

University of Limerick Mobile & Marine Robotics

# OceanRINGS: Current State of Development and Future Work

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University of Limerick

Contact:

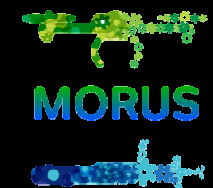
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[www.mmrrc.ul.ie](http://www.mmrrc.ul.ie)



EMRA 2017, Girona, Spain



# SFI Research Infrastructure



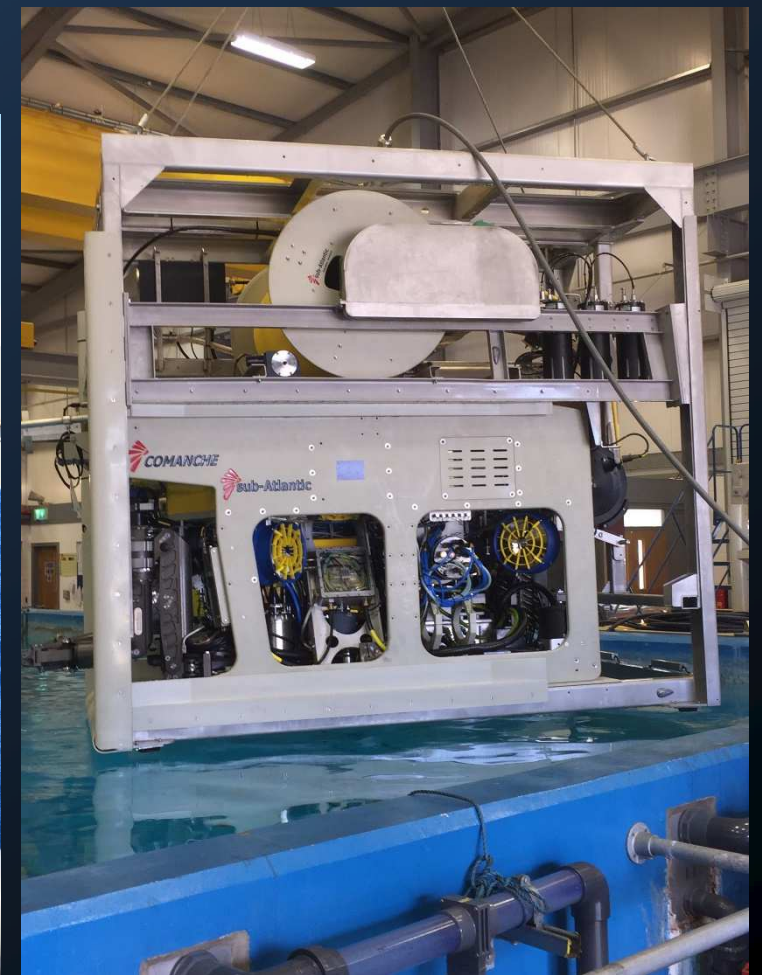
Mobile & Marine Robotics

## OCEAN RINGS

Advanced Technology for Submersible Operations

## MRE-ROV: Marine Renewable Energy Remotely Operated Vehicle for Challenging Conditions (Wave, Tidal, Wind)

€1.9M out of €28.8M total funding



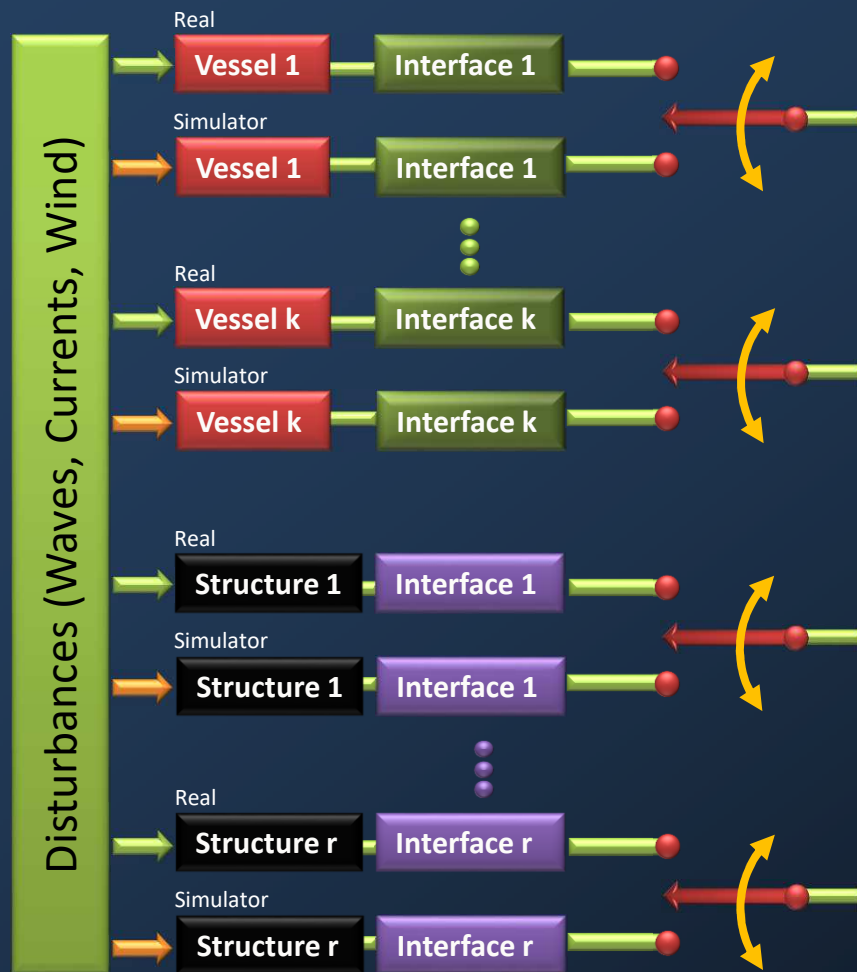
# Concept



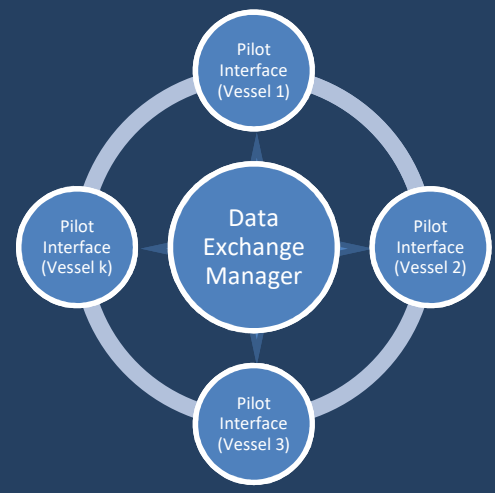
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OCEAN RINGS  
Smart Technologies for Subsea Operations

**Vessels:** ROVs, AUVs, ASVs, UAVs, Ships, Boats, ...



OCEAN RINGS  
Smart Technologies for Subsea Operations



**2D Display**

- Interaction Devices:**
- VR Headsets,
  - Microphones,
  - Touchscreens,
  - Hand Gesture Recognition Devices, ...

