Team BangaloreRobotics
LASSIE III – An Autonomous Underwater Master- Slave AUV system for ROBOSUB 2015

Team Member	Representing
Dr. G Venkatesh (Mentor)	BANGALORE ROBOTICS PVT. LTD., INDIA
Arul Vishwanathan (Advisor)	NOKIA SIEMENS, INDIA
Deepak Narayanan (Captain)	JYOTHY INSTITUTE OF TECHNOLOGY, INDIA
Varun S	JYOTHY INSTITUTE OF TECHNOLOGY, INDIA
Nithyananda RS	KSSE, INDIA
Kaushal Vishnukanth Rathi	ALPINE PUBLIC SCHOOL, INDIA
Ajith Aiswarya Kailash	BBUL JAIN VIDYALAYA, INDIA
Yoon Yati Htike	JIANGSU UNIVERSITY, CHINA
Andrin Thimo Schmid	ADVANCED SCHOOL, SWITZERLAND
Nagendra Babu	RHEIN WAAL UNI. OF APPLIED SCI., GERMANY
Vishnu	UNIVERSITY OF BURGUNDY LE CREUSOT., FRANCE
Olaleye Oluwafemi Paul	UNIVERSITY OF BURGUNDY LE CREUSOT., FRANCE
Nischal Dinesh	SPRING HILL ELEMENTARY SCHOOL, USA
Niranjan Dinesh	N VIRGINIA COMM. COLLEGE, USA

***Abstract* – LASSIE III was developed in 2014 as the concept AUV for Robosub 2015 & 2016. The AUV incorporates key advancements and innovations to make it agile, cheap and redundant. This time we have a whole new concept for our AUV, i.e, the Master-Slave system. undocking and docking, and Underwater communication between the Master and slave. All of the AUV's wiring resides within having no contact with the water making it robust and reliable. The Dome hull incorporates a novel inflated Butyl tube gasket. The AUV structure and program control systems are discussed in the paper.**

I. Introduction

The "Team BangaloreRobotics", an International multi-disciplinary and a multi-University team from Bangalore working together at the Bangalore Robotics center since Jan' 2014 has developed the AUV Lassie III for the Robosub 2015 competition. The competition is held on July 20-26 at the TRANSDEC facility, part of SPAWAR Systems Center Pacific in San Diego, California. The competition is designed to challenge the AUV's with tasks that simulate real-world missions. These include visual and acoustic detection of identified element, obstacle avoidance and navigation. The elements to be identified range from different shapes, color recognition and torpedo firing. These tasks are to be completed by the AUV autonomously without any human control or interaction.

II. Design Overview.

The AUV was designed with the main objective of making it as light weight and agile as possible. This time a cylindrical-dome structure is chosen as the hulls for both Master & Slave AUV. Lassie features two different hulls with an integrated cameras. The master AUV is powered by Archimedes screw Propulsion thruster & four BTD-150 Thrusters for the Slave AUV. Arducopter APM2.6 IMU board provides the autopilot for the vehicle along with a modified Depth Sensor MS5803-14A and external Digital Compass HM5833. The board incorporates a variety of sensors on-board and has the possibility to incorporate external sensors for greater fine-grained control. The vehicle is powered by 4x 11.1v,5Ah Li-Po batteries. The Master's AUV Software & Hardware is Radxa with Android/ Ubuntu, and the slave AUV with NUC with Ubuntu/Roborealm OpenCV and Roborealm libraries.

III.Mechanical Systems

A. The Hull

The Hull was designed with a main objective of making the AUV as light as possible. Hence a simple dome design was opted for the Hull structure with the measurements approximately being 60*50*8.5 cm.

The material for the Hull was also chosen based on the density and strength. The materials that were chosen for the design were

Polycarbonate Safeguard UVX and Acrylic.

