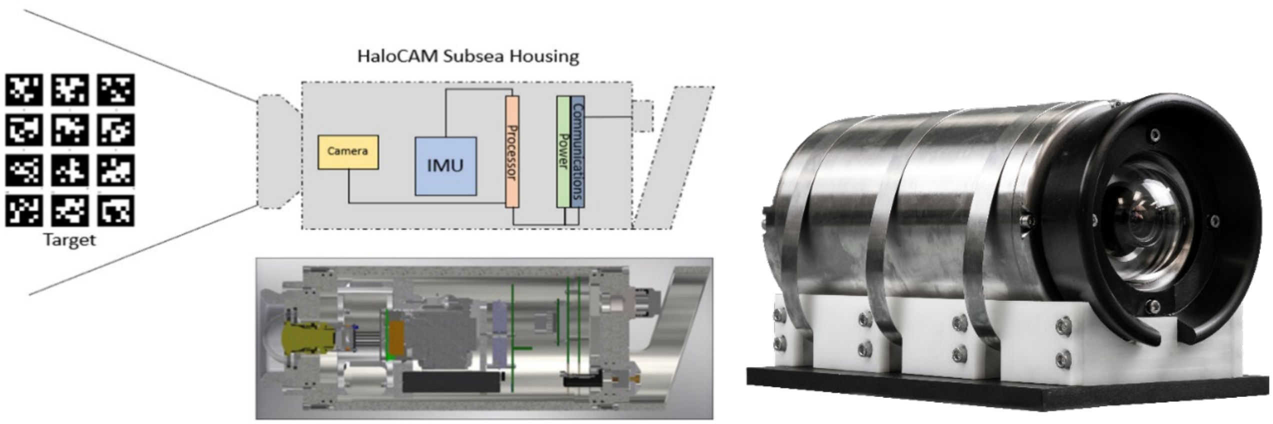
If HaloCAM (Navigation grade IMU) is interfaced with an ROV with 10/100MB. The imagery data will be provided normally at 5 Hz and allow virtual markers to be displayed on the seabed to indicate the wellsite for the topside drilling engineer's initial spud in.

This feature will display virtual markers on the seabed to the same level of accuracy as the ROV absolute positioning solution. The INS capability of the solution will "smooth" noisy LBL and USBL data, but if the absolute reference system is uncalibrated or very noisy the HaloCAM will not be able to fix the external navigation system shortcomings.

HaloCAM will "place" the markers on the seabed based on absolute position provided. These markers are displayed in a client specified pattern and are arranged relative to the other markers displayed as defined in the config file. The center of the virtual pattern displayed will be updated around the provided wellsite coordinates at a 5 Hz refresh rate. The marker configuration is defined in an externally editable config file. If USBL or LBL are available, the positioning solution will be directly integrated into the virtual marker buoy solution. If Sparse LBL is utilized for the marker positioning, the IMU contained within HaloCAM can be enabled to provide the survey-grade INS data to the Sparse LBL solution. In both cases HaloCAM will be physically mounted to the ROV and a DC survey will be completed to compute lever arm offsets to the acoustic positioning transducers on the ROV (USBL responder/transponder or LBL transceiver).

Physical Specifications

If HaloCAM (precise configuration) is to be used as an integrated INS solution for the subsea vehicle, the system will be physically mounted to the ROV (whether on calibrated tilt-arm or fixed in place) to provide a known lever arm offset for the navigation solution. If HaloCAM will solely be used for structure positioning and market buoy placement, HaloCAM can be held by the vehicle manipulator.



Operating Environment	
Water Depth Rating	4,000m Titanium
Power supply	9Vdc to 72Vdc Nominal 24Vdc
Power consumption	< 70W Nominal
Dimensions	H 266mm x Dia 150mm
Weight	Air 12kg, Water 7.5kg
Operating/Storage temperature	-10°C to +70°C /-30°C to +80°C
MTBF (computed / observed)	40 000 hours / 80 000 hours
Warranty	12 months international warranty
Export Control	ECCN 7A003

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.

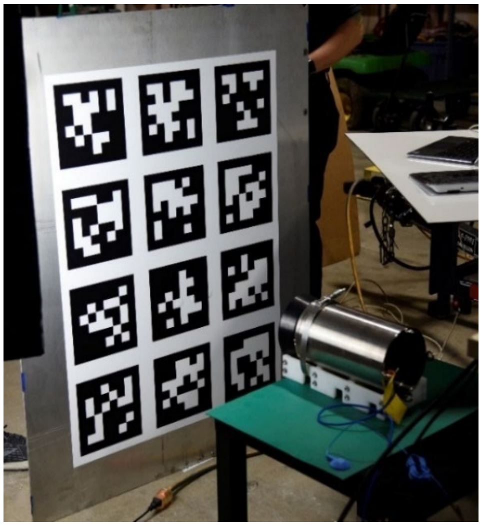
The pressure transducer within HaloCAM is one such sensor that requires annual calibration. To facilitate this, we have designed the top end cap so that the pressure transducer and associated PCB can be easily removed from the top end cap without opening the pressure housing.

Interfaces and Connectors	
Interfaces	3 x configurable bi-directional RS-232 1 x Ethernet 100 Mbits TCP client / TCP server / web server (GUI)
Connectors	Seacon MIN-CON
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, ASCII, BINARY
Data output rate	0.1 Hz to 10 Hz

As mentioned above, if imagery data is to be displayed for the topside user, HaloCAM requires a 10/100MB Ethernet connection from the ROV as well as of the RS-232 serial connection.

Structure Verticality/Positioning Specifications

Positioning Specifications of Target Mounted on Structure (No additional aiding sensors)	
Heading	+/- 0.15° sec Lat (navigation grade)
Pitch and Roll (Verticality)	+/- 0.1° (nav) +/- 0.25° (MEMS)
Differential Depth (Stick up height)	+/- 0.1 meter
Relative to Structure Position of ROV	+/- 0.02 meter



The above specifications for the HPR and position of structures being installed are based on HaloCAM being offset at <=2 meters and 15cm x 20cm individual fiducial targets. If visibility is poor or HaloCAM is significantly further from the structure being imaged the quoted accuracies will degrade. These specifications are with respect to the target. It is the responsibility of the end user to dimensionally control the target to the structure.

Higher accuracy may be achieved by increasing camera resolution, reducing the relative distance between HaloCAM and the target (structure being positioned), or increasing the size of the target being viewed. All of these methods are easily achievable based on project/scope demands; however considerations must be made when changing any of these parameters. HaloCAM allows for interchangeable block cameras based on the project needs, however increasing the camera resolution beyond the "base" 2048 x 2448 camera will reduce the sensor update rate. Additionally, increasing the size of the target may be the least expensive method of increasing the accuracy of HaloCAM (if reducing distance to the target is not possible), however larger targets become more suspectable to damage incurred prior to deployment.

Differential depth accuracy is not affected by inertial drift as the internal high resolution pressure transducer is utilized to aid the vertical channel of the INS solution.

Positioning accuracy of virtual marker buoys will follow the same positional accuracy of the ROV positioning solution (USBL, LBL, Sparse LBL).