**3D Display**

**Structures:** Offshore Wind Turbines, MRE Devices, ...

# Control System



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Heading Controller	
Type:	Position Controller
Output:	$Y_d$
Inputs:	User Setpoint, Desired Course, Fixed Point, System States
Heading Modes:	HM1: Independent HM2: Follow Course HM3: Fixed Point HM4: Relative to Course HM5: Follow Ref. Frame

Speed Controller	
Type:	Velocity Controller
Output:	$u_d, v_d$
Inputs:	User Setpoints, Absolute Target, Relative Target, System States
Speed Modes:	SM1: Manual Surge & Sway SM2: Speed & Course Controller SM3: Hold Position SM4: Go To Position
Tracking Modes:	TM1: Follow Absolute Target TM2: Follow Relative Target
Target Actions:	TA1: Hold Absolute Position TA2: Hold Relative Position TA3: Go To Absolute Target TA4: Go To Relative Target

Horizontal Plane

## Middle Level Controllers (MLC)

# Control

## Heading Controller

HM2: Follow Course

## Speed Controller

SM2: Speed & Course Controller

### HEADING

Heading Mode: HM2: Follow Course

HM3: Fixed Point HM3: Ahead

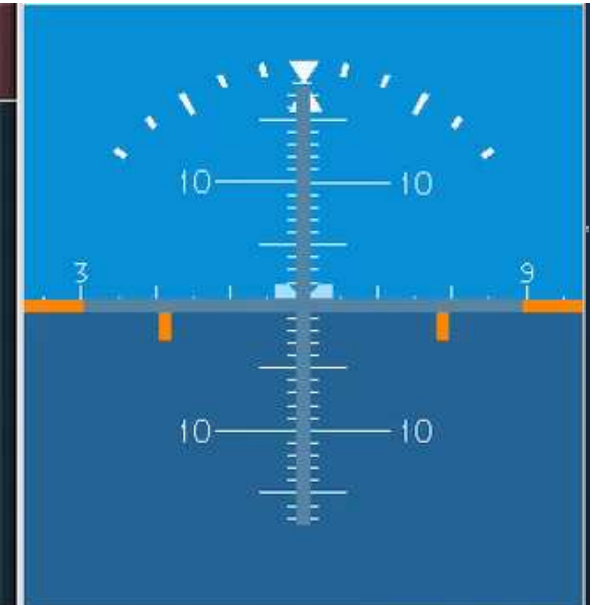
HM4: Offset: +90

$\tau N$  (VJ): 0.00

SP: 60



Surge  Sway



### SPEED

$\tau X$  (VJ): 0.00

$\tau Y$  (VJ): 0.00

Speed Mode:

- SM1:  Manual Surge & Sway
- SM2:  Speed & Course Controller
- SM3:  Hold Position
- SM4:  Go To Position

Tracking Mode:

- TM1:  Follow Absolute Target
- TM2:  Follow Relative Target

Course<sub>M</sub>(COG):



Speed (SOG):

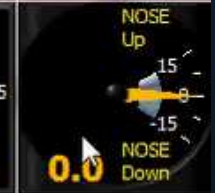


SP: 60

### ROLL



### PITCH



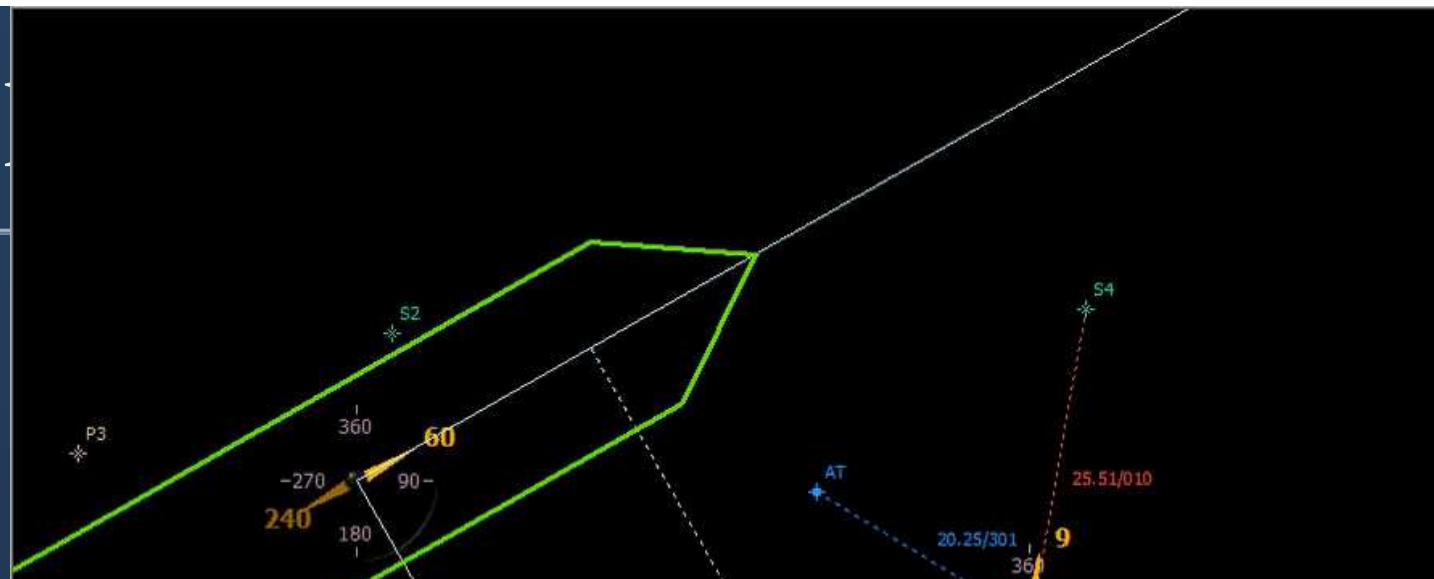
# Control

## Heading Controller

HM3: Fixed Point (S4)