Material	Density[1]
Polycarbonate Safeguard UVX	1.20 g/cm^3
Acrylic	1.20 g/cm^3
Polypropylene Uniboard Standard	0.65g/cm^3

Considering all the characteristics, Acrylic was chosen. It is water proof and hence all the electronic components are arranged in the Hull.

The Master Hull accommodates 2 batteries, Motherboard (Radexa), Arduino board, Ardupilot-IMU.

The Slave AUV has an Intel NUC motherboard, Ardupilot 2.6 Arduino Mega with a modified MS5803 Barometer sensor and associated Motor drivers for navigation .

B. Torpedo Launcher and Marker Dropper

The design for the torpedo systems has been revised this time.
The DC motor driven Torpedo is held captive by magnets and are deployed by changing the magnetic poles. The motor is triggered by a magnetic reed switch, which simply connects the inbuilt power to the motor. The motor is ON for a timed duration, not exceeding the distance to be travelled.

C. Grabber

For the performance of the **"Recovery Area"** task a grabber has been added to the AUV.The Grabber is an Expandable Leg design. The Leg is expanded by a Motor driven screw rod. The technique is to trap the cheese and moon samples by expanding the lower extremity of the Leg ourwards at an angle of 120 deg.. The release is when the Leg is contracted to a vertical angle.

D. Thrusters

The Propulsion was provided by four brushless motor commercial off-the-shelf (COTS) thrusters. Two thrusters are oriented in each of the vehicle's main axes for the up/down and Front/back movement of the AUV. The thrusters are all BTD-150 thrusters. This mounting scheme provides the vehicle with Linear control, as well as Pitch and Yaw.
The Roll control was eliminated by making the structure stable for self-righting the AUV. This was decided on to minimize the motors and drivers, and hence, to minimize the Power budget of the system.

III. Sensors

A. Camera

The vehicle has 2 CAM's onboard. 2 camera types were chosen – OV 5640 system camera. The USB type, C210/C270.

B. Acoustic Processing

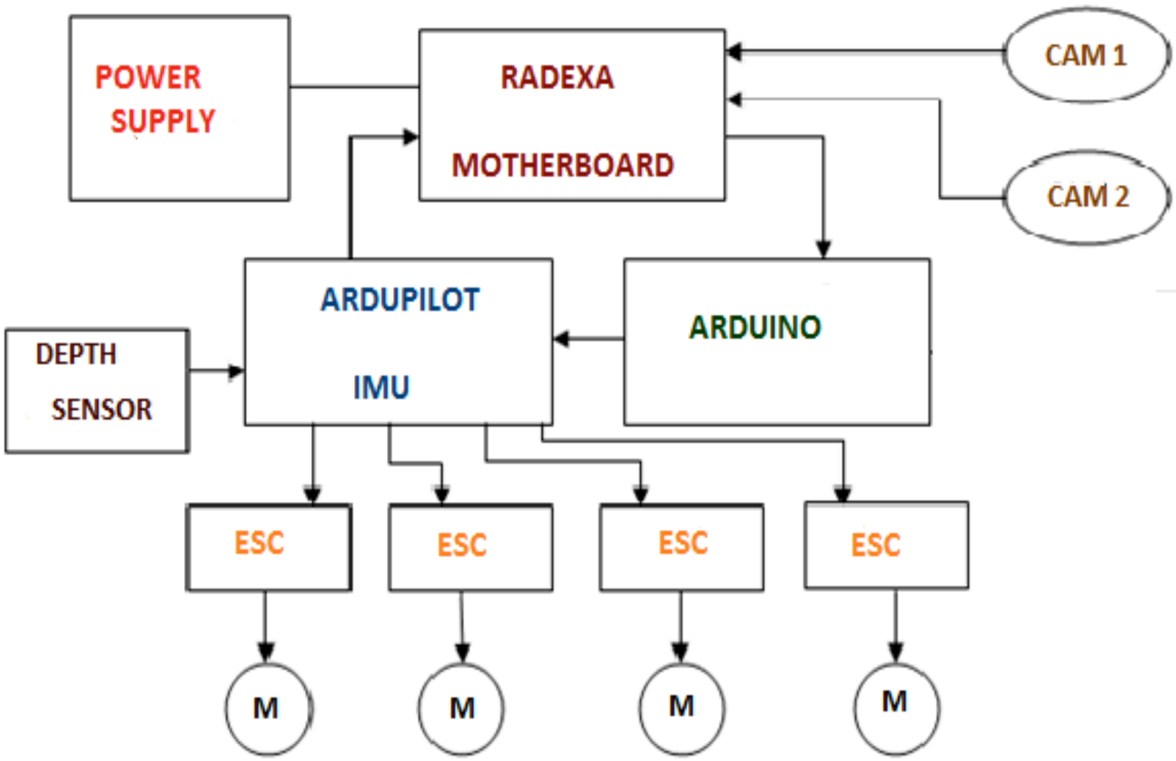
[1]Density is calculated by dividing the mass of the material by the volume and is normally expressed in g/cm^3.Specific Gravity (SG) is defined as the ratio of density of the material to the density of water (1 g/cm^3) at a specified temperature. Material with Specific Gravity less than 1 means that the material will float in the water.

