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Submitted by

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DECLARATION

I, Nimesh Khandelwal, declare that the training report titled "Survivor Detection in flood affected areas using UAVs and Navigation Scheduling of UAVs for autonomous wall construction" being submitted by me in partial fulfilment of the degree of B.Tech. (Mechanical Engineering) is a project work carried out by me under the supervision of Dr. Debashish Ghose and Mr. Abhishek Kashyap, and the contents of this internship work, in full or in parts, have not been submitted to any other institute or University for the award of any certificate or diploma. I also certify that no part of this project work has been copied or borrowed from anyone else. In case any type of plagiarism is found out, I will be solely and completely responsible for it.

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Internships are essential to gain the practical exposure which otherwise, is not possible when studying in the college. This research experience has taught me immensely, but without the support of the faculty members of the *Department of Mechanical Engineering, Malaviya National Institute of Technology,* this would not have been possible.

It has been a wonderful experience during my internship at *IISc*. However, this would not have been so without the aid of the experienced professionals and many greatly talented people there. Thus, it gives me immense pleasure to thank the few people with whom I got the chance to work and gain the essence of research work, in general.

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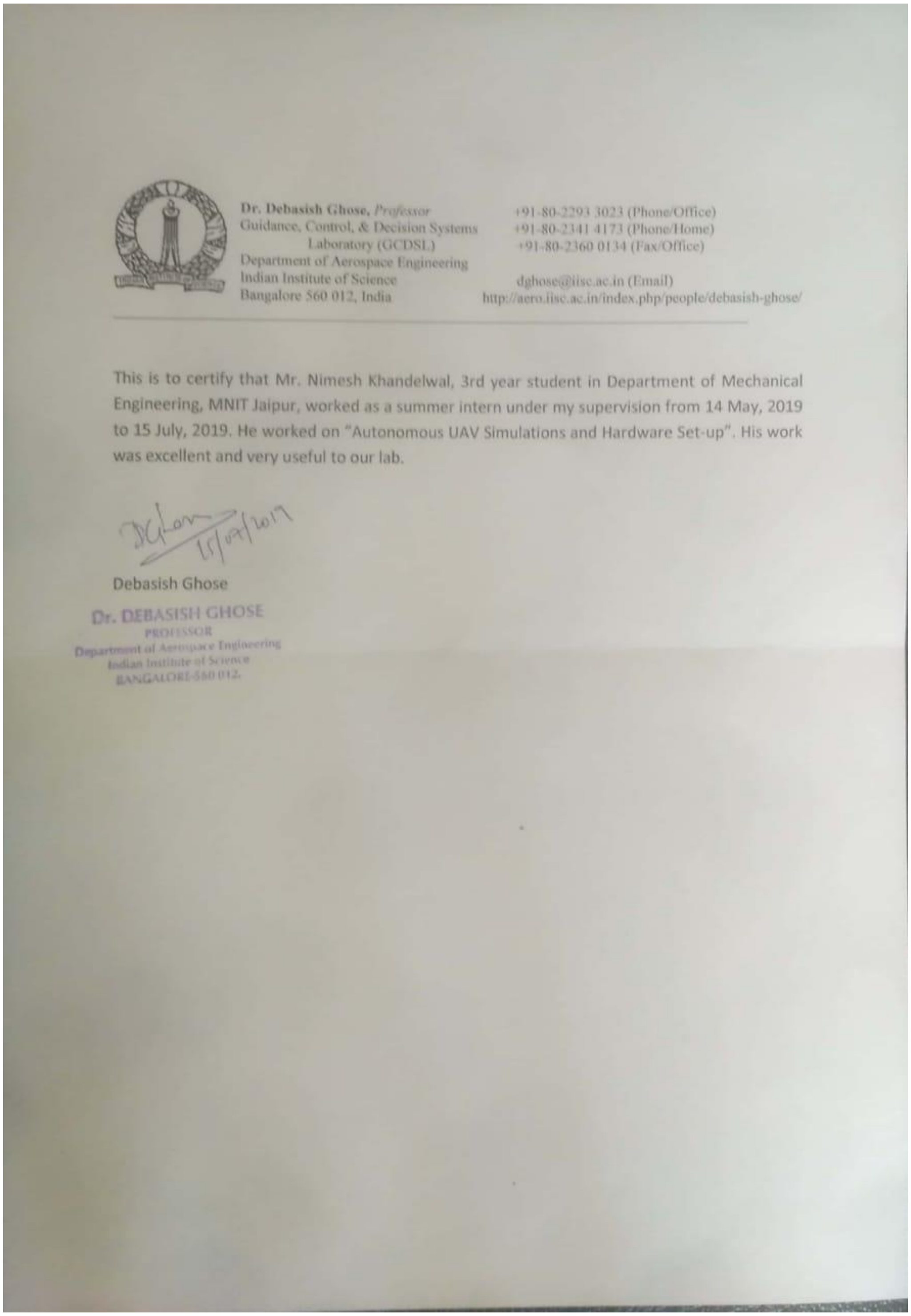
Lastly, it is never without my parents, who shower their unconditional love on me, I could have completed my internship and the projects given to me during this period.

Nimesh Khandelwal

(Author)

Certificate



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This is to certify that Mr. Nimesh Khandelwal, 3rd year student in Department of Mechanical Engineering, MNIT Jaipur, worked as a summer intern under my supervision from 14 May, 2019 to 15 July, 2019. He worked on "Autonomous UAV Simulations and Hardware Set-up". His work was excellent and very useful to our lab.

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Preface

This report was made as a part of the internship project that was given to the author during the summer of 2019 (May 15-July 15). The topics of the report cover: Survivor Detection in flood affected areas using UAVs and Navigation Scheduling of UAV swarm for autonomous wall construction.

An Unmanned Aerial Vehicle (UAV) (or Uncrewed Aerial Vehicle, commonly known as a drone) is an aircraft without human pilot on board and a type of Unmanned Vehicle. UAVs are a component of an Unmanned Aircraft System (UAS); which include a UAV, a ground-based controller, and a system of communications between the two. The flights of UAVs may operate with various degrees of autonomy: either under remote control by a human operator or autonomously by onboard computers or by sending control commands to the UAV via a ground-based controller (also known as a Ground Station).

Swarm robotics is an approach to the coordination of multiple robots as a system which consist of large numbers of mostly simple physical robots. It is supposed that a desired collective behaviour emerges from the interactions between the robots and interactions of robots with the environment. Autonomous UAV swarms have a great potential to complete tasks in a much more fast and efficient manner than conventional manually controlled single UAV systems. They play a major role in disaster relief, as they can reach areas that are difficult to reach for humans and drop packages containing food or medicines, survey the flood affected region for survivors, and also make a real time map of the region as well. The project report covers the aforementioned ideas and their application in simulated as well as in real environment.

A simulation is an approximate limitation of the operation of a process or system;[1] the act of simulating first requires a model is developed. This model is a well-defined description of the simulated subject, and represents its key characteristics, such as its behaviour, functions and abstract or physical properties. Simulation are critical to test the systems that cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist. Majority of the time in the project was spent in simulating the different scenarios to test various algorithms including control as well as the dynamics of the proposed systems.

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CHAPTER 1 Introduction

1.1 *Indian Institute of Science*

Indian Institute of Science (IISc) is a public institute for research and higher education in science, engineering, design, and management. It is a premier scientific research institute in India and has been ranked 1st in the 'university' and 'overall' category for the last three consecutive years (2016–18) and first in the current year (2019) in the NIRF rankings (by the Government of India).

Figure 1.1 IISc Logo

Figure 1.2 Jamsetji Tata. The Visionary and Founder of IISc

Located in Bangalore, India, IISc was established in 1909 with active support from Jamsetji Tata and Krishna Raja Wadiyar IV and thus is also locally known as the "Tata Institute". It was granted the Deemed University status in 1958. After an accidental meeting between Jamsetji Tata and Swami Vivekananda, on a ship in 1893 where they discussed Tata's plan of bringing the steel industry to India, Tata wrote to Vivekananda five years later: "I trust, you remember me as a fellow-traveler on your voyage from Japan to Chicago. I very much recall at this moment your views on the growth of the ascetic spirit in India... I recall these ideas in connection with my scheme of Research Institute of Science for India, of which you have doubtless heard or read."

The Institute was the first to introduce Masters programs in Engineering. It has also started integrated doctoral programs in Biological, Chemical, Physical and Mathematical Sciences for natural science graduates.

1.1.1 Rankings

- IISc is currently ranked as India's #1 university in the NIRF Rankings released by Government of India.
- IISc was ranked 251–300 in the world by the Times Higher Education World University Rankings of 2018, the top institute in India, as well as 21 in Asian the 2018 ranking and 14 among BRICS & Emerging Economies University Rankings in 2017.
- The QS World University Rankings of 2019 ranked IISc 170 in the world, as well as 51 in Asia and 10 among BRICS nations.
- In 2019, it ranked 353rd among the universities around the world by SCImago Institutions Rankings.
- The Academic Ranking of World Universities ranked it 301–400 in the world in 2017, the only institute in India to be ranked by this ranking.
- QS World University rankings ranked IISc second in the world in terms of citations per faculty

1.1.2 Campus Location and Facilities

The IISc campus is located in the north of Bengaluru, about 4 kilometers from Bangalore City Railway Station and Kempegowda Bus Station, on the way to Yeshwantpur. The Institute is about 35 kilometers from Kempegowda International Airport. A number of other research institutes, Raman Research Institute, Indian Space Research Organization (ISRO), Wood Research Institute and Central Power Research Institute (CPRI), are close to IISc. Most of these institutes are connected to IISc by a regular shuttle bus service.

Figure 1.3 IISc Campus as viewed from the Google maps satellite view

- The campus houses more than 40 departments marked by routes such as the Gulmohar Marg, the Mahogany Marg, the Badami Marg, the Tala Marg, the Ashoka Marg, the Nilgiri Marg, the Silver Oak Marg, the Amra Marg and the Arjuna Marg. The Institute is fully residential and is spread over 400 acres of land in the heart of Bengaluru city.
- The campus features:
    - Six canteens (cafeterias)
    - Gymkhana (gymnasium and sports complex)
    - Football ground
    - Cricket ground
    - Four dining messes (halls)
    - One multi cuisine restaurant
    - Nine men's and five women's hostels (dormitories)
    - An air-strip
    - A library
    - Two shopping centers
    - Residences of the faculty members and other staff

  ……….. besides other amenities.
- The IISc campus harbors both exotic and indigenous plant species with about 110 species of woody plants. The roads on the campus are named after the dominant avenue tree species

1.1.3 Some important Places

1.1.3.1 JRD Tata Memorial Library

Apart from the main library, the Institute also has independent departmental libraries. The library moved into the present premises in January 1965, built out of grants provided by University Grants Commission (UGC), in commemoration of the golden jubilee celebrations of the Institute in 1959. In 1995, the library was renamed as "J. R. D. Tata Memorial Library".

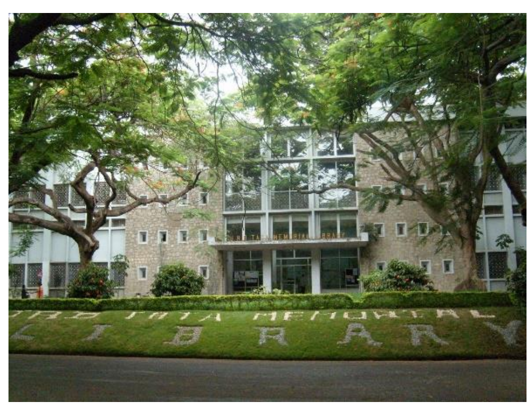

Figure 1.4 JRD TATA Memorial Library Front

The National Board for Higher Mathematics (NBHM) has recognized this library as Regional Centre for Mathematics for the south region and continued to award a special grant towards subscription of Journals in Mathematics.

The annual budget of the library is over Rs. 100 million (almost US$2,500,000) of which subscription towards periodicals alone is about Rs. 90 million. The library currently receives over 1,734 periodical titles, of which 1381 are subscribed, while the remaining titles are received as gratis or on an exchange basis. About 600 titles are accessible through the library subscription. In addition, over 10,000 journals are accessible online, thanks to INDEST subscription. The total holdings of the library exceed 411,000 documents.

1.1.3.1 Central Computing Facility

The Computer Centre, established in 1970 as a central computing facility, became Supercomputer Education and Research Centre (SERC) in 1990 to provide state-of-the-art computing facility to the faculty and students of the Institute. SERC is created and fully funded by the Ministry of Human Resource Development (MHRD) to commemorate the platinum jubilee of the Institute. It houses India's first petascale supercomputer CrayXC-40 and also the fastest supercomputer in India.