## Speed Controller

TA3: Go To Absolute Target



**$\tau X$  (VJ)**  
Move FWD: 1.0  
Move BACK: -1.0  
VJ: 0.00

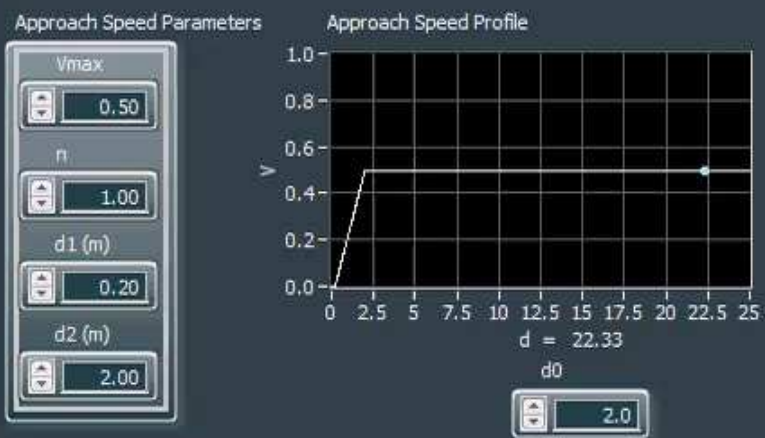
**$\tau Y$  (VJ)**  
Move PORT: -1.0  
Move STBD: 1.0  
VJ: 0.00

**Speed Mode**

- SM1:  Manual Surge & Sway
- SM2:  Speed & Course Controller
- SM3:  Hold Position
- SM4:  Go To Position

**Tracking Mode**

- TM1:  Follow Absolute Target
- TM2:  Follow Relative Target



# HEADING

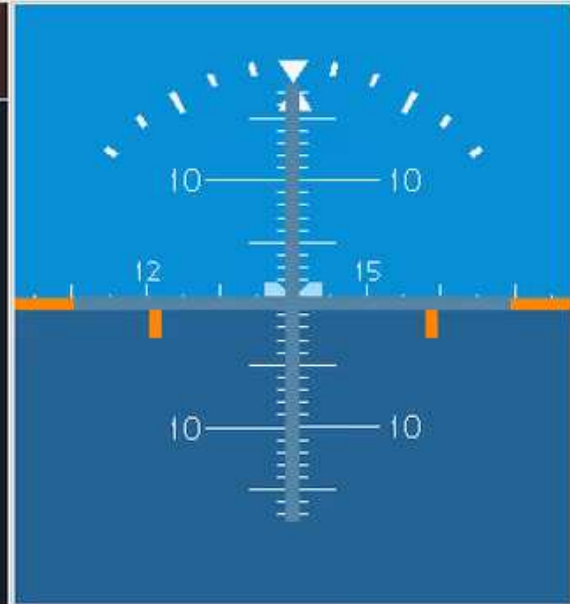
Heading Mode: HM3: Fixed Point HM3: Ahead  
HM4: Relative to Course S4 Fwd N

$\tau N$  (VJ) 0.00  
Turn CCW Turn CW

SP 140 140 320



W 140 E 320 S



# SPEED

Surge Sway

$\tau X$  (VJ) 0.00  
Move FWD Move BACK

$\tau Y$  (VJ) 0.00  
Move PORT Move STBD

Speed Mode  
SM1: Manual Surge & Sway  
SM2: Speed & Course Controller  
SM3: Hold Position  
SM4: Go To Position

Tracking Mode  
TM1: Follow Absolute Target  
TM2: Follow Relative Target

Course<sub>M</sub> (COG) 50  
Speed (SOG) 0.00



# ROLL



# PITCH



Ballycuggaran Loop Start



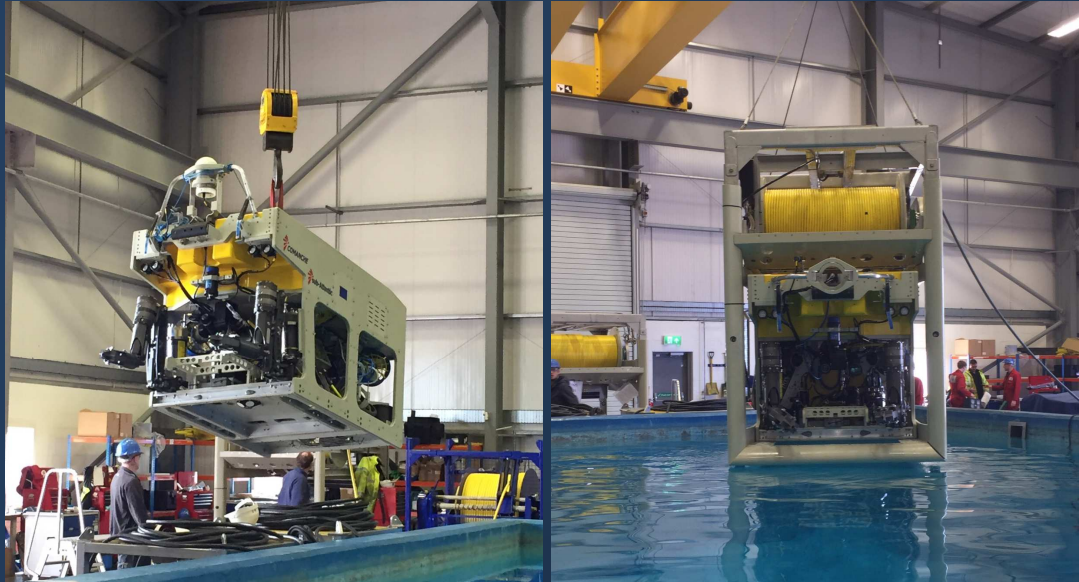
# MRE ROV



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GNSS: Applied Acoustic Engineering