The Pinger detection system consists of a self designed array of Hydrophones using water proof transducers. The Transducers are connected to the GPIO of the Motherboard for processing.
The software is coded to sample and hold the received 20Khz-4-KHZ signal. The software sub-routine then aligns the AUV towards the maximum signal direction.

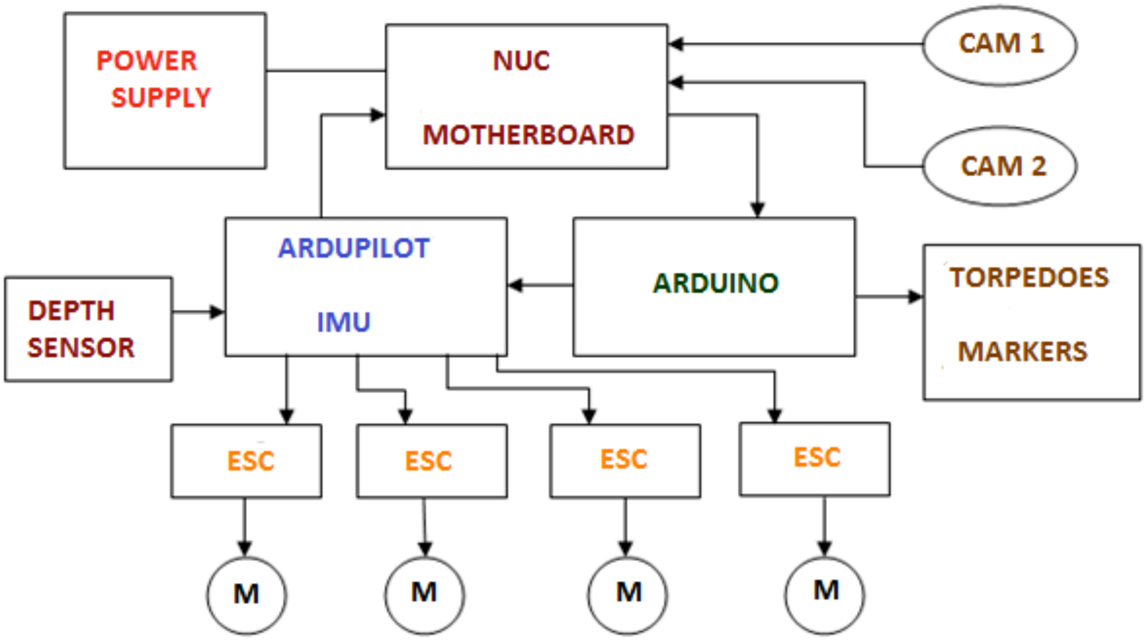
Underwater Communication

For the underwater communication between Masker & Slave, a 200khz transceiver is used.
A dual mode 500hz- 15khz Light-Voice channel inter sub communication system.