Figure 1.5 Supercomputer at IISc

Apart from functioning as a central computing facility of IISc, the SERC is engaged in education and research programs in areas relating to supercomputer development and application. The Centre is also involved in several sponsored research projects in collaboration with several high-profile government and private agencies.

1.2 *Department of Aerospace Engineering*

Figure 2 Building of Department of Aerospace Engineering

When World War II started, the factory set up in 1940 by Walchand Hirachand, primarily for automobiles, was transformed into Hindustan Aeronautics Ltd. (HAL) for assembly and repair of aircraft. There was a great need to create manpower trained in aeronautics in the country. This necessitated the establishment of a Department of Aeronautical Engineering-in the country, preferably in Bangalore, to meet the trained man power requirements. Perceiving this, the court of the Institute, presided over by Sir M. Visveswariah, adopted the following resolution in 1941.

“That in view of the scientific and practical importance of advanced instruction and research in aeronautical engineering and metallurgical sciences and of research in automobile engineering, the Court recommends to the Council that the Government of India, the Provincial governments, the Indian States and the Industrialists be approached for funds which will enable the Institute to equip itself with facilities for such work”.

The department of Aeronautical Engineering was started in December 1942. Thus, after the department of Electrical Technology, the Department of Aeronautical Engineering is the oldest engineering department at the Institute. The services of Dr. V.M. Ghatage, one of the few trained aeronautical engineers in the country at that time and who was working in HAL, were lent to the Institute during 1942-1947. He was the head of the department till 1945. During 1945-48, Dr. R.G. Harris of the Royal Aircraft Establishment U.K. was professor and Head of the Department. Prof. O.G. Tietjens was appointed as the Head of the department in 1949 and continued till 1954.

1.3 Projects undertaken during the internship

During the internship, I was assigned two projects. They are as follows:

I. Survivor detection algorithms in flood affected areas using autonomous UAVs.

In this project, the main objective was to **prepare a real time map of the flood affected region and to detect survivors in that region.** The idea is to have different observer nodes at different strategic locations that have a detection range and if any survivor falls within that range, it reports the location of the survivor and then the UAV approaches the reported location.

Mission Statement:

"To build Hardware and software systems capable of detecting flood affected regions as well as look for survivors with the aid of strategically placed static observer nodes and probabilistic methods."

The following were the key expectations from the project:

- **Able to provide a real time map of the flood affected areas, that can be used to re-route resources accordingly.**
- **Detect, track and report survivor location in the flood affected region.**
- **Should be Autonomous (minimal manual control only if required).**
- **Hardware available and manufactured in India should be used to encourage "Make in India".**

During the project, my responsibility was to prepare and test algorithms in a simulated environment using ROS & Gazebo.

II. Autonomous wall construction using UAV swarm

This project was done as a part of the MBZIRC-2020, Challenge 2. The main objective was to **autonomously locate, pick, transport and assemble different types of brick shaped objects to build pre-defined structures.** Our approach included using UGVs for assistance only bots and using UAVs as the primary builders that detect, pick and drop bricks to and from their respective positions.

Mission Statement:

“To have a team of UAVs and a UGV that collaborate to autonomously locate, pick, transport and assemble different types of brick shaped objects to build pre-defined structures, in an outdoor environment.”

The following were the key expectations from the project:

- **To locate the Regions of interest (ROI), i.e., the pickup and the drop zones**
- **Picking up the brick from the pile using a manipulator.**
- **Dropping the bricks perfectly to construct the given structure.**
- **Coordination between the UAVs to carry out the task in an efficient manner.**

During the project, my responsibility was to prepare navigation algorithms & collision avoidance systems as well as testing them in a simulated environment using ROS & Gazebo.

CHAPTER 2 Technology's Role in Disaster Aid Relief

Current approach & Future Scope

Thousands of people are killed every year in natural disasters. Rescue teams and aid agencies often rely on technology to conduct rescue missions and help those who have been affected. Over the years, new technologies have been developed to improve the efficiency and effectiveness of first responders, further deepening the role played by technology in disaster aid relief.

2.1 The Number and Impact of Natural Disasters

Since 2010, there have been a total of 2,018 natural disasters, which translates to 336 disasters per year. On the other hand, 525 storms and 822 floods were reported during the same period. It is estimated that 139 million people are affected by natural disasters every year. On average, natural disasters cause 72,205 fatalities annually.

2.2 Recent High Impact Disasters

- **Indonesia: Earthquake and Tsunami**
  - **Deaths**: 2,783
  - A 7.5 magnitude earthquake and subsequent 20-foot tsunami brought widespread devastation to Sulawesi island in Indonesia in late September, levelling entire cities and rendering more than 330,000 people homeless, according to World Vision, a global humanitarian non-profit.
- **Indonesia: Earthquake**
  - **Deaths**: 468
  - On Aug. 5, a 6.9 magnitude earthquake struck the Indonesian island of Lombok and neighbouring Bali. The earthquake was preceded with a 6.4 magnitude quake in late July, and the areas also were hit with a number of aftershocks.

- **Guatemala: Volcanic Eruption**
    - **Deaths**: 425
    - When Guatemala's Fuego volcano erupted in early June, surrounding areas were soon engulfed in a deadly pyroclastic flow, a mixture of hot gas and volcanic rock that can move at speeds up to 90 miles per hour, according to The New York Times. The ground was so hot in areas that the soles of some rescue workers' boots were coming apart
- **India: Floods**
    - **Deaths**: 361
    - Monsoon flooding in India killed more than 300 people in August, mostly in the southern Indian state of Kerala. The Kerala government said many victims died after being crushed by debris after landslides, the BBC reported. Officials said it was the worst flood recorded in 100 years.
- **Japan: Floods**
    - **Deaths**: 220
    - Torrential rain and landslides impacted large areas of Japan in July, killing more than 200 people. Officials said the flooding was particularly bad because much of the rain fell in mountainous areas and funnelled down into cities, CNN reported. In Uwajima, a city on Japan's Shikoku island, local news stations reported that almost 15 inches of rain fell in two hours on one Sunday morning, according to CNN's report.
- **Nigeria: Floods**
    - **Deaths**: 200
    - September flooding in Nigeria displaced more than half a million people and, according to Flood-list, destroyed more than 13,000 homes. The floods struck one-third of Nigeria's 36 states, affecting nearly 2 million people.

2.3 Technology Assistance at Disaster Sites

In recent times, technology has been employed to fast track disaster relief efforts. For instance, drones and robots have been used to locate survivors and transmit information to emergency teams. They have also been used to drop humanitarian aid.

- The **SERVAL** project was developed in response to the Haiti earthquake. The technology allows mobile phones to communicate directly with each other even when there is no network coverage

- **TERA** (Trilogy Emergency Relief Application) is an SMS text system designed for two-way communication between aid agencies and people affected by natural disasters. The technology has been in use since the 2010 Haiti earthquake.

- The NASA Finder was developed in response to the 2015 Nepal earthquake. This is a suitcase-size device which can detect human heartbeats under 20 ft of solid concrete and 30 ft of rubble.

- **ALIRT** (Airborne Lidar Imaging Research Testbed) is a technology that can produce high-resolution 3D renderings of terrain and infrastructure. Among other things, the technology can help identify population changes at displaced persons camps, helicopter landing zones and road travel conditions. This information can help aid agencies to effectively dispatch vital resources, such as tents, blankets, water, food and medical supplies.

2.3 Online Tools & Applications Developed to Aid in Disaster Relief

- **Micromapper** was launched in 2013 and used in the 2015 Nepal earthquake, Typhoon Hayian in 2013 and several other disasters. The application creates a map from social media relief updates and sends it to aid agencies that get real-time updates from affected areas. Micromapper helps aid organizations to effectively plan relief efforts before going into disaster zones. During the 2015 Nepal earthquake, Micromappers processed over 60,000 images and tweets.

- **Google People Finder** is another innovative piece of technology which can help with disaster relief efforts. It was developed in 2010 in response to the Haiti earthquake. It is an open source web application, which is available in over 40 languages. The application allows users to post and search for the status of people affected by a disaster. During the 2015 Nepal earthquake, well over 7,500 records on the people finder were searched.
- **The Red Cross Emergency App** has been incredibly helpful with disaster relief in the recent times. It gives survivors weather updates, preparedness information and safety tips. The Red Cross credits the application for saving several lives in the United States.

2.4 Unmanned Aerial Vehicles in Disaster Management

UAVs have received mixed criticism because of their associations with invasion of privacy and with their armed deployment in war. There is another more positive use that provides safety, protection and relief from disasters. Natural and man-made disasters destroy environments, often making conditions so difficult that relief workers are unable to access areas and provide assistance. Drones have the ability to take on roles where relief workers and manned vehicles fall short.

2.4.1 Hazardous Chemical Spills

Dangerous or nuclear chemicals can leak into the environment for various reasons. Some causes include factory or power plant malfunctions, spills during transportation or even terrorist attacks. In these and similar instances, measuring the damage and providing relief must be swift and effective. These events, known as CBRNE events (chemical, biological, radiological, nuclear or explosive) make for unsafe conditions, not only for the people exposed to the hazardous materials in nearby areas, but also for relief workers.

- In March 2011, a powerful earthquake caused a tsunami to hit Japan, resulting in severe damage to the Fukushima Daiichi nuclear plant. The damage led to a full-scale evacuation because of the amount of dangerous nuclear material that was released.

- Drones were deployed in the air and on the ground at the first possible instance to assess the extent of the destruction.
- These unmanned vehicles were able to provide aid in monitoring for radiation exposure, repairing destroyed areas and rebuilding efforts — all while minimizing nuclear fallout exposure for relief workers.

2.4.2 The Need for Mapping

Areas that are prone to large-scale disasters such as earthquakes and flooding benefit greatly from visual imaging and 3D mapping. Manned aircraft are often too expensive to use, satellite mapping does not meet high-resolution needs, and both take too much time during emergency situations.

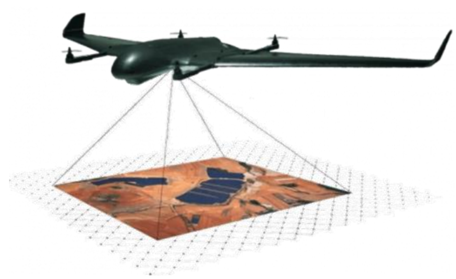

Figure 2.1 Concept of using drones for mapping

- In the aftermath of the 2015 Nepal earthquake, drones assisted in creating 3D maps and models through image processing software. These aided in assessing the widespread damage, operating search and evacuation missions, reconstructing buildings and preserving areas of the city.

2.4.3 Assessing Structural Damage

Relief workers often find it difficult and dangerous to assess structural damage from natural disasters. They often encounter buildings that are on the verge of collapsing, potential explosions due to chemical leaks and places that are hard to access such as tunnels and bridges. After an F-5 tornado in Wichita, Kansas, drones were used to identify infrastructure that was critically damaged. Equipped with “sniffers” to detect high levels of methane, they were able to locate broken gas lines.

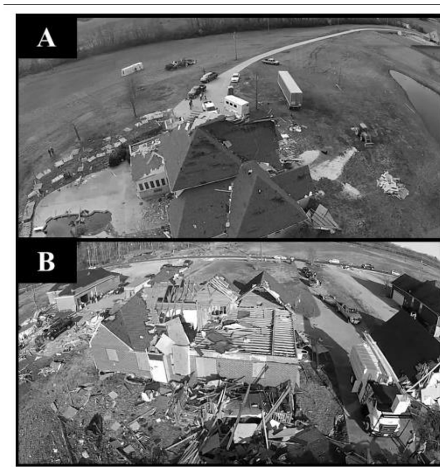

Figure 2.2 Drone video footage giving an idea of damage

2.4.4 Delivering Emergency Infrastructures and Supplies

Often after natural disasters or terrorist attacks, infrastructure supply lines are cut and disabled. When roads, bridges, communication cables and gas and water lines are compromised, the safety of residents in the area is also compromised. To mitigate suffering and further damage, rescue teams can utilize drones to support infrastructures, deliver supplies and establish communication.

Figure 2.3 Drones used for medical kit dropping

- In areas that are nearly impossible to reach, drones can deliver supplies such as water and food to those in need, eliminating the risks of placing human-operated aircraft in harm's way. AWACS, or airborne warning and control systems, allow for temporary establishment of Wi-Fi and cell phone access to environments without power lines or functioning cell towers.