INS: PHINS 6000



DVL: Nortek



Depth: Valeport UV-SVP

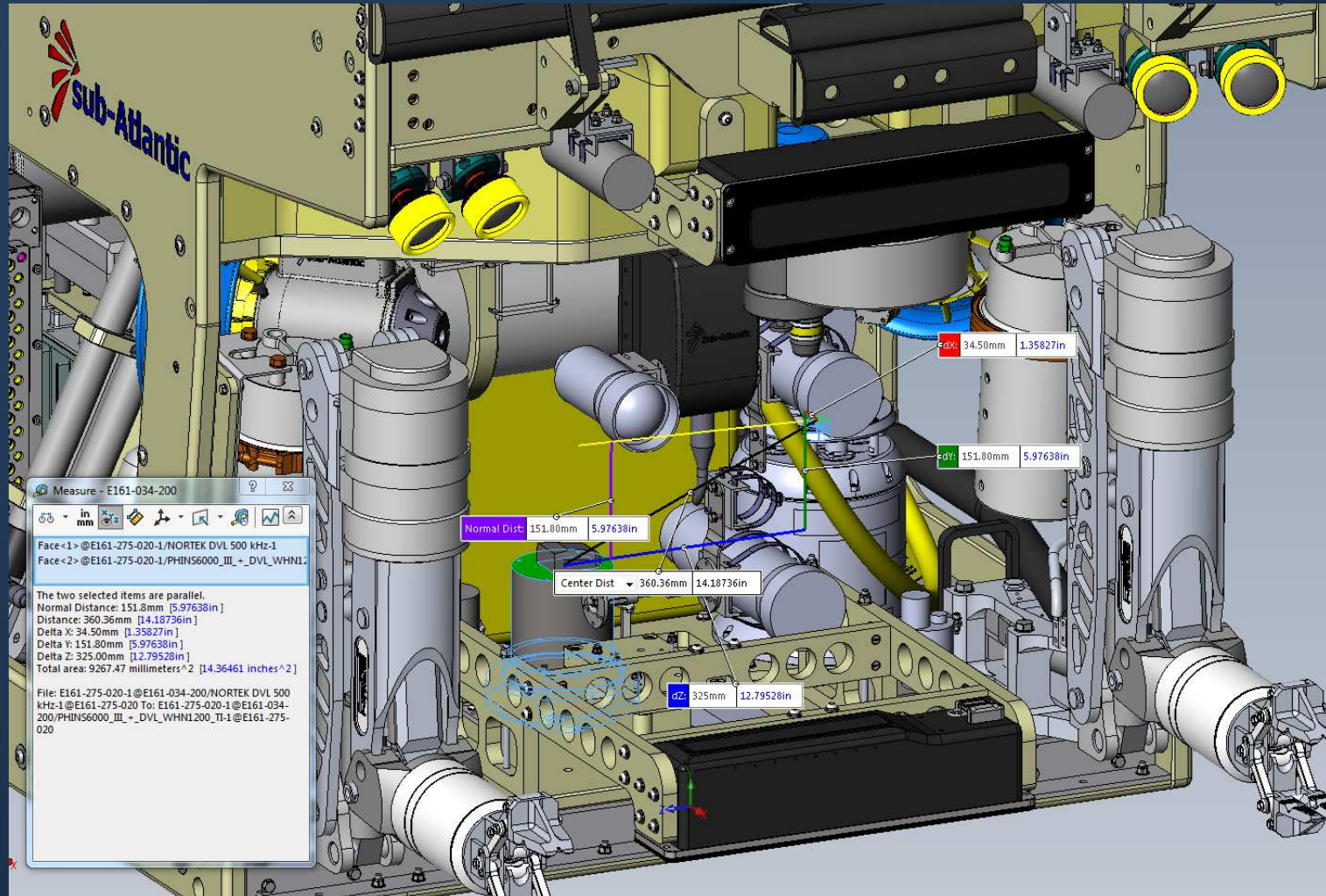
# MRE ROV



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Smart Technology for Global Operations



Lever Arms

NAVIGATION DATA - PHINS6000 - IXBLUE - Mozilla Firefox

192.168.1.111/control\_expertview/



### NAVIGATION DATA

Heading & Attitude		Heave		Speed	
Heading	67.486° (±0.157°)	Heave	0.06 m	Speed Norm	0.03 m/s
Roll	0.597° (±0.002°)	Surge	0.02 m	North Speed	-0.022 m/s (±0.031 m/s)
Pitch	1.438° (±0.001°)	Sway	0.06 m	East Speed	0.025 m/s (±0.032 m/s)
Position		Time		Vert. Speed	0.076 m/s (±0.005 m/s)
Latitude	54.25346763° N (±13.758 m)	Run Time	00 d 01:18:39.000	Current	
Longitude	0.93541498° W (±13.399 m)	UTC Time	01:18:39.000	North Current	-0.037 m/s (±0.096 m/s)
Depth	0.92 m (±0.257 m)	Last UTC Sync Time	---	East Current	0.007 m/s (±0.096 m/s)
DVL		GPS 1		Depth	
Bottom Speed X	0.011 m/s	Latitude	---	Depth	1.349 m
Bottom Speed Y	0.018 m/s	Longitude	---	Time	01:18:38.767
Bottom Speed Z	0.072 m/s	Altitude	---	CTD	
Water Speed X	0.088 m/s	Std. Dev.	---	Speed	1477.110 m/s
Water Speed Y	-0.053 m/s	Time	---		
Water Speed Z	0.035 m/s	Mode	---		
Range to Bottom	4.0500 m	Delay	---		
Sound Speed	1519.000 m/s				
Time	01:18:38.957				

Lever Arms

# MRE ROV



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HMI Parser\_IXBLUE\_STD\_BIN.rtf Block Diagram on MREROV\_Project.hproj/Mr Computer  
 File Edit View Project Operate Tools Window Help  
 13pt Application Font

Bit Mask 1

Bit n°	Internal Block description	INS <sup>(*)</sup>	AHRS <sup>(**)</sup>
0	Attitude & Heading	X	X
1	Attitude & Heading standard deviation	X	N/A
2	Real time Heave/Surge/Sway	X	X
3	Smart Heave™	X	X
4	Heading/Roll/Pitch Rate	X	X
5	Rotation rate in vessel frame	X	X
6	Acceleration in vessel frame	X	X
7	Position	X	N/A
8	Position standard deviation	X	N/A
9	Speed in geographic frame	X	N/A
10	Speed std dev in geographic frame	X	N/A
11	Current in geographic frame	X	N/A
12	Current std dev in geographic frame	X	N/A
13	System date	X	X
14	INS/AHRS sensor status	X	X

Bit Mask 2

Bit n°	Block description	INS <sup>(*)</sup>
0	UTC data	X
1	GPS1 data	X
2	GPS2 data	X
3	Manual GPS data	X
4, 5	EMLOG1, EMLOG 2 data	X
6, 7, 8	USBL1 - 3 data	X
9	Depth data	X
10	DVL Ground Speed	X
11	DVL Water Speed	X
12	Sound Velocity	X
13	DMI	X
14 - 17	LBL1 - 4 data	X
18 - 20	Event marker A, B, C	X
21	DVL2 Ground Speed	X
22	DVL2 Water Speed	X
23 to 31	Reserved	N/A

Header	Navigation data blocks	External sensor data blocks	Checksum
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header