Functional Block Diagram



MASTER AUV



SLAVE AUV

3

C. Depth Measurement

The depth measurement is through the MS5803-14A. This is basically an Altimeter but is used to measure water pressure pressure. The Sensor outputs are calibrated to indicate depth in feet.

Depth data is used as one of the Waypoint info and is correlated with the Magnetometer data of the IMU. Together, they hopefully indicate a fairly accurate position of the AUV in the competition scene.

The vehicle has an Arducopter APM2.6 auto-piloting module. This board hosts a MS5803-14BA pressure sensor, Gyro and an accelerometer. There is also a depth sensor integrated externally to the ardupilot module. The auto-piloting system is controlled from an Arduino board through the Ubuntu/Android, Roborealm softwares. The arduino board additionally controls the grabber and the torpedo systems onboard. The thrusters are controlled directly by the Ardupilot via the brushed Motor ESC.

IV. Software

All high level functionality including the mission tasks are achieved via the vehicles software system. The systems software is built around Windows 7 operating system and Ubuntu/Android the image processing softwares OpenCV and Roborealm. The Ardupilot auto-piloting module is controlled from an Arduino based platform.
The Open-source code is modified for AUV functionality. This being different from in –the-air machines with respect to linear speed, reaction time and Motor RPM.

Vision Processing

There are two cameras onboard of each of the vehicle. The data from the same are processed by OpenCV or Roborealm which then control the auto-piloting system of the vehicle. Based on a selection criteria output from one of the systems and the sensor information recorded by the APM board, the vehicles navigation and task system is controlled.

The AVM Navigator module in Roborealm is tasked with the vehicles object recognition. Apart from this the module offers Navigation capabilities based on the object being tracked.

V. Computer

The software on the Master vehicle is powered by an RADEXA Rock Pro which has quad core processor running at 1.6Ghz.

The software on the Slave vehicle is powered by NUC, which has a processor frequency of 2.39GHz.

System Mother board: MASTER AUV:

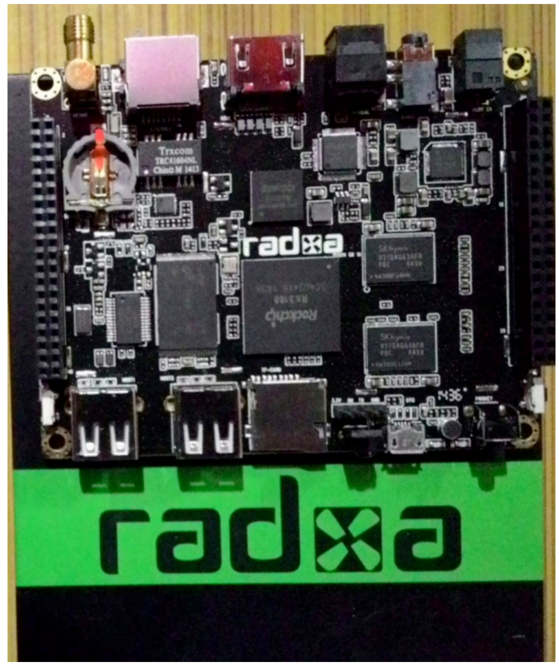
RADXA Rock Pro:

Radxa Rock is a single-board computer integrated with Bluetooth 4.0.This board offers 80 pins to interface and offers a much faster core CPU, up to 2GB RAM and 8GB of on board flash storage. This board mainly provides support to Linux and Android platforms.

FEATURES:

As a key feature for developers, this has a dual 40 pin headers which provide support including GPIO, I2C, SPI, Line In, USB 2.0,

PWM, ADC, LCD, GPS' etc.



Radxa Rock for Master AUV

This also has 10/100M Ethernet Port. This package comes with an antenna and Wi-Fi up to 150Mbps.

This provides analog video out and main GPU support Mail400-mp4@533Mhz, OpenGL ES 2.0.