2.4.5 Extinguishing Wildfires

The U.S. Fire Administration found that in 2013, firefighters sustained 34 deaths and 29,760 injuries while combating volatile fires. Because aircraft must fly at low altitudes to fight wildfires, pilots and crews are put in serious danger and made to endure high temperatures, low visibility, dangerous winds and high stress.

For these reasons and beyond, drones are being used more often in emergency and disaster response situations. This forward-thinking unmanned technology has vast potential. It is already proving its ability to save lives and prevent damage in dire situations.

2.5 The Future of Prediction Technologies

Fatalities and injuries from natural disasters can be reduced if the disaster can be predicted and advance warning given to people in the danger zone. Several disaster prediction technologies have been developed over the years.

- Wildfire Prediction, for instance, was developed by the National Centre for Atmospheric Research to predict wildfires through computer simulation. The computer model is updated every 12 hours with the latest satellite data and observations, thereby allowing scientists to issue forecasts and warnings.
- Flood Prediction uses radar, streamflow computer simulations and highly detailed computer model weather simulations. The predictions can be used by decision-makers to decide whether or not to issue warnings.
- Earthquake Prediction is part of an earthquake early warning system developed by the U.S. Geological Survey. The system uses high-grade ground motion sensors. A popular example of an earthquake warning system is California's SHAKEALERT.

CHAPTER 3 Un-manned Aerial Vehicles (UAV)

"Drones overall will be more impactful then I think people recognize, in positive ways to help society" -Bill Gates

3.1 Terminology

Multiple terms are used for unmanned aerial vehicles, which generally refer to the same concept.

The term **drone**, more widely used by the public, was coined in reference to the early remotely-flown target aircraft used for practice firing of a battleship's guns, and the term was first used with the 1920s Fairey Queen and 1930's de Havilland Queen Bee target aircraft. These two were followed in service by the similarly-named Airspeed Queen Wasp and Miles Queen Martinet, before ultimate replacement by the GAF Jindivik.

The term **Unmanned Aircraft System (UAS)** was adopted by the United States Department of Defense (DoD) and the United States Federal Aviation Administration in 2005 according to their Unmanned Aircraft System Roadmap 2005–2030. The International Civil Aviation Organization (ICAO) and the British Civil Aviation Authority adopted this term, also used in the European Union's Single-European-Sky (SES) Air-Traffic-Management (ATM) Research (SESAR Joint Undertaking) roadmap for 2020. This term emphasizes the importance of elements other than the aircraft. It includes elements such as ground control stations, data links and other support equipment.

A similar term is an unmanned-aircraft vehicle system (UAVS), remotely piloted aerial vehicle (RPAV), remotely piloted aircraft system (RPAS).[10] Many similar terms are in use.

3.2 History

The earliest recorded use of an unmanned aerial vehicle for warfighting occurred on July 1849,[14][15] serving as a balloon carrier (the precursor to the aircraft carrier) in the first offensive use of air power in naval aviation. Austrian forces besieging Venice attempted to launch some 200 incendiary balloons at the besieged city. The balloons were launched mainly from land; however, some were also launched from the Austrian ship SMS Vulcano.

At least one bomb fell in the city; however, due to the wind changing after launch, most of the balloons missed their target, and some drifted back over Austrian lines and the launching ship Vulcano.

UAV innovations started in the early 1900s and originally focused on providing practice targets for training military personnel. UAV development continued during World War I, when the Dayton-Wright Airplane Company invented a pilotless aerial torpedo that would explode at a preset time.

Figure 3.1 Winston Churchill and others waiting to watch the launch of a de Havilland Queen Bee target drone, 6 June 1941

Figure 3.2 A Ryan Firebee, one of a series of target drones/unpiloted aerial vehicles that first flew in 1951. Israeli Air Force Museum, Hatzerim airbase, Israel, 2006

The earliest attempt at a powered UAV was A. M. Low's "Aerial Target" in 1916. Nikola Tesla described a fleet of un-crewed aerial combat vehicles in 1915. Advances followed during and after World War I, including the Hewitt-Sperry Automatic Airplane. This development also inspired the development of the Kettering Bug by Charles Kettering from Dayton, Ohio.

Jet engines entered service after World War II in vehicles such as the Australian GAF Jindivik, and Teledyne Ryan Firebee I of 1951, while companies like Beechcraft offered their Model 1001 for the U.S. Navy in 1955. Nevertheless, they were little more than remote-controlled airplanes until the Vietnam War.

During the War of Attrition (1967–1970) the first tactical UAVs installed with reconnaissance cameras were first tested by the Israeli intelligence, successfully bringing photos from across the Suez Canal. This was the first time that tactical UAVs, which could be launched and landed on any short runway (unlike the heavier jet-based UAVs), were developed and tested in battle.

Figure 3.3 Last preparations before the first tactical UVA mission across the Suez Canal (1969).

Figure 3.4 The Israeli Tadiran Mastiff, which first flew in 1975, is seen by many as the first modern battlefield UAV, due to its data-link system, endurance-loitering, and live video-streaming.

With the maturing and miniaturization of applicable technologies in the 1980s and 1990s, interest in UAVs grew within the higher echelons of the U.S. military. In the 1990s, the U.S. DoD gave a contract to AAI Corporation along with Israeli company Malat. The U.S. Navy bought the AAI Pioneer UAV that AAI and Malat developed jointly. Many of these UAVs saw service in the 1991 Gulf War. UAVs demonstrated the possibility of cheaper, more capable fighting machines, deployable without risk to aircrews. Initial generations primarily involved surveillance aircraft, but some carried armaments, such as the General Atomics MQ-1 Predator, that launched AGM-114 Hellfire air-to-ground missiles.

CAPECON was a European Union project to develop UAVs,[42] running from 1 May 2002 to 31 December 2005.

In 2013 at least 50 countries used UAVs. China, Iran, Israel, Pakistan, and others designed and built their own varieties.

3.3 Classification

UAVs typically fall into one of six functional categories (although multi-role airframe platforms are becoming more prevalent):

- Reconnaissance – providing battlefield intelligence
- Logistics – delivering cargo

- Target and decoy – providing ground and aerial gunnery a target that simulates an enemy aircraft or missile
- Combat – providing attack capability for high-risk missions
- Research and development – improve UAV technologies
- Civil and commercial UAVs – agriculture, aerial photography, data collection

The U.S. Military UAV tier system is used by military planners to designate the various individual aircraft elements in an overall usage plan.

Vehicles can be categorized in terms of range/altitude. The following has been advanced as relevant at industry events such as ParcAberporth Unmanned Systems forum:

- Hand-held 2,000 ft (600 m) altitude, about 2 km range
- Close 5,000 ft (1,500 m) altitude, up to 10 km range
- NATO type 10,000 ft (3,000 m) altitude, up to 50 km range
- Tactical 18,000 ft (5,500 m) altitude, about 160 km range
- MALE (medium altitude, long endurance) up to 30,000 ft (9,000 m) and range over 200 km
- HALE (high altitude, long endurance) over 30,000 ft (9,100 m) and indefinite range
- Hypersonic high-speed, supersonic (Mach 1–5) or hypersonic (Mach 5+) 50,000 ft (15,200 m) or suborbital altitude, range over 200 km
- Orbital low earth orbit (Mach 25+)
- CIS Lunar Earth-Moon transfer
- Computer Assisted Carrier Guidance System (CACGS) for UAVs

Other categories include:

- Hobbyist UAVs – which can be further divided into
    - Ready-to-fly (RTF)/Commercial-off-the-shelf (COTS)
    - Bind-and-fly (BNF) – require minimum knowledge to fly the platform
    - Almost-ready-to-fly (ARF)/Do-it-yourself (DIY) – require significant knowledge to get in the air
    - Bare frame – requires significant knowledge and your own parts to get it in the air

- Midsize military and commercial UAVs
- Large military-specific UAVs
- Stealth combat UAVs
- Crewed aircraft transformed into un-crewed (and Optionally Piloted UAVS or OPVs)

Classifications according to aircraft weight are quite simpler:

- Micro air vehicle (MAV) – the smallest UAVs that can weigh less than 1g
- Miniature UAV (also called SUAS) – approximately less than 25 kg
- Heavier UAVs

3.4 UAV Components

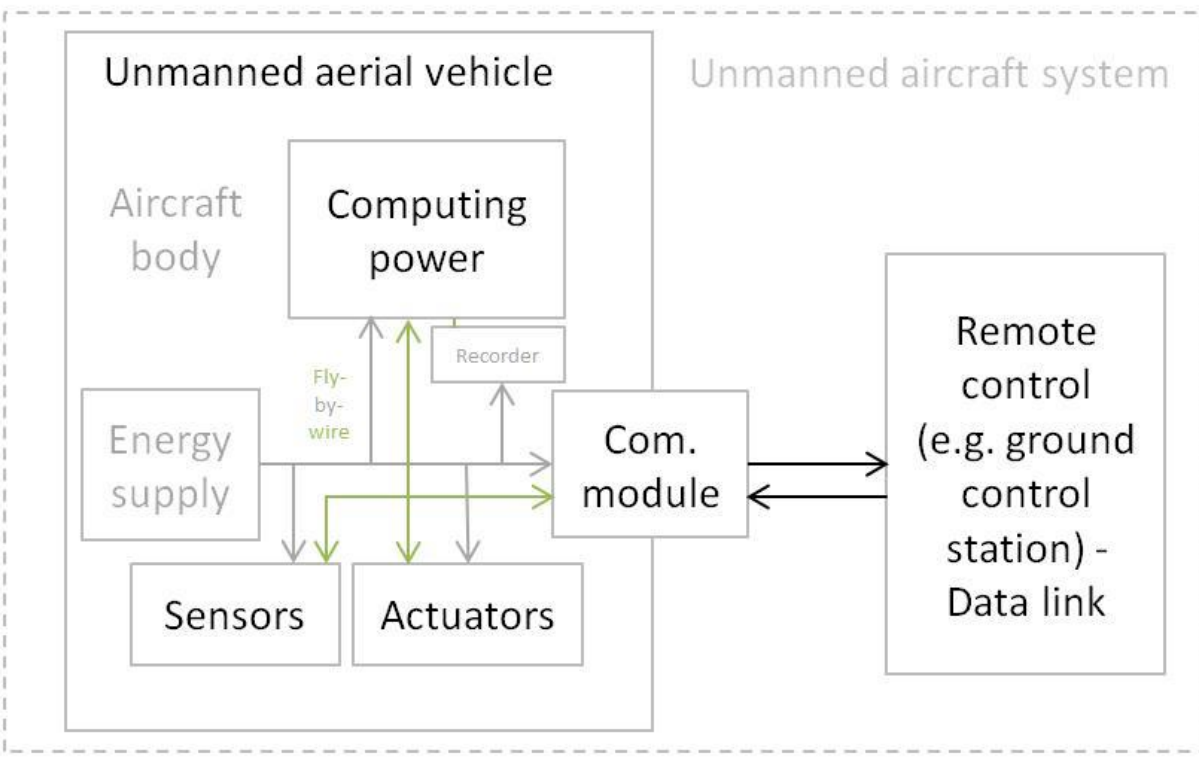

Figure 3.5 General physical structure of an UAV

Crewed and un-crewed aircraft of the same type generally have recognizably similar physical components. The main exceptions are the cockpit and environmental control system or life support systems. Some UAVs carry payloads (such as a camera) that weigh considerably less than an adult human, and as a result can be considerably smaller. Though they carry heavy payloads, weaponized military UAVs are lighter than their crewed counterparts with comparable armaments.

3.4.1 Body

The primary difference for planes is the absence of the cockpit area and its windows. Tailless quadcopters are a common form factor for rotary wing UAVs while tailed mono- and bi-copters are common for crewed platforms.

3.4.2 Power Supply and platform

Small UAVs mostly use lithium-polymer batteries (Li-Po), while larger vehicles rely on conventional airplane engines. Scale or size of aircraft is not the defining or limiting characteristic of energy supply for a UAV. At present, the energy density of Li-Po is far less than gasoline. The record of travel for a UAV (built from balsa wood and mylar skin) across the North Atlantic Ocean is held by a gasoline model airplane or UAV. Manard Hill in "in 2003 when one of his creations flew 1,882 miles across the Atlantic Ocean on less than a gallon of fuel" holds this record. Electric power is used as less work is required for a flight and electric motors are quieter. Also, properly designed, the thrust to weight ratio for an electric or gasoline motor driving a propeller can hover or climb vertically. Botmite airplane is an example of an electric UAV which can climb vertically.

Battery elimination circuitry (BEC) is used to centralize power distribution and often harbors a microcontroller unit (MCU). Costlier switching BECs diminish heating on the platform

3.4.3 Computing

UAV computing capability followed the advances of computing technology, beginning with analog controls and evolving into microcontrollers, then system-on-a-chip (SOC) and single-board computers (SBC).