Data	Format	Units
Header 1	Byte	Value : 'I'
Header 2	Byte	Value : 'X'
Protocol version	Byte	0x02
Bit Mask 1	DWord	Bloc combination identification bit mask
Navigation data blocks		Bit is set to 1 when bloc is output, 0 otherwise.
Bit Mask 2	DWord	Bloc combination identification bit mask
External data		Bit is set to 1 when bloc is output, 0 otherwise.
Total tologram size	Word	Number of bytes of the message including 21 byte header
Navigation data validity time	Dword	Validity time in steps of 100us
Counter	DWord	Cycling counter inside [0:2 <sup>32</sup> -1]

Bit n°	Internal Block description	INS <sup>(*)</sup>	AHRS <sup>(**)</sup>
15	INS algorithm status	X	N/A
16	INS system status	X	N/A
17	INS user status	X	N/A
18	AHRS algorithm status	N/A	X
19	AHRS system status	N/A	X
20	AHRS user status	N/A	X
21	Heave, surge and sway speeds	X	X
22	Speed in vessel frame	X	N/A
23	Acceleration in geographic frame	X	N/A
24	Course and speed over ground	X	N/A
25	Temperatures (ACC/FOG/ANA)	X	X
26 to 31	Reserved	N/A	N/A

Quality indicator	Corresponding SD attributed to GPS position fix if no GST is received	Positioning system mode indicator
0	Data invalid	N/A
1	10 m	Natural
2	3 m	Differential
3	10 m	Military
4	0.1 m	RTK
5	0.3 m	Float RTK
6 - 255	Data invalid	Other mode

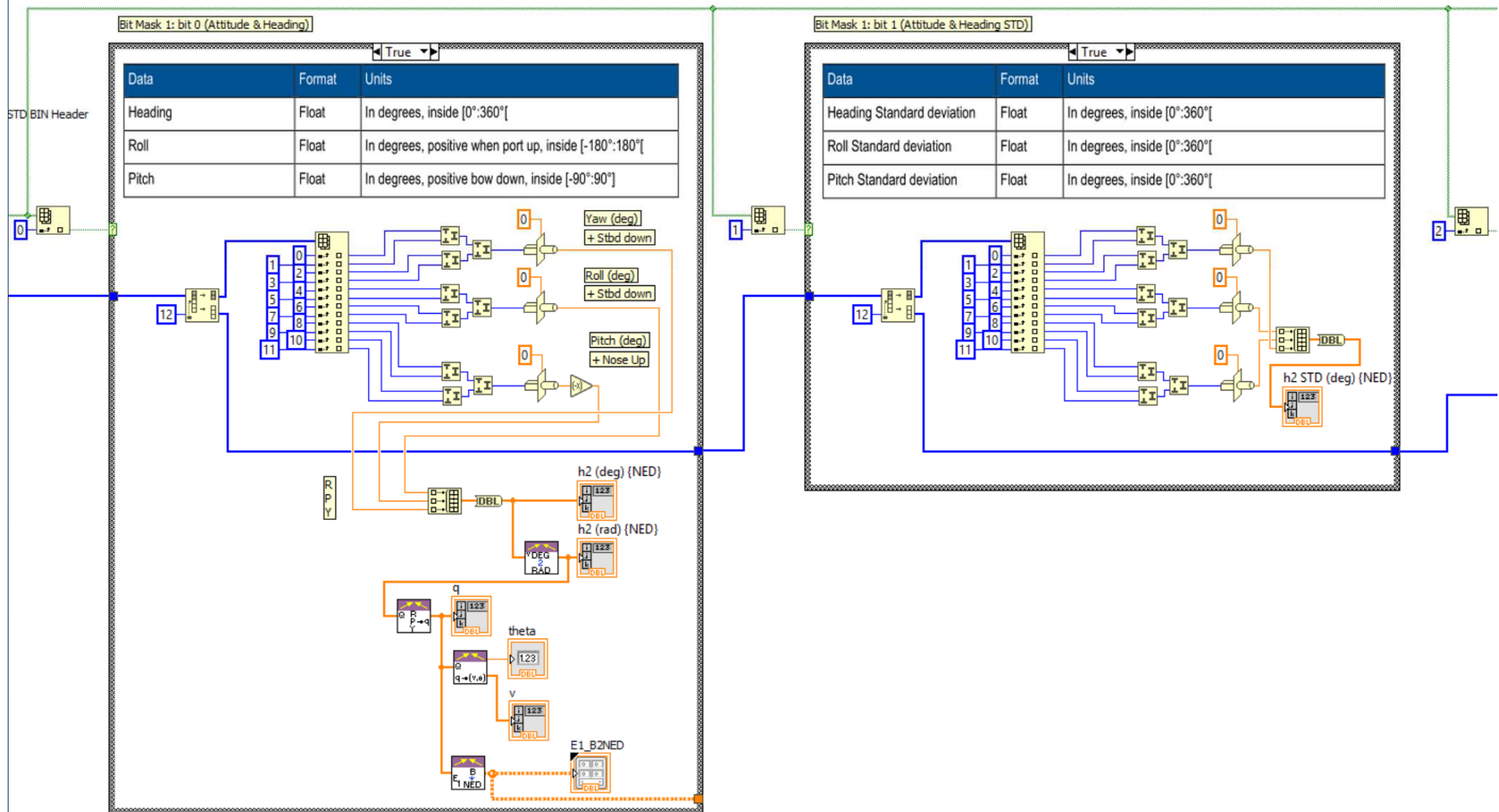
## Output Message: IXBLUE STD BIN (20Hz)

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Output Message: IXBLUE STD BIN (20Hz)

# MRE ROV



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**MRE Control Allocation**

Horizontal Thrusters (Layer 0) **Enable HT**

HT Saturation Bounds

HT1 HT2 HT3 HT4

Horizontal Thrusters (Layer 1) **Enable HT**

HT Saturation Bounds

HT1 HT2 HT3 HT4

Vertical Thrusters **Enable VT**

VT Saturation Bounds

VT1 VT2 VT3 VT4

**MRE Thruster Forces Visualisation**

Horizontal Thrusters (Layer 0)

4 HT (Configuration 1)

Horizontal Thrusters (Layer 1)