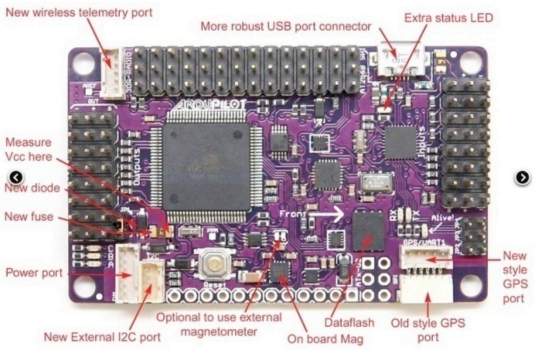
This board also contains Serial Console for debugging.

System Mother board: SLAVE AUV:

NUC Kit DN2820FYKH for

The INTEL NUC, has a Intel Celeron Processor N2820 which supports up to 2.4Ghz Dual core, 1MB cache and 7.5W TDP. The main features are:

1. Supports Intel Visual Bios
2. Compatible with Linux.



The IMU Sensors Over view

The ArduPilotMega 2.5 system features a newly designed enclosure and an optional Power Module with integrated 5.3V regulator and current and voltage sensing.

The ArduPilot Mega 2.6 is a complete open source autopilot developed specifically for Autonomous Flying vehicles. It is employed here to control our AUV with Waypoint Navigation.

The Board is a Atmega2560 based system, with built in 3 Axis accelerometer, Barometer, Gyroscope, Magnetometer. While the internal Barometer is fairly good, it is left unused.

Underwater Communication

An attempt is made to demonstrate underwater intercommunication methods. The AUV is equipped to communicate with a carrier frequency from 1Khz to 19Khz. Low baudrate audio channels were tested in the limited pool time and AFSK was tried with some success.

Simultaneous Light modulation was also tried in parallel with the Audio channels. Further tests to validate accurate communication could not be done due to the lack of Blue and Green high powered light sources during the limited pool time available.

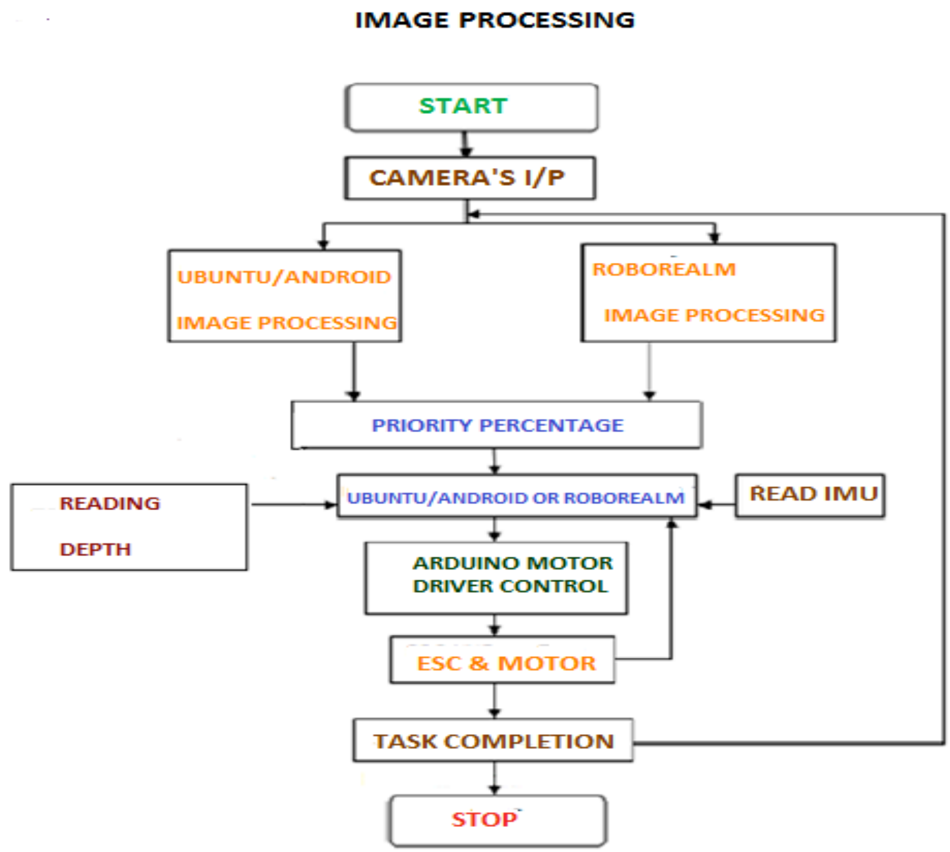
A 30W RGB flood light was employed with some success till the breakdown of the LED driver.