System hardware for small UAVs is often called the flight controller (FC), flight controller board (FCB) or autopilot.

3.4.4 Sensors

Position and movement sensors give information about the aircraft state. Exteroceptive sensors deal with external information like distance measurements, while ex-proprioceptive ones correlate internal and external states.

Non-cooperative sensors are able to detect targets autonomously so they are used for separation assurance and collision avoidance.

Degrees of freedom (DOF) refers to both the amount and quality of sensors on-board: 6 DOF implies 3-axis gyroscopes and accelerometers (a typical inertial measurement unit – IMU), 9 DOF refers to an IMU plus a compass, 10 DOF adds a barometer and 11 DOF usually adds a GPS receiver.

3.4.5 Actuators

UAV actuators include digital electronic speed controllers (which control the RPM of the motors) linked to motors/engines and propellers, servomotors (for planes and helicopters mostly), weapons, payload actuators, LEDs and speakers.

3.4.6 Software

UAV software called the flight stack or autopilot. UAVs are real-time systems that require rapid response to changing sensor data. Examples include Raspberry Pis, Beagleboards, etc. shielded with NavIO, PXFMini, etc. or designed from scratch such as Nuttx, preemptive-RT Linux, Xenomai, Orocos-Robot Operating System or DDS-ROS 2.0.

Table 3.1 Flight Stack Overview

Layer	**Requirement**	**Operations**	**Example**
Firmware	Time-critical	From machine code to processor execution, memory access	ArduCopter-v1, px4
Middleware	Time-critical	Flight control, navigation, radio management	Cleanflight, ArduPilot
Operating system	Computer-intensive	Optic flow, obstacle avoidance, SLAM, decision-making	ROS, Nuttx, Linux distributions, Microsoft IOT

Civil-use open-source stacks include:

- ArduCopter
    - DroneCode (forked from ArduCopter)
- CrazyFlie
- KKMultiCopter
- MultiWii
    - BaseFlight (forked from MultiWii)
        - CleanFlight (forked from BaseFlight)
            - BetaFlight (forked from CleanFlight)
            - iNav (forked from CleanFlight)
            - RaceFlight (forked from CleanFlight)
- OpenPilot
    - dRonin (forked from OpenPilot)
    - LibrePilot (forked from OpenPilot)
    - TauLabs (forked from OpenPilot)
- Paparazzi

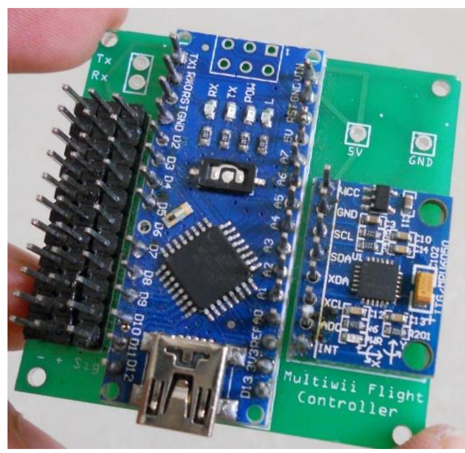

Figure 3.6 DIY Arduino Controlled MultiWii Flight Controller

3.4.7 Loop Principles

UAVs employ open-loop, closed-loop or hybrid control architectures.

- Open loop – This type provides a positive control signal (faster, slower, left, right, up, down) without incorporating feedback from sensor data.
- Closed loop – This type incorporates sensor feedback to adjust behavior (reduce speed to reflect tailwind, move to altitude 300 feet). The PID controller is common.

Sometimes, feedforward is employed, transferring the need to close the loop further.

3.4.8 Flight Controls

UAVs can be programmed to perform aggressive manœuvres or landing/perching on inclined surfaces, and then to climb toward better communication spots. Some UAVs can control flight with varying flight modulization such as VTOL designs.

UAVs can also implement perching on a flat vertical surface.

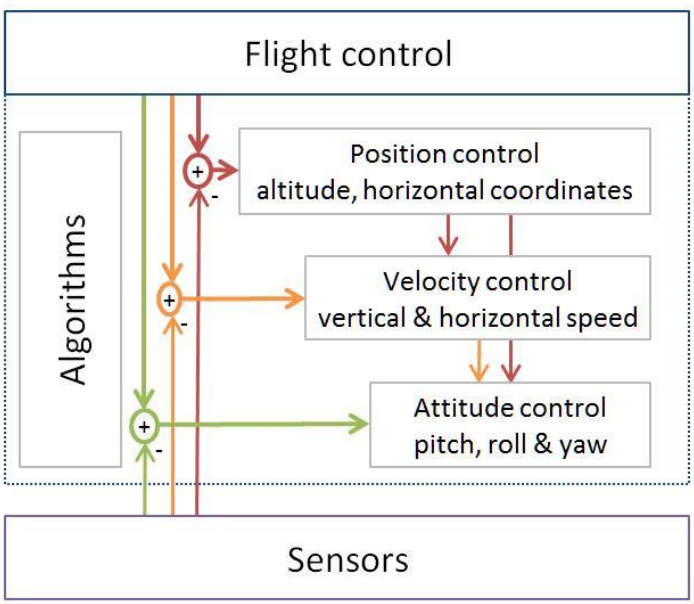

Figure 3.7 Typical flight-control loops for a multirotor

3.4.9 Communications

Most UAVs use a radio for remote control and exchange of video and other data. Early UAVs had only narrowband uplink. Downlinks came later. These bi-directional narrowband radio links carried command and control (C&C) and telemetry data about the status of aircraft systems to the remote operator. For very long-range flights, military UAVs also use satellite receivers as part of satellite navigation systems. In cases when video transmission was required, the UAVs will implement a separate analog video radio link.

In the most modern UAV applications, video transmission is required. So instead of having 2 separate links for C&C, telemetry and video traffic, a broadband link is used to carry all types of data on a single radio link. These broadband links can leverage quality of service techniques to optimize the C&C traffic for low latency. Usually these broadband links carry TCP/IP traffic that can be routed over the Internet.

The radio signal from the operator side can be issued from either:

- Ground control – a human operating a radio transmitter/receiver, a smartphone, a tablet, a computer, or the original meaning of a military ground control station (GCS). Recently control from wearable devices, human movement recognition, human brain waves was also demonstrated.
- Remote network system, such as satellite duplex data links for some military powers. Downstream digital video over mobile networks has also entered consumer markets,[64] while direct UAV control uplink over the cellular mesh and LTE have been demonstrated and are in trials.
- Another aircraft, serving as a relay or mobile control station – military manned-unmanned teaming (MUM-T).
- A protocol MAVLink is increasingly becoming popular to carry command and control data between the ground control and the vehicle

3.5 UAV Autonomy

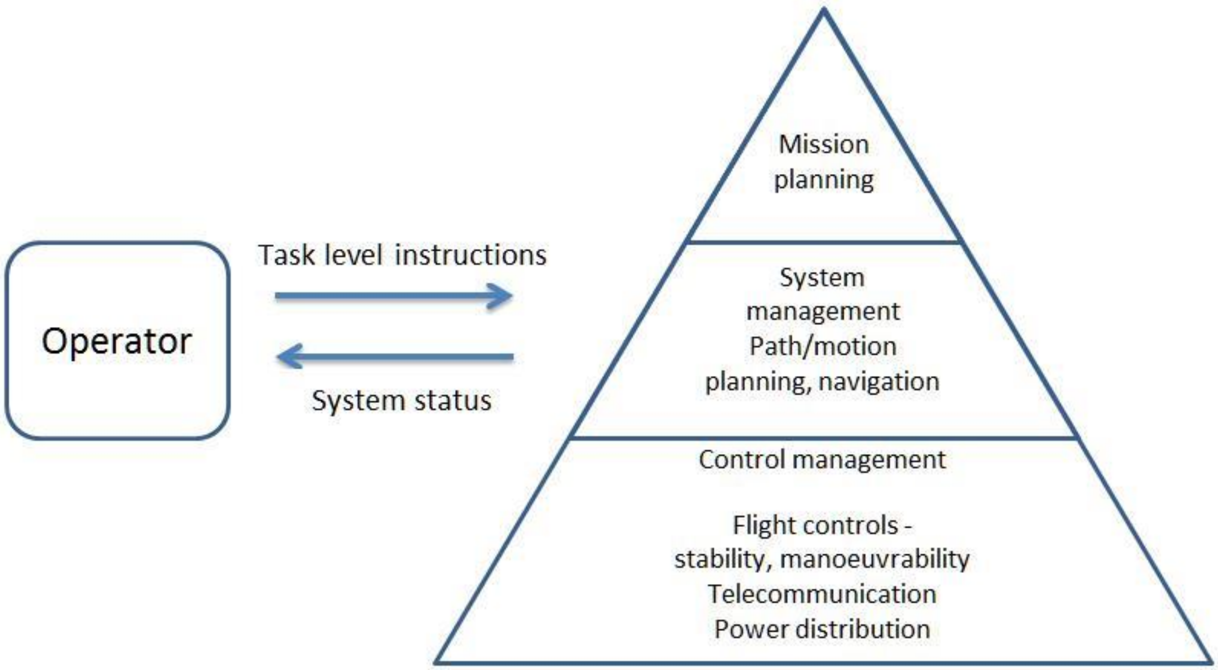

Figure 3.8 Autonomous control basics

ICAO classifies un-crewed aircraft as either remotely piloted aircraft or fully autonomous. Actual UAVs may offer intermediate degrees of autonomy. E.g., a vehicle that is remotely piloted in most contexts may have an autonomous return-to-base operation.

Basic autonomy comes from proprioceptive sensors. Advanced autonomy calls for situational awareness, knowledge about the environment surrounding the aircraft from exteroceptive sensors: sensor fusion integrates information from multiple sensors.

3.5.1 Basic Principles

One way to achieve autonomous control employs multiple control-loop layers, as in hierarchical control systems. As of 2016 the low-layer loops (i.e. for flight control) tick as fast as 32,000 times per second, while higher-level loops may cycle once per second.

The principle is to decompose the aircraft's behaviour into manageable "chunks", or states, with known transitions. Hierarchical control system types range from simple scripts to finite state machines, behaviour trees and hierarchical task planners. The most common control mechanism used in these layers is the PID controller which can be used to achieve hover for a quadcopter by using data from the IMU to calculate precise inputs for the electronic speed controllers and motors.

Examples of mid-layer algorithms:

- Path planning: determining an optimal path for vehicle to follow while meeting mission objectives and constraints, such as obstacles or fuel requirements.
- Trajectory generation (motion planning): determining control manoeuvres to take in order to follow a given path or to go from one location to another.
- Trajectory regulation: constraining a vehicle within some tolerance to a trajectory.

Evolved UAV hierarchical task planners use methods like state tree searches or genetic algorithms.