4 HT (Configuration 1)

Vertical Thrusters

3 VT (Configuration 6)

Stop

## Fault-Tolerant Control

# MRE ROV

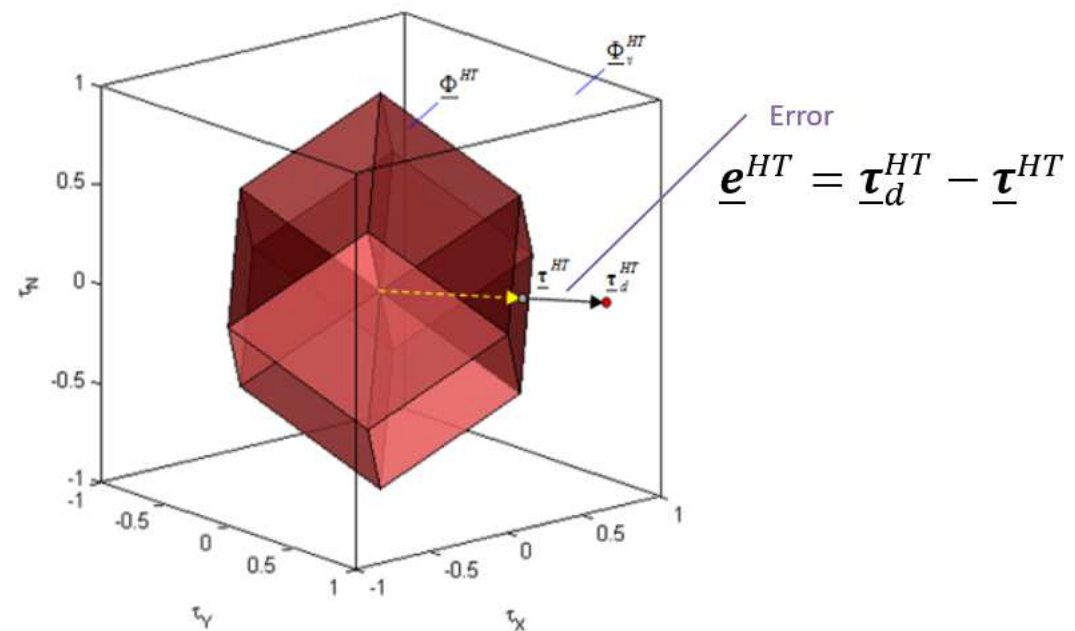
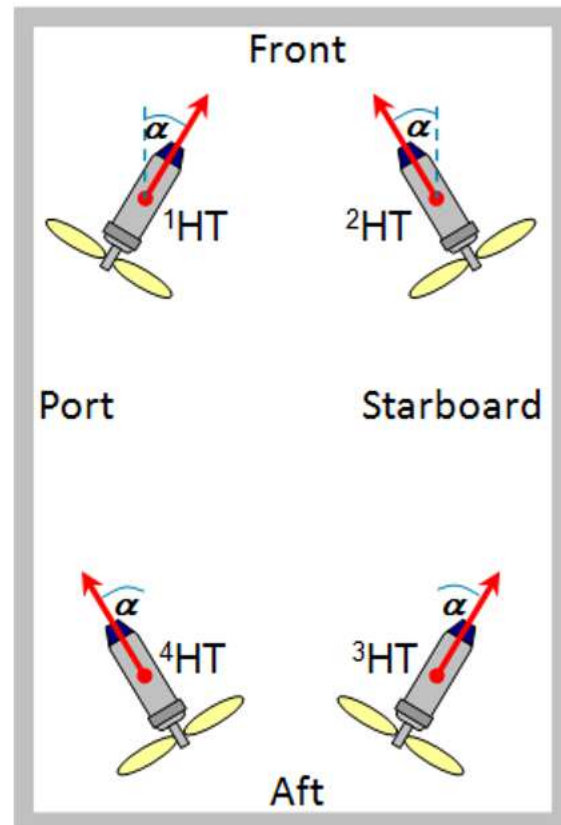