Possibility of multi-mode Audio frequency communication seems to work upto 60ft underwater. While there were broken packets, simple Morse code was decoded at the receiving end.

The Dome Hull and Bicycle inner Tube Gasket

The AUV system is made using 300mm and 250mm Polycarbonate and Acrylic Domes. The water seal is an innovative inflated Butyl rubber tube, specifically the inner tube of bicycle tyres. The tube is inflated to 40PSI and holds good under 80ft of fresh water.

FLOWCHART



Thruster Motor

BTD 150

3"(76mm)", 2 blade, generates 4.85 pounds of thrust or Peak thrust of 6.4 pounds from 19VDC volts

Hard anodized Aluminum finish for maximum corrosion resistance in salt and fresh water

Four Motors are used , 2 for up/down and 2 for Linear movement and YAW.

Motor Controller

The BTD150 motors are controlled by 30A 12V Electronic Speed controllers.

The Controllers run a bit warm but are sufficient to drive the motors to peak RPM.

Conclusion

The Present LASSIE III AUV is the 3rd in the series of a unique design and competition effort of Team BangaloreRobotics.

The Design was evaluated mainly for Three major parameters:

1. **Multiple Vehicles Master – Slave AUV system**
2. **Dome cap Hull**
3. **Inflated Butyl Rubber gasket**
4. **Redundant Analysis and Control system**
5. **Underwater Communication system.**

- ✓ **The emphasis was Multiple vehicles that can facilitate Autonomy and .**
- ✓ **A lighter Slave AUV needs a low power budget.**
- ✓ **The Mission time of useful deployment is comparatively longer.**
- ✓ **An attempt was made to construct a lighter AUV.**
- ✓ **Limited budget and time constraints have limited the number of innovative ideas to a lower number than was desired.**
- ✓ **A major part of the Design was the Mechanical and structural variations.**

The Team is thankful To the AUVSI Foundation and ONR for providing this opportunity to be a part of the ROBOSUB competition 2015.

- Mentor
- Team Captain

Team BangaloreRobotics

FIRST NAME	LAST NAME	TASKS
GURAPPA	VENKATESH	TEAM MENTOR
ARUL	VISHWANATHAN	TEAM ADVISOR
DEEPAK	NARAYANAN	Electronics , OpenCV Ubuntu IP, Hull , paper work
VARUN	S	Android System IP, Camera, Props
NITHYANANDA	RS	Android System, Hardware, Man Friday
KAUSHAL	VISHNUKANTH RATI	Ardupilot Depth Sensor, Software testing, Torpedo/ Marker system, The Kid.
AJITH AISWARYA KAILASH	BABUKUMAR	RADEXA, Pixy CAM, Mechanical , Torpedo/ /Marker Deployment
YOON	YATI HTIKE	Arduino, Depth Management
ANDRIN	THIMO SCHMID	Android Programming
NAGENDRA	BABU	Electronics systems, Poster
VISHNU	MUTHU	Systems testing
OLALEYE OLUWAFEMI	PAUL	Electronics
NISCHAL	DINESH	Electronics, water testing
NIRANJAN	DINESH	Navigation, Pool tests

Web: http://auvsi.bangalorerobotics.in/2015