3.5.2 Autonomy Features

UAV manufacturers often build in specific autonomous operations, such as:

- Self-level: attitude stabilization on the pitch and roll axes.
- Altitude hold: The aircraft maintains its altitude using barometric or ground sensors.
- Hover/position hold: Keep level pitch and roll, stable yaw heading and altitude while maintaining position using GNSS or inertial sensors.
- Headless mode: Pitch control relative to the position of the pilot rather than relative to the vehicle's axes.
- Care-free: automatic roll and yaw control while moving horizontally
- Take-off and landing (using a variety of aircraft or ground-based sensors and systems
- Failsafe: automatic landing or return-to-home upon loss of control signal

- Return-to-home: Fly back to the point of take-off (often gaining altitude first to avoid possible intervening obstructions such as trees or buildings).
- Follow-me: Maintain relative position to a moving pilot or other object using GNSS, image recognition or homing beacon.
- GPS waypoint navigation: Using GNSS to navigate to an intermediate location on a travel path.
- Orbit around an object: Similar to Follow-me but continuously circle a target.
- Pre-programmed aerobatics (such as rolls and loops)

3.5 UAV Autonomy

Full autonomy is available for specific tasks, but higher-level tasks call for greater computing, sensing and actuating capabilities. One approach to quantifying autonomous capabilities is based on OODA terminology, as suggested by a 2002 US Air Force Research Laboratory, and used in the table below:

Table 3.2 United States Autonomous control levels chart

Level	Level descriptor	Observe	Orient	Decide	Act
		Perception/Situational awareness	Analysis/Coordination	Decision making	Capability
10	**Fully Autonomous**	Cognizant of all within battlespace	Coordinates as necessary	Capable of total independence	Requires little guidance to do job
9	**Battlespace Swarm Cognizance**	Battlespace inference – Intent of self and others (allied and foes). Complex/Intense environment – on-board tracking	Strategic group goals assigned Enemy strategy inferred	Distributed tactical group planning Individual determination of tactical goal Individual task planning/execution Choose tactical targets	Group accomplishment of strategic goal with no supervisory assistance

8	**Battlespace Cognizance**	Proximity inference – Intent of self and others (allied and foes) Reduces dependence upon off-board data	Strategic group goals assigned Enemy tactics inferred ATR	Coordinated tactical group planning Individual task planning/execution Choose target of opportunity	Group accomplishment of strategic goal with minimal supervisory assistance (example: go SCUD hunting)
7	**Battlespace Knowledge**	Short track awareness – History and predictive battlespace Data in limited range, timeframe and numbers Limited inference supplemented by off-board data	Tactical group goals assigned Enemy trajectory estimated	Individual task planning/execution to meet goals	Group accomplishment of tactical goals with minimal supervisory assistance
6	**Real Time** **Multi-Vehicle Cooperation**	Ranged awareness – on-board sensing for long range, supplemented by off-board data	Tactical group goals assigned Enemy trajectory sensed/estimated	Coordinated trajectory planning and execution to meet goals – group optimization	Group accomplishment of tactical goals with minimal supervisory assistance Possible: close air space separation (+/-100yds) for AAR, formation in non-threat conditions

5	**Real Time** **Multi-Vehicle Coordination**	Sensed awareness – Local sensors to detect others, Fused with off-board data	Tactical group plan assigned RT Health Diagnosis Ability to compensate for most failures and flight conditions; Ability to predict onset of failures (e.g. Prognostic Health Mgmt) Group diagnosis and resource management	On-board trajectory replanning – optimizes for current and predictive conditions Collision avoidance	Self accomplishment of tactical plan as externally assigned Medium vehicle airspace separation (hundreds of yds)
4	**Fault/Event Adaptative** **Vehicle**	Deliberate awareness – allies communicate data	Tactical group plan assigned Assigned Rules of Engagement RT Health Diagnosis; Ability to compensate for most failures and flight conditions – inner loop changes reflected in outer loop performance	On-board trajectory replanning – event driven Self resource management Deconfliction	Self accomplishment of tactical plan as externally assigned Medium vehicle airspace separation (hundreds of yds)
3	**Robust Response to Real Time Faults/Events**	Health/status history & models	Tactical group plan assigned RT Health Diagnosis (What is the extent of the problems?) Ability to compensate for most failures and flight conditions (i.e. adaptative inner loop control)	Evaluate status vs required mission capabilities Abort/RTB is insufficient	Self accomplishment of tactical plan as externally assigned
2	**Changeable mission**	Health/status sensors	RT Health diagnosis (Do I have problems?) Off-board replan (as required)	Execute preprogrammed or uploaded plans in response to mission and health conditions	Self accomplishment of tactical plan as externally assigned

1	**Execute Preplanned Mission**	Preloaded mission data Flight Control and Navigation Sensing	Pre/Post flight BIT Report status	Preprogrammed mission and abort plans	Wide airspace separation requirements (miles)
0	**Remotely Piloted Vehicle**	Flight Control (attitude, rates) sensing Nose camera	Telemetered data Remote pilot commands	N/A	Control by remote pilot

Medium levels of autonomy, such as reactive autonomy and high levels using cognitive autonomy, have already been achieved to some extent and are very active research fields.

3.5.1 Reactive autonomy

Reactive autonomy, such as collective flight, real-time collision avoidance, wall following and corridor centering, relies on telecommunication and situational awareness provided by range sensors: optic flow, lidars (light radars), radars, sonars.

Most range sensors analyze electromagnetic radiation, reflected off the environment and coming to the sensor. The cameras (for visual flow) act as simple receivers. Lidars, radars and sonars (with sound mechanical waves) emit and receive waves, measuring the round-trip transit time. UAV cameras do not require emitting power, reducing total consumption.

Radars and sonars are mostly used for military applications.

Reactive autonomy has in some forms already reached consumer markets: it may be widely available in less than a decade.

3.5.2 Simultaneous localization and mapping

SLAM combines odometry and external data to represent the world and the position of the UAV in it in three dimensions.

High-altitude outdoor navigation does not require large vertical fields-of-view and can rely on GPS coordinates (which makes it simple mapping rather than SLAM).

Two related research fields are photogrammetry and LIDAR, especially in low-altitude and indoor 3D environments.

- Indoor photogrammetric and stereo photogrammetric SLAM has been demonstrated with quadcopters.
- Lidar platforms with heavy, costly and gimbaled traditional laser platforms are proven. Research attempts to address production cost, 2D to 3D expansion, power-to-range ratio, weight and dimensions. LED range-finding applications are commercialized for low-distance sensing capabilities. Research investigates hybridization between light emission and computing power: phased array spatial light modulators,[77][78] and frequency-modulated-continuous-wave (FMCW) MEMS-tuneable vertical-cavity surface-emitting lasers (VCSELs).

3.5.3 Swarming

Robot swarming refers to networks of agents able to dynamically reconfigure as elements leave or enter the network. They provide greater flexibility than multi-agent cooperation. Swarming may open the path to data fusion. Some bio-inspired flight swarms use steering behaviors and flocking.

3.5.4 Future Military Potential

In the military sector, American Predators and Reapers are made for counterterrorism operations and in war zones in which the enemy lacks sufficient firepower to shoot them down. They are not designed to withstand antiaircraft defenses or air-to-air combat. In September 2013, the chief of the US Air Combat Command stated that current UAVs were "useless in a contested environment" unless crewed aircraft were there to protect them.

3.6 Applications

There are numerous civilian, commercial, military, and aerospace applications for UAVs. These include:

Table 3.3 UAV Applications

CIVIL	COMMERCIAL	MILITARY
• Disaster Relief • Archeology • Conservation of Biodiversity and Habitat • Law enforcement • Crime and Terrorism	• Aerial Surveillance • Filmmaking • Journalism • Scientific Research • Surveying • Cargo Transport • Agriculture	• Reconnaissance • Attack • Demining • Target practice

3.7 Safety & Security

Figure 3.9 US Department of Agriculture poster warning about the risks of flying UAVs near wildfires

- **Air Traffic**: UAVs can threaten airspace security in numerous ways, including unintentional collisions or other interference with other aircraft, deliberate attacks or by distracting pilots or flight controllers.

- **Malicious use:** UAVs could be loaded with dangerous payloads, and crashed into vulnerable targets. Payloads could include explosives, chemical, radiological or biological hazards.

- **Counter unmanned air system:** The malicious use of UAVs has led to the development of counter unmanned air system (C-UAS) technologies such as the Rafael Drone Dome and the Raytheon Coyote. Anti-aircraft missile systems, such as the Iron Dome are also being enhanced with C-UAS technologies.

- **Security vulnerabilities:** The interest in UAVs cyber security has been raised greatly after the Predator UAV video stream hijacking incident in 2009,[125] where Islamic militants used cheap, off-the-shelf equipment to stream video feeds from a UAV. Another risk is the possibility of hijacking or jamming a UAV in flight.

Figure 3.10 Italian Army soldiers of the 17th Anti-aircraft Artillery Regiment "Sforzesca" with a portable CPM-Drone Jammer in Rome

- **Wildfires:** In the United States, flying close to a wildfire is punishable by a maximum $25,000 fine. Nonetheless, in 2014 and 2015, firefighting air support in California was hindered on several occasions, including at the Lake Fire and the North Fire. In response, California legislators introduced a bill that would allow firefighters to disable UAVs which invaded restricted airspace. The FAA later required registration of most UAVs.

During the internship, the testing and simulations were done for a **Swarm** of **Quadrotor** with **ArduCopter** Flight stack on PixHawk Hardware with **GPS** as the primary sensor. It used **electric brushless DC motors** as actuators powered by a **LiPo** Battery. The communication was done via **MAVLink** telemetry.

The security restrictions that had to be followed were that the drone should not go beyond 120m altitude and should only fly within the air field area inside the campus.

CHAPTER 4 Projects undertaken during internship

Project #1

This Project was done as a sub-set of the ongoing flood project currently being carried out at Mobile Robotics Laboratory, Department of Aerospace Engineering, IISc, Bangalore.

4.1 Mission Statement

"To build Autonomous Hardware and software systems capable of detecting flood affected regions as well as look for survivors with the aid of strategically placed static observer nodes and probabilistic methods."

The key targets of this project included:

- Generation of actual real time flood map of the affected area, that will be more reliable than current technique of using crowd-sourced data.
- Provide data that can be used to solve the transportation problem for allocation of resources during crisis.
- Surveying the affected region for survivor detection with help from observer node data.
- Use the Game Theory based probabilistic approach to predict the next position of the survivor once its position has been reported by the observer.

4.2 Hardware Setup

The drone used in this project for hardware testing was the Tarot Quadrotor Drone with the following specifications:

- Tarot Carbon Fibre Frame: Arms diameter: 16mm. Motor to motor: 600mm
- PX4 based PixHawk Flight Controller
- ArduPilot Firmware
- T-Motor 4006 380KV BLDC Motor

- 16*5.4 tarot carbon Fibre Props
- 5.8 GHz FlySky FSi6 RC Transmitter with compatible 5.8GHz FlySky IA6B receiver
- 433MHz Telemetry Tx/Rx pair
- Tarot T-3D V gimbal
- GoPro Hero 5 black
- AKK X-2 Ultimate 1200mw 5.8Ghz Video Transmitter
- HDMI2AV Converter
- Circular Polarized Omnidirectional Antenna
- 5.8Ghz Video Receiver with an in-built ADC

Figure 4.1 Hardware Components used for the project

4.3 Software Setup

On the software side, the tools being used were:

- Ardu Pilot (ArduCopter) Firmware
- Robot Operating System (ROS)
- Gazebo
- MAVROS
- SITL of the autopilot firmware
- MAVLink Telemetry Serial Communication Protocol
- Ubuntu OS
- Mission Planner (For planning autonomous missions & initial calibration)
- QGroundControl (For uploading firmware & GCS during simulation)
- Turtlebot Simulation

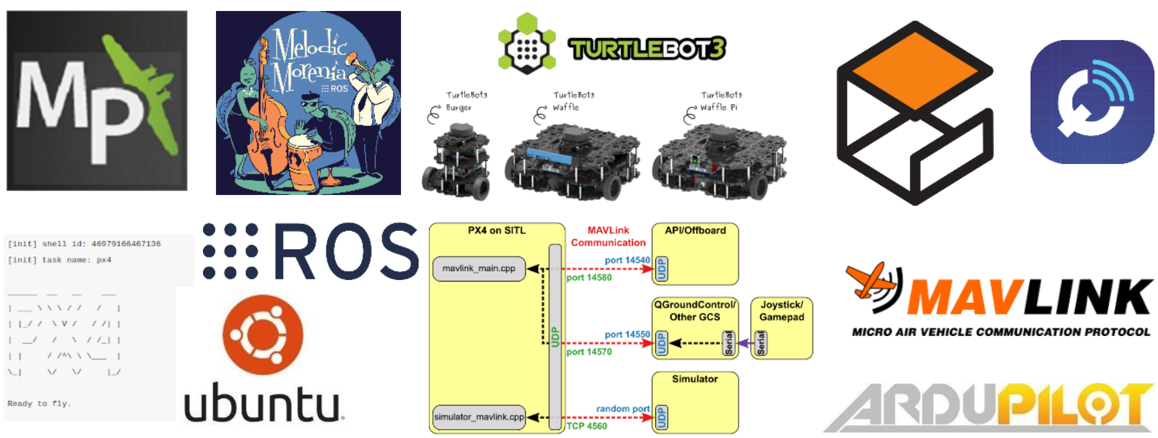

Figure 4.2 Tools used in the software stack of the current project

4.4 Working:

The quadrotor drone with above specified hardware and software stacks was used in the current project. Controlling the drone to carry out any task can be using two ways:

I. **Manual Control:**

In this type of control, the drone is controlled via a **Hand-held remote transmitter** (Tx) that communicates with the compatible binded receiver (Rx) on the other end. The receiver relays the control commands to the Flight Controller Board that fuses the control input data with the inertial data from the IMU, and then sends output control commands to the motors, modulating the RPM of the motors, and consequently the thrust produced at each motor.

II. **Autonomous Control:**

In this type of control, the flight controller is connected to a **Ground Control Station**(GCS), via a radio **telemetry** module that relays the vehicle status information **from flight controller to the GCS**, as well as status query & **vehicle control commands from GCS to the flight controller**, which then responds to this control input that is incoming via the telemetry radio. The telemetry protocol used in this project is the **Micro Air Vehicle Communication** (MAVLINK) Protocol. At the GCS, the telemetry data can be processed via a mission planning software (e.g. Mission Planner) or via **ROS nodes using MAVROS**.

In the current project, second approach was used as it is more flexible and requires minimum human intervention. The vehicle is connected to the ground station via the telemetry module. On the ground control station, there is a ROS node running that is communicating with the UAV via MAVROS node. The MAVROS node publishes the vehicle status and other information as ROS topics which can be subscribed to and published as well when required.

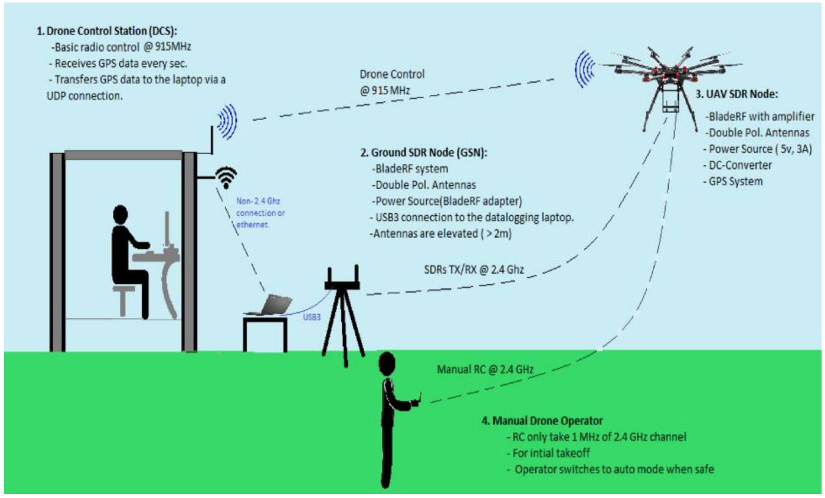

Figure 4.3 Multiple Control Modes for a UAV

For sending the control commands, two approaches were tested

Table 4.1 UAV Control approaches

Position Control	Velocity Control
• Used the mavros topic **setpoint_position/local** to write position • The FCU decides the velocity profiles and gives correction signals. **PROS:** • Accurate position hold control until next command. • Automatic velocity profiles to prevent overshooting and stagnation. **CONS:** • No control over velocity • Less flexible to work with	• Used the mavros topic **setpoint_raw/local** to write the **velocities** in **local frame**. • **FCU** controls only the **stabilization** part. **PROS:** • Provides opportunity to change the path without changing the target waypoint. • More flexible to work with (custom velocity profiles can be set). **CONS:** • Position Hold control not as good as in Position Control • Yaw control is slower

Formula used for the calculation of velocity vectors in the selected velocity approach is:

VEL_X = MAX_VELOCITY * NF(DELTA_X / SF)

Where,

VEL_X: desired velocity in the X-direction in the global frame

MAX_VELOCITY: maximum permissible velocity of the UAV in any direction

NF(): normalization function. Outputs a number between -1 to 1 for any input

SF: Softening Factor used to soften the UAV correction behavior.

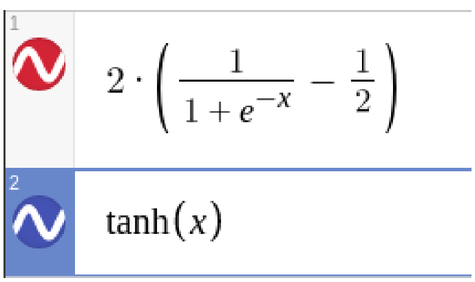

Figure 4.4 Mathematical Equations of the tested normalization functions.1) Shifted Sigmoid function 2) Hyperbolic Tan function

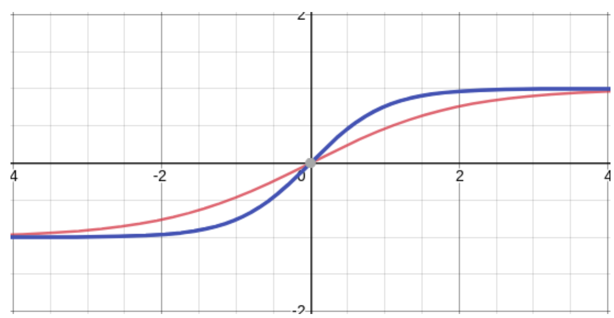

Figure 4.5 Graphical Representation of the given normalization functions

After running the simulations of the two approaches, the following results were observed:

- Mean Position error in velocity control is far lesser (max 0.04m) as compared to position control (max 0.08m)
- The hover characteristics of the quadrotor were much smoother in position control and a bit jerky in velocity control

Considering these results and due to more flexibility in control commands provided by the **velocity approach**, it was chosen for further development.

4.5 Simulation Environment & Algorithm

The simulation was performed on Gazebo using SITL instance of the autopilot firmware. The basic idea of the simulation world looks like this:

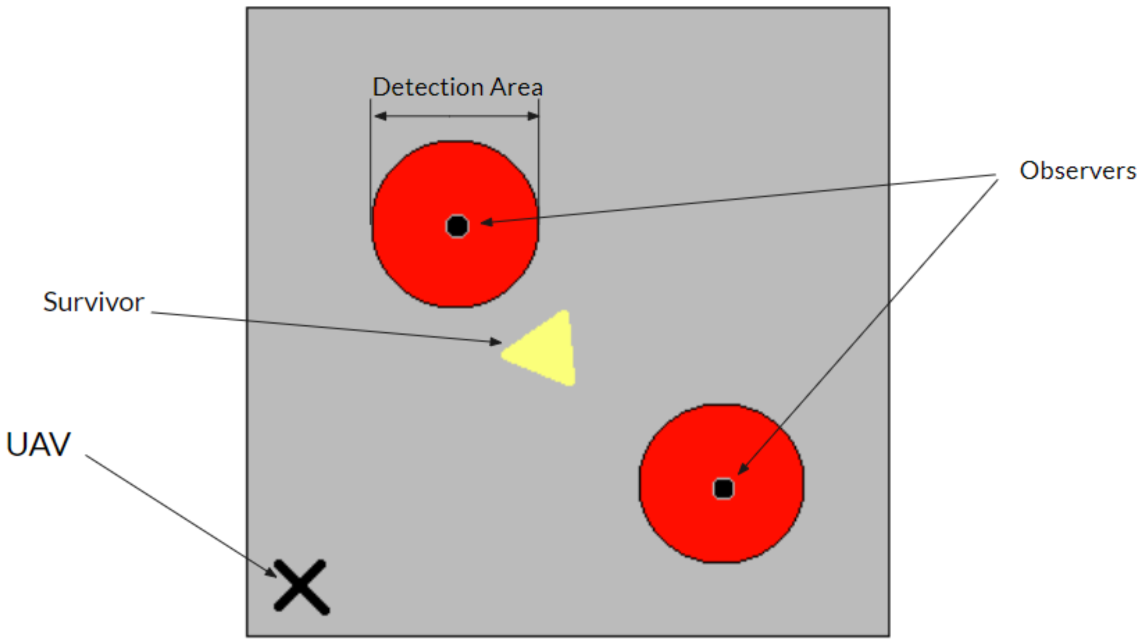

Figure 4.6 Simulation Idea for the project

The algorithm that is employed to find the survivor is:

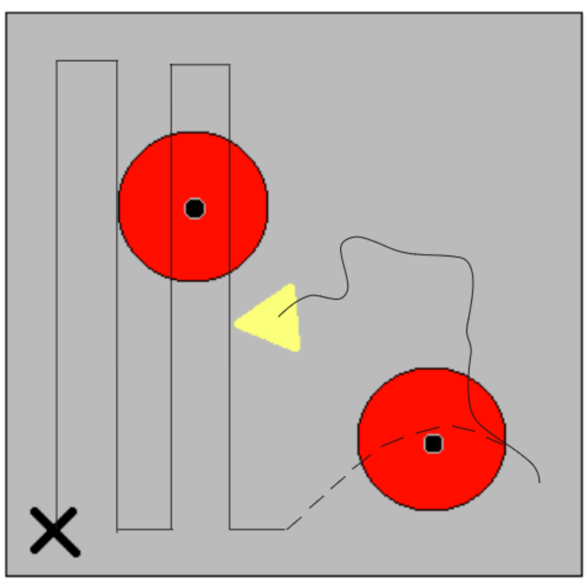

Figure 4.7 Visual representation of Algorithm

4.6 Flow Chart of the Algorithm

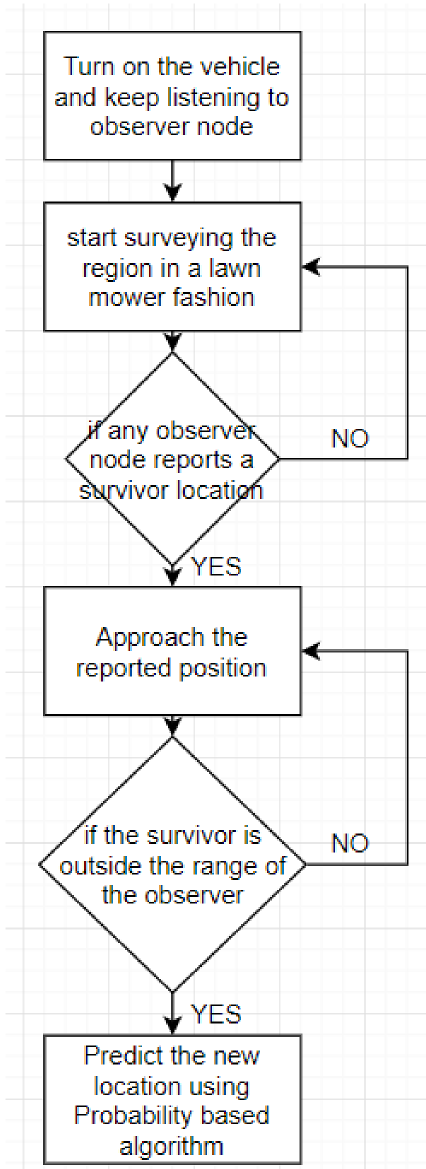

Figure 4.8 Flow chart of the Algorithm

Project #2

This Project was done as a part of MBZIRC-2020 Challenge 2 being done at MBZIRC Laboratory, Department of Aerospace Engineering, IISc, Bangalore.

4.7 Mission Statement

"To have a team of UAVs and a UGV that collaborate to autonomously locate, pick, transport and assemble different types of brick shaped objects to build pre-defined structures, in an outdoor environment."

The key targets of this project included:

- To locate the Regions of interest (ROI), i.e., the pickup and the drop zones
- Picking up the brick from the pile using a manipulator.
- Dropping the bricks perfectly to construct the given structure.
- Coordination between the UAVs to carry out the task in an efficient manner.

For hardware, software & control approach, Refer section 4.2, 4.3 & 4.4 Respectively

4.8 Algorithm

The algorithm is based on the juggling analogy for scheduling the UAVs for autonomous pickup and drop of the bricks as required by a given sequence.

Three Zones are defined for the UAVs:

- Picking zone (Hand 1)
- Dropping Zone (Hand 2)
- Idle Zone (Air)

The UAVs in the environment following this algorithm can have one of the 6 states:

- Ready to pick
- Ready to drop
- Ready to idle
- Current picking
- Current Dropping
- Current Idle

4.9 Visual Representation of Algorithm

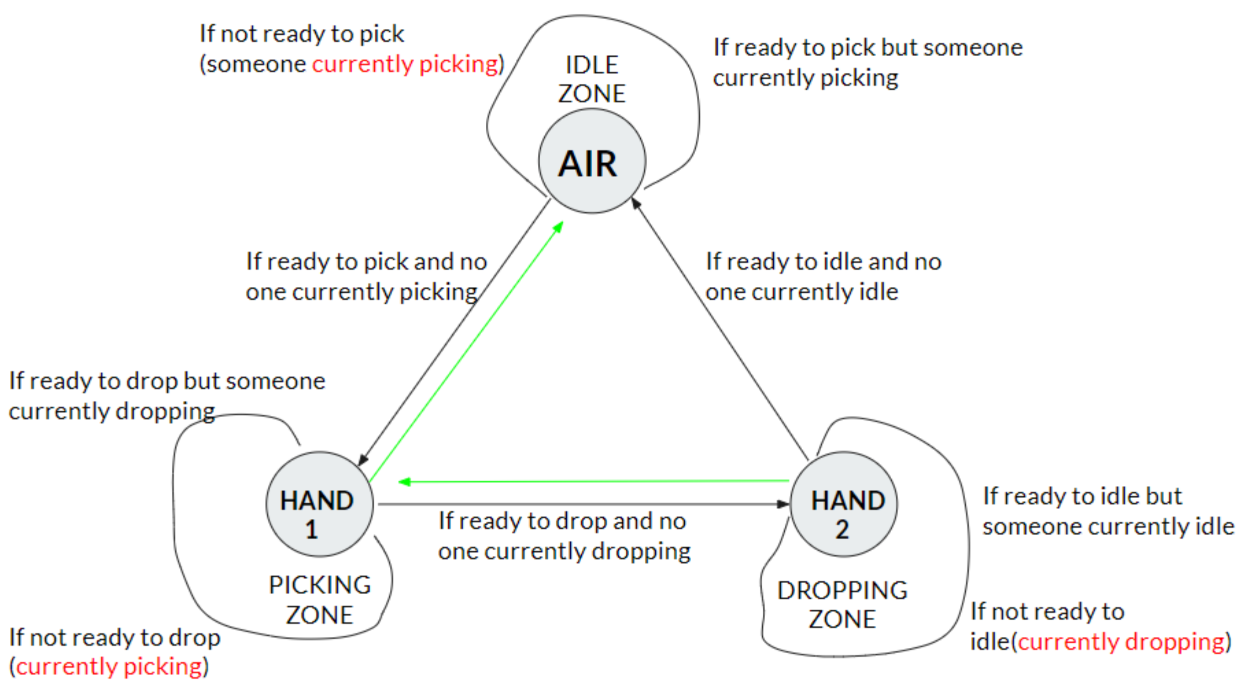

Figure 4.9 Scheduling algorithm for the swarm

4.10 Modified Algorithm

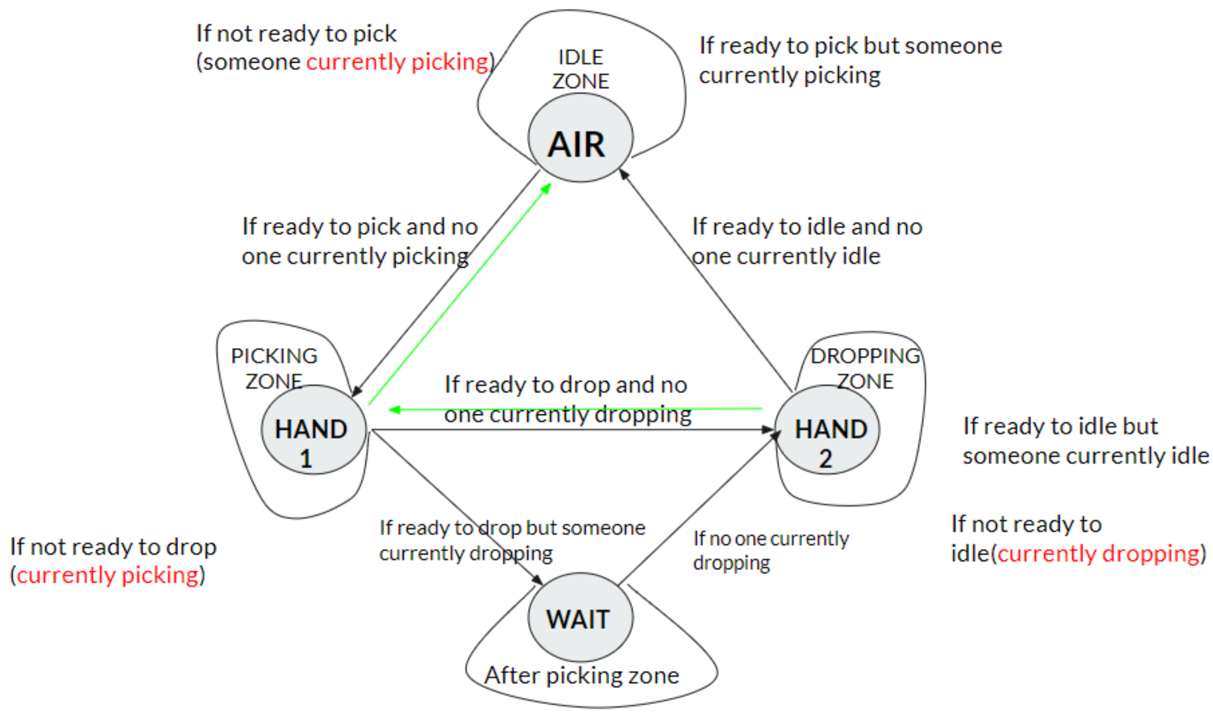

Figure 4.10 Modified scheduling Algorithm for the swarm

References:

1) https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle
2) https://safetymanagement.eku.edu/blog/when-disaster-strikes-technologys-role-in-disaster-aid-relief/
3) https://safetymanagement.eku.edu/blog/5-ways-drones-are-being-used-for-disaster-relief/
4) Google Images
5) https://www.iisc.ac.in/
6) http://aero.iisc.ac.in/
7) https://en.wikipedia.org/wiki/Disaster_response#Disaster_response_technologies
8) https://www.virgin.com/virgin-unite/business-innovation/humanitarian-sky-drones-disaster-response

DAY 1

It was the first day at the internship at INA bearings. The pronunciation is not the abbreviation but is rather pronounced as the name according to the IPA in English. On the very first day we met the HR. Her name was Mr. Anjali Scott and she was the one who induced us about the internship details and about all the minute aspects of working in a plant as big as INA bearings. The following are some of the details or the key aspects of the things she told us about:

- While taking any project, be clear about the expectations of your mentor and be on his head at all times since no one in the company has the time to look after interns. This fact became quite eminent later.
- The Manufacturing section is working 5 days a week and usually we have a holiday on Saturday. Thus, we were asked to confirm with our so-called mentors to let us know if they required our services on Saturday.
- The internship was to be for a duration of 2 months with a Stipend of INR 8,500 per month on a daily-wage basis

Next, we were told about the mentors and some of the key people to look out for in the plant. Hence, we were introduced to Mr. Vinod Kumar who was to be the one to assign us the project and all the other necessary guidelines required for the safety in the plant. However, we realized that it was Mr. Yusuf the safety manager who was to guide us and give us a detailed overview about the safety aspects in general that were pertaining to this plant.

Some of the key aspects of his talk on Safety measures that are necessary for the proper conduct of the personnel and to ensure that we are safe from all the hazards at all times:

- **typical differences between the machines that are found in a college to that which are found in the industries- the ones in the college are meant to be OPEN MACHINES unlike the ones in the industries which are high speed and high functioning and require a lot of safety measures to be considered**
- **General Safety Methodology:**
  - **identify the hazards**
  - **analyze risk**
  - **Provide control**
- **Keep in mind the Quality aspect of the product at all times**
- **The projects that are to be provided to you as interns are to be mainly study based projects**
- **Mostly you will not be in direct physical contact with the machine for sometime in order to make you more skilled and confident on the machines. The primary schematic of any machine involves the Energy and the Removal type of the machine. For example, a machine will run on PNEUMATIC, HYDRAULIC, ELECTRICITY and will have pure rotating parts and sliding parts. Chemicals and solvents are hazardous and thus one must be wary of their procedure to use and handle or dispose them.**
- **Identify the hidden hazards and primarily spend ample amount of time to understand the function and the working of the machine. Pay 100% attention to your surroundings at all times**

The following are the emergency protocols that are to be followed in case one occurs:

1. Siren, alarm systems and other safety equipment are the ones that are

nearest to you.
2. Alert others
3. Find the exit that is the nearest to you
4. Don't panic while assisting others
5. Inform the supervisor and the project guide
6. Wear safety shoes at all times. **The safety shoe comprises of a steel cap toe which is the primary characteristic of the shoe. That is all that is to it.**
7. **There are marked walkways and one should always use them to walk in the plant and must not walk on random pathways.**
8. It is important for the plant members to know about the map of the plant and identify the locations of the basic amenities in the plant.

CHAIN LINE

I was shown as a project to the line by Mr. Gangwal who was appointed to me by Mr. Vinod Kumar. Later I was to work with Mr. Sarthi who was the primary mentor throughout the day. **A chain line is the line or the assembly line where a chain is made. Here (the one which I was shown) made chains as per the specifications that were given by Mahindra (M&M), HYUNDAI, AND MARUTI SUZUKI****

The chain assembly line comprises of the following work stations where there is at least one worker who is monitoring at all times either he is working or he is only monitoring.

1. Link Assembly
2. Chain Assembly
3. Closing
4. Marking
5. Riveting
6. Stretching
7. Testing
8. Bins for Re-use and rejects

A brief summary of each of the key aspects of the machines is mentioned here:

– Link Assembly

The chain comprises of links which are all joined together. The four parts of the link are

- The inner plate; two in number
- Bushing; two in number

The work of this machine is to basically only make the link. This is done by feeding the parts mentioned before into three hoppers. The feeder is controlled based on the principle that at any instant of time there must not be any empty line or rail and that all times there must be a constant level of material at each level. Next the various parts are passed based on cam based mechanism that guides the inner plate and the bushes and then uses the forming process to make the link.
NOTE: Only links are made here and the number of links can be controlled by the operator.

For the safety of the operator all the machines in the plant have curtain cum sensor that immediately stops the machine when any object is too close to it or if anything passes the curtain.

– Chain Assembly

The job of the machine which is placed in the chain assembly is to assemble the chain. The following are some of the key aspects of this machine which make it a bit different from the one used during the link assembly:

- It has the operator who has to initially feed the number of links that are going to be present in the entire chain. The number of links are specified by the customer and the number of links that are going to be input by the operator are to be divided by two when entering the number in the controller.

DAY 2

On my second day I have been asked to work again on the chain line. This is the line where my project will come from. The mentor, Mr. Sarthi has finally explained what will be his expectations from me. As I have mentioned earlier my job will be suggest improvements in order to increase the overall productivity of the line and reduce the cycle time. He has given me a brief insight by showing me a project.

The following products are made in this plant:

1. Hydraulic lash adjuster
2. Roller finger follower
3. Water ppump bearing
4. Mehanical tappet
5. RSEMZ
6. OAP
7. Chain drive system
8. Shift tower
9. Chain guide
10. Sliding Pad
11. BSR pulley
12. Drawn Cup bearing
13. Turned cage bearing
14. Plastic cage bearings
15. Welded cage bearings
16. Flat aress

Apart from this I have made a layout of the plant as of 2016. (the picture comes here)
My project has been kept in segment one of the manufacturing department and

I have to work in this section from now on.

CHAIN ASSEMBLY LINE

VISUAL STANDARD OPERATING PROCEDURE for the **CHAIN ASSEMBLY M/C**

Working sequence

1. Take the outer plate, pin & feed into the machine feeder
2. Ensure oil in the lubrication level on the display as well as on the bank below
3. Ensure air pressure of 5-6 bar in the machine and -ve 5 bar in the feeder(This is required to suck the completed link to the next machine.
4. Adjust the speed to 40-50 Hz
5. the feed must be check label information and that acknowledgment to the line and to all the information as per the batch size in accordance to fill the inner plates
6. Same goes for the bushes
7. The display unit shows the sensor, no. of produ…

Quality tips or the most probable failures that are observed in the product. These tips are displayed on each and every machine in aiding the operator to identify any errors or defects in the product. Some of the quality tips that are mentioned for the link assembly machine are as follows:

- Bush Missing

- Bush orientation
- Bush Angle
- Foreign material failure

Plausible defects on the chain assembly:
There are no such defects that were displayed on the machine however, the following are the defects that are fooound on the chain lines in general:

- Riveting ok
- all pins ok
- pin missing
- plate thickness ok

DAY 3

Today's agenda includes the understanding of the knitting machines in a totality and in depth. The following are some of the key points of the link assembly machine, a rough schematic of which I will be drawing here. The major points of the feeding are mentioned here and some of the important features and the technology used in them will be mentioned.

Primarily, the machine comprises of a mechanism to assemble the link in an orderly fashion. As a whole there is/are:

- Feeding mechanism
- Tooling mechanism
- checking mechanism

The feeding mechanism is peculiar for each of the components which are the inner plate and the bush.
In the bush feeding mechanism there is a HOPPER AND A FEEDER. The functions of these two components or parts is to ensure that the bush enters the pipes in the assembly machine in a proper orientation.
The hopper is a container like structure where the operator puts the maaterial manually. It comprises of a conveyor belt the function of which is to let the bush pass through a channel which is the input to the feeder. In the feeder there is a vibrating element which is attached to the base of the feeder whose purpose is to primarily rotate the bush raw material in a clock wise motion. An adjustment knob has been provided which sets the speed of the rotation. From my inference, I suppose its purpose is to control the frequency of the vibration however, not to control the amplitude.

When the vibrating element has been put in effect there is a provision of two pneumatic pipes which are there to ensure that the bush enters the two pipes in a vertical fashion which shall be shown using a figure. There are a total of four pneumatic pipes, two for each lane.

For the inner plates there is a similar vibrating element which serves a similar purpose to that in case of the bush. Before entering into the final channel there is a conveyor belt which transports these plates to the top of the vibrating base. From here with the aid of gravity and partially due to the force of vibration the feed of the inner plates can be controlled. Normally, this feed is fixed. There are a series of POKA YOKE which have been minutely incorporated at each and every step of the hopper and the feeding mechanisms.

Some of the notable ones have been mentioned:

1. continued …

There are a series of sensors that have been used to determine the flow of the various raw materials in the machine. There are two sensors on each lane of the inner plate (two) and one sensor on each of the bush lanes (two in number). The main purpose of these sensors is to sense the part. If there is no part in the contact of sensor the machine will slow and/or stop depending on the level of the parts already in the vertical lane. These will help the operator in detecting where exactly is the material missing from and where the feed has been disrupted in the series of the materials/raw par.
Thus there are a total of 6 errors that will occur in the machine due to

the lack of raw material in the continuous operation of the machine.

PLATES	**ROLLER (BUSH)**
LANE 1 MINI	LANE 1 MINI
LANE 1 MED	LANE 2 MED
LANE 2 MINI	
LANE 2 MED	

The layout of the control panel is shown here as follows.

DAY 4

The majority of day 4 was spent on studying the various POKA YOKE on each of the machines in the chain line. A detailed document was made illustrating the various poka yoke that are present on each station. The reference of none of these will be shared here as it is completely confidential. However, I will have to try and ask sir. About the knitting machine the major poka yoke is present in the feeding section and that too in the link assembly machine.
The other common poka yoke are the fixtures and the various locking mechanisms to ensure that none of the parts are missing while the chain or the link is being assembled. Apart from that there exist poka yoke in the form of sensor based technology and in the form of control systems as well. A classic example of the same is the sensor which has been used in the proof loading center and the riveting center which ensures the position of the chain. Moreover, there is an interlinking control system which ensures that the machine, only if it is working, will allow the machine preceding it to work. This interlinking ensures that the operator does not miss any steps on the chain line which would be quite plausible otherwise.
Some other noteworthy poka yoke are on the pad printing machine and the closing chain station. The fixture on the pad printing machine ensures that the chain be only fit in one order for the marking to take place. In any other order the marking will not happen. There is also a provision of two green buttons which have to be pressed together and simultaneously in order for the printing to start. This is to ensure that both the hands of the operator are on the table and are not inside the machine. There is also poka yoke to install the marking head or the pad of the printing machine. Also, the two marking pads must be in place for the machine to start working. Then there is a sensor which is placed at the bottom of the press, on the pressing table to sense the outer plate. If it is not on, the sensor indicates that an outer plate is missing from the closing link and this might cause the chain to be assembled or closed in a wrong fashion.
Such poka yoke mechanism have made the chain line assembly mistake proof

and has helped the novice operators immensely.

A project that is being given to me in this respect is to make a poka yoke to ensure that the chain is placed in the right orientation while closing it. There is a camera which has been innately installed on the machine. Being the trial period, however, it is not functional to ensure that the bush holes are facing outward and not inward. For that I suggested that a pin be used and this will ensure that the chain's proper orientation is maintained at all times. That was mostly the part of day 4.

DAY 5

Today's agenda will include working on the final parts of the document and confirming the poka yoke. Then once this is printed I'll have to design and implement my own poka yoke which has to be meticulously designed. Once this design has been completed I'll have to start working on the BSRA line. This is the line I worked on DAY1. The BSRA line is a classic example of how the things are extremely simplified with the help of a poka yoke. The job of the bsra is to make idler pulleys. Currently, there is a line for it, however now it is being implemented in two steps where the outer ring is attached later. This is a classic line which comprises of a poka yoke to put all the parts and the operation takes place in series on each machine. Initially, I was asked to take a project on this line, where my job was to reduce the cycle time of the operator by automating the loading and the unloading process.

Today, I am working on the chain line to design a poka yoke that will be suitable to for the closing chain in order to determine orientation of the chain. The chain must always close in the right orientation that is the bush hole outside for the oiling to happen. If this is not correct then the entire chain becomes scrap. This is one of the most difficult problems of all time. THIS IS THE HOTSPOT FOR CHAIN ERRORS IN THE LINE.

DAY 7
(ABSENT)

DAY 8

Today, I had to finally identify and differentiate between a Poka Yoke and a machine control. As my mentor defines it, the **Poka Yoke is an additional control that ensures the various product characteristics: Appearance, dimension, orientation and fitment. It is for the product at the customer end and in not any way related to the working of the machine or the safety of the operator.**

Apart from that some other vital characteristics of a poka yoke are as follows:

1. It must be cross checked or verifiable.
2. The verification method should be stated and it must be such that it doesn't hinder the operation of the machine.
3. A poka-yoke is different from a machine control in a sense that the machine control are for defining the process/manufacturing sequence. But, a poka yoke is not to ensure the proper sequence but ensure the final product.

A classic example which my mentor mentioned relating to this was in the pad printing section of the chain. Here, if the chain is not properly aligned by the worker then the marking will not be at a correct location.

For this to happen the chain must be placed in an orderly fashion in the fixture, which has been provided as a Poka Yoke. Next, he told me how the locking mechanism and other chain sensors were not a part of the poka yoke. As the Parksons Machine already ensured that these errors don't occur we need not call these as poka yoke, but machine controls.

THUS BROADLY SPEAKING A POKA YOKE WILL ENSURE THE PRODUCT CHARACTERISTICS AT THE CONSUMER END FROM THE WORKER OR ANY WHERE IN THE PROCESS.

FINAL PROJECT: VALUE STREAM DESIGNING OF THE CHAIN DRIVE SYSTEMS

There are a few things which have to be kept in mind while designing the value stream map of the entire chain line.

DAY 9

Today Schaeffler face lifted the quality policy of the company which is called FIT FOR QUALITY. There were a lot of points that were different from the previous axioms which were established as a part of Fit for Quality. The new Axioms are given to every member in the form of a brochure. A presentation of about 40 min was kept in the morning just to give a brief insight about the new and noteworthy aspects of the new policy.

Some of the key points that make this facelift unique are as follows:

- The reason for the facelift is to meet up with the changing customer expectations
- The new policy emphasizes on the philosophy of self-realization and self-identification. Unlike the previous policy where it was some external party identifying the problems there is a room for the workers to express their problems pertaining to maintaining quality for they know what is the best for them.
- A number of tools were introduced in the previous version such as: Poka Yoke, SWOT (Strength weakness Opportunity and Threat), Layered Auditing and etc. These tools were essential however, they were not a part of a culture and thus to incorporate the spirit of quality in the culture of the organization the axioms are now based on the Plan Do Check and Act system. PDCA
- Like the previous version of Fit for Quality the emphasis on the ZERO-DEFFECT policy remains intact. They still are striving for null customer complaints.

The best part of the presentation was the short inspirational speech by the plant head which was the most skeptical. He told the workers and the audience about the fact that the FIT FOR QUALITY program goes by many names in the companies. Be it the Ford Quality or GMQuality ,etc. the spirit and the fundamental of the quality remains intact.
He was very specific about the fact if the worker maintains DISCIPLINE AND HYGIENE at all times and keeps a commitment that he/she shall not let any faulty part meet the customer then that day would be the day when 70% customer complaints and the defect would be gone.

Take care of the small things and the big ones will fall into place.
Mix up of the NOT OK parts with the okay parts should be avoided.
Keep the surroundings neat and clean and organized at all times.

DAY 10

I was asked to study the VSD for the SLH Line. I have been asked to study the SLH line and then draw some conclusions. He said that it will take only 2- 3 DAYS to complete my project. For the references of understanding the various aspects of the VSD the book to refer is Learning to See. There are certain processes that take place on the OAP line and RSEMB line which I have been asked to make. There are a total of 11 parts that are required on the RSEMB line. My job was to study the process and calculate the following times and data for the process:

- cycle time
- change over time
- number of shifts
- number of operators
- scrap rate
- process time (if it is a batch)
- working time

These are the main times which must be observed and noted. Once these are noted the rest is fine and will follow. However, there is also a need to plot all the existing symbols on the map

DAY 11

Today’s agenda involves the study of the flow of information for a particular line. Who and where gets the exact demand from the customer. This is essential to verify that there is actual pull based process taking place in the plant.

Before that I will have to learn about TIME STUDY and how are the various times measured and calculated…

To study the information flow

I had to identify the information flow for which I had to understand how the orders were taken in the company. It must be noted that the company has the policy to forecast the demand for 3-4 months even before the customer places the order. Based on these calculations there is only and error of about 5-10 %. Once this is known it becomes easier for the company to order the raw materials from the places which would have taken 3 months otherwise. Hence, it saves the time and helps in delivery on time. The customer first places the order to the marketing and the sales team. After that, KAM gives this order to the SCM which ultimately places the order of the raw materials. Once this is done, the order is then placed to the planner who at the end of the month or just at the beginning of the month confirms and gives the monthly target to the managers. This way they have already planned the production for the month. There is however, a daily plan which is also placed next to the line, which has the following format. INSERT IMAGE OF THE DAILY PLAN, THE ACTUAL OUTPUT AND THE NAME OF THE OPERATOR AND THE SHIFT.

This target is obtained on the basis of the efficiency of the machine. For the chain knitting line this efficiency is 80% given that the machine can produce 1500 parts in a day, the daily target is placed at 1200 chains only. For the OAP line this number is a 92%.

There was a discussion regarding the importance of delivery and reliability on the company and how does it help in the various aspects of the company policy. Based on these there were a few noteworthy points that I must highlight.

- The company basically places the customer and its satisfaction on the top of everything else. Thus, a lot of emphasis is placed on the fact that the packaging be full-proof and without any defects. If the packaging is not defect free then the product might get damaged during shipping which will be detrimental for the company.
- Reliability is based on two important features. One, based on the customer satisfaction and that too every time a product reaches a customer. Thus, there is a factor of time associated with it. If there is continuous customer satisfaction then everything is going to be alright and the customer will be happy to do business with you.
- If the delivery is on time there is no inventory and the demand is met too. Hence, the system idealizes and the JIT policy becomes more effective at every stage of the value stream.
- Also, the worker will be at peace, since he knows that his target is met within the production schedule and he has no burden whatsoever.

Understanding the Kanban system.

The KANBAN system works on the pull based process where the raw material is only ordered based on the need of the next downstream process. In the plant this is done by a person who pays an hourly visit to the station/line and then based on the KANBAN cards that are placed in the bin, he will bring the material in the next visit. Thus, normally, the workers and the operators of the line see that they ensure placing the kanban card an hour prior to their process. This comes from experience and an educated guess as to what will their production rate be. Normally, there is a supervisor who might also take regular watches to see that the production is going smoothly.

DAY 12

Today's agenda comprised of primarily working and understanding the KANBAN system. Mr. Vishnu told me that the KANBAN system has a number of cards which will be of the same product and at times of the same part. However, these will be in multiples and it offers an advantage to the worker to order only what is required and nothing more.
For example, if the worker has a card for a pulley or an outer ring which says the quantity of the material as 125. However, if in case he needs about 400 pieces of the pulley the operator will place 4 such cards. Thus, when the logistician comes for the next time he will fill only the amount of material based on the request which is passed on the form of cards. Hence, the line of OAP works. Even the store has a FIFO system which ensures that only the dedicated amount of raw material is released.

With every raw material there is an attached expiry date. These parts will start to rust otherwise. Hence, the store places an order of the raw material only and only when the need occurs and not without the need.

There are three reasons why this is done.

To save space this is done to install machines in the future.
This type of KANBAN system also reduces the rejection rate. Initially, when a large inventory was being brought to a process and they operate based on the push based any mistake or error in the process gets discovered very late and the product still remains in the stream. This makes tracing the root cause of the product and also the mistake itself very tedious and thus, it is a bad practice to work as per the push based system because otherwise there will be a huge amount of pile up and it sucks.

Tuesday, June 07, 2016

What is it?

Poka-yoke (poh-kah yoh-keh) was coined in Japan during the 1960s by Shigeo Shingo who was one of the industrial engineers at Toyota. Shigeo Shingo is also credited with creating and formalizing Zero Quality Control (poka-yoke techniques to correct possible defects