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## Force Feedback

$$\underline{f}_{FF}^{HT} = -K\underline{e}^{HT}$$



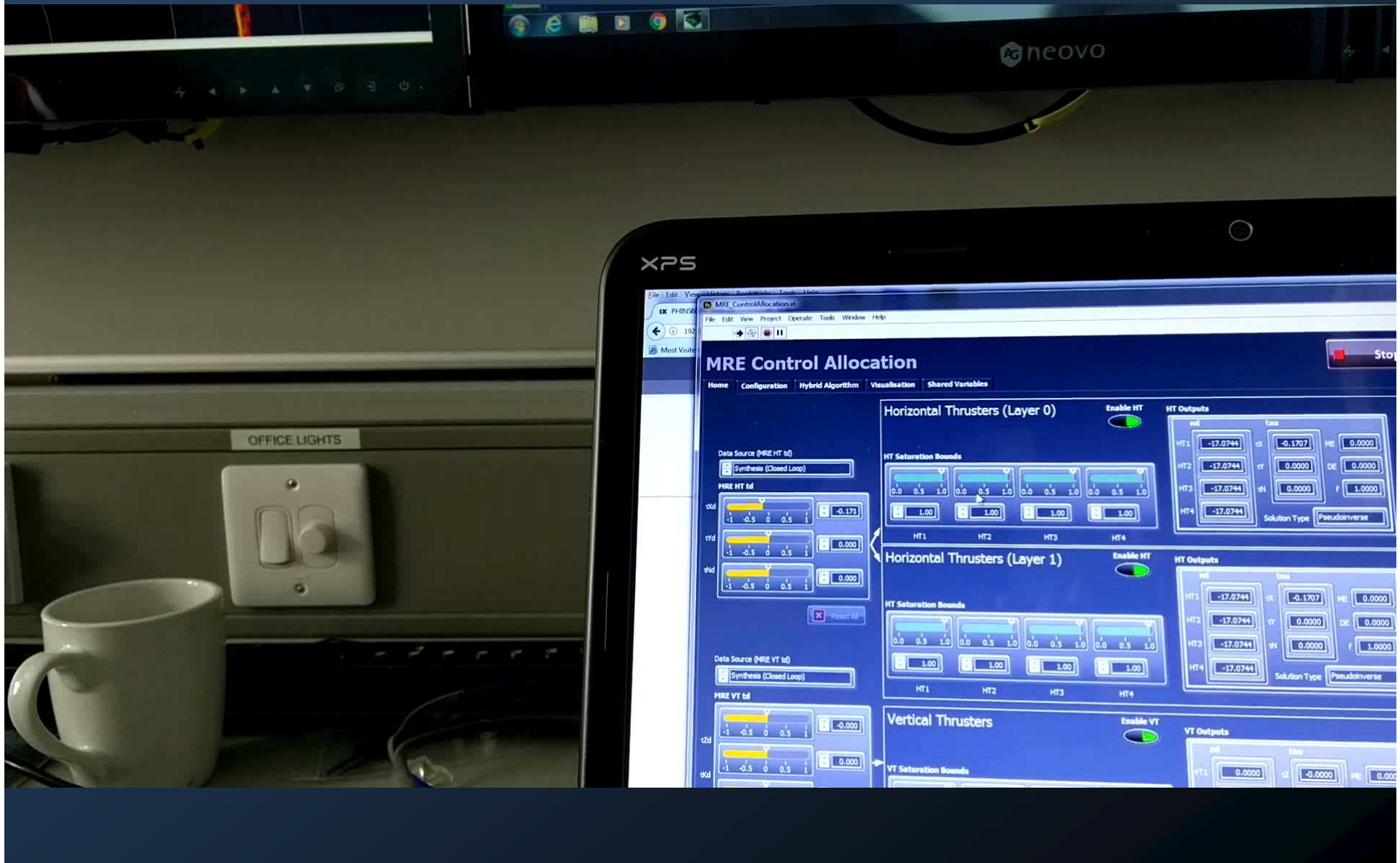
## Fault-Tolerant Control

# MRE ROV



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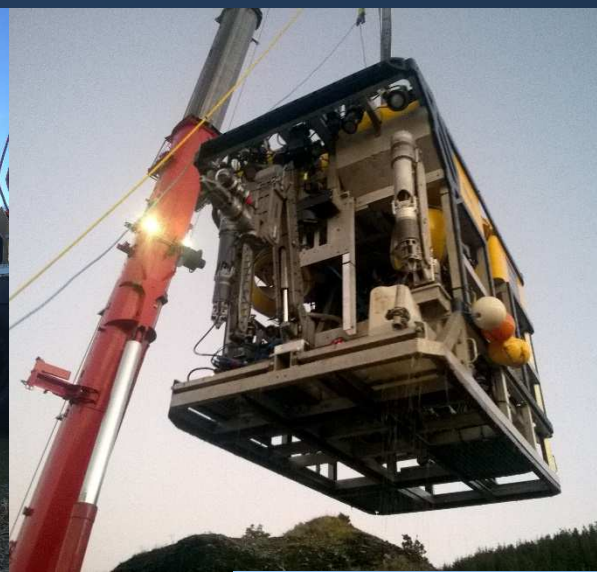
# Trials at Portroe, Nov 2016



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Trials at Portroe, Nov 2016



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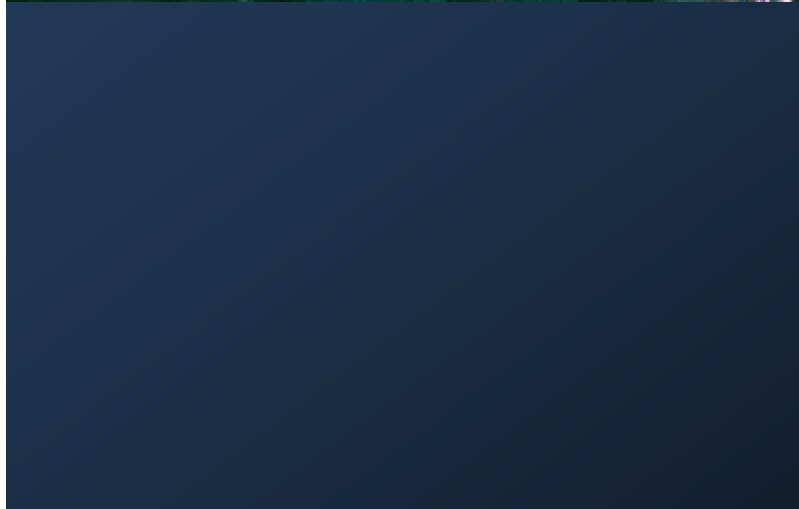


# Trials at Portroe, Nov 2016



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# Trials at Portroe, Nov 2016



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Open Technology for Submersible Operations

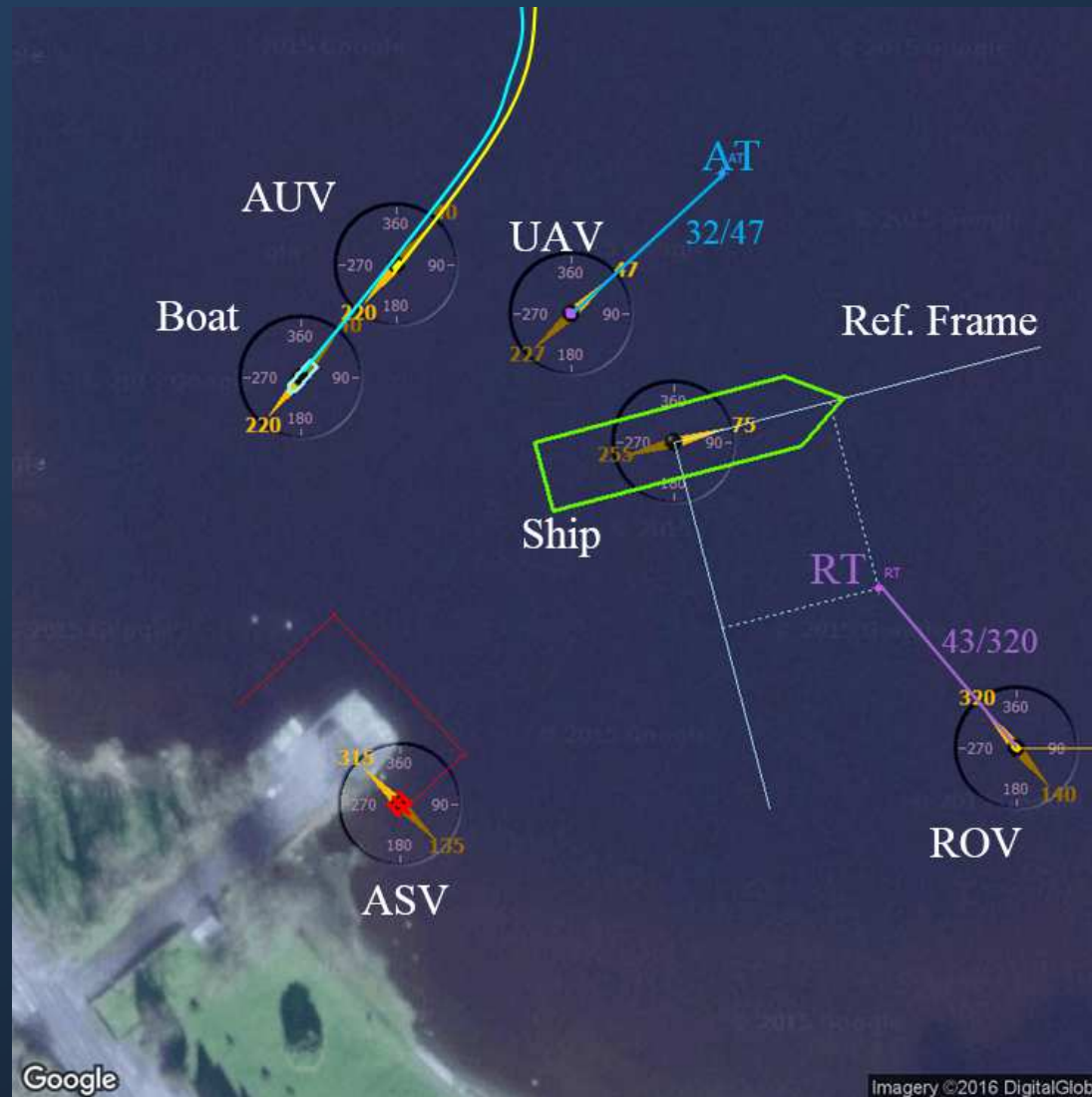


# 2D Display



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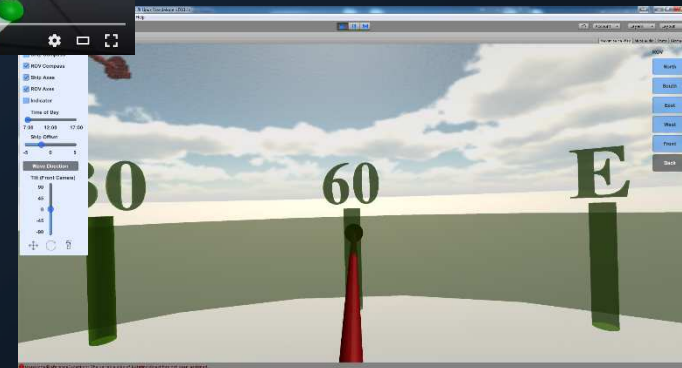
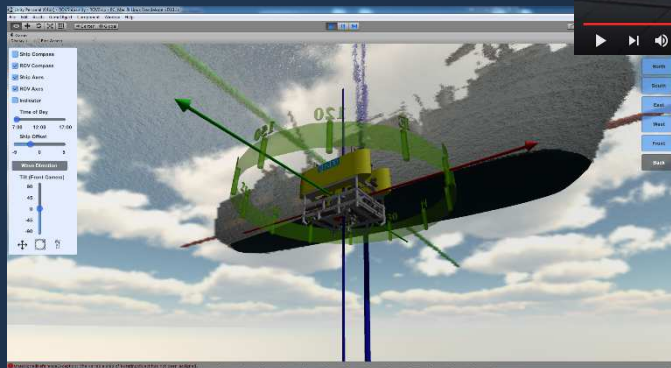
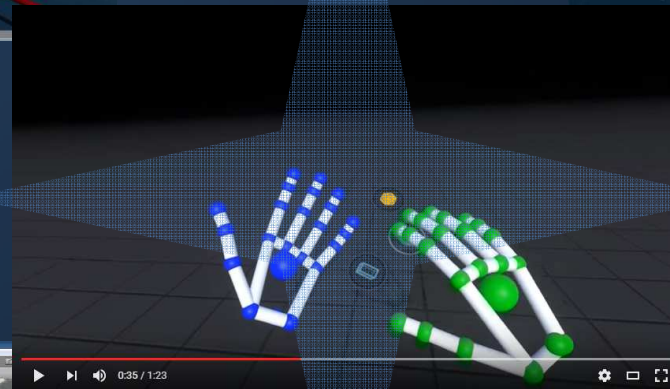
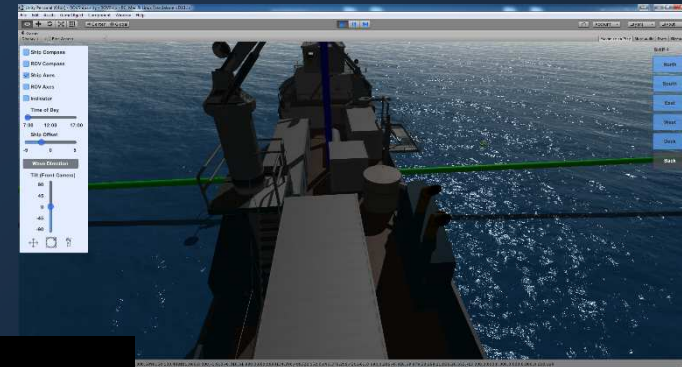
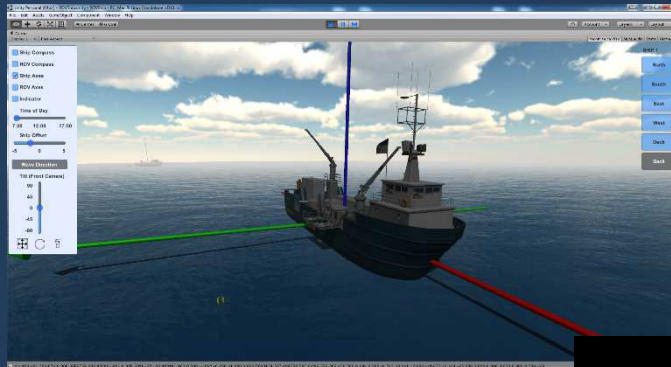
2D visualisation of mission progress with six heterogeneous vehicles

# 3D Display



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Open-Source Platform for Submersible Operations



Activation of virtual switches with LeapMotion Orion tracking device can be used to switch 3D viewpoints, improve situation awareness and aid remote control

# 3D Display



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Open-Source Technology for Submersible Operations

Unity Personal (64-bit) - ROVShip.unity - ROVShip - PC, Mac & Linux Standalone <DX11>

File Edit Assets GameObject Component Window Help



Center Local



Account Layers Layout

Game Display 1 Free Aspect

Scale 1x Measure on Play Mute audio Stats Gizmos

- Ship Compass
- ROV Compass
- Ship Axes
- ROV Axes
- Indicator

Time of Day

7:00 12:00 17:00

Ship Offset

-5 0 5

Wave Direction

Tilt (Front Camera)

90 45 0 -45 -90



SHIP 1

- North
- South
- East
- West
- Deck
- Back

400.109,380.073,0.000,5889758.032,487801.891,0.000,5890158.141,488181.964,0.000,0.090,-0.680,60.360,-0.180,5890134.141,488222.423,0.706,376.109,420.532,0.706,-0.125,-1.035,59.867,28.947,40.144,29.209,39.954,0.000,0.000,0.000,0.000,0.039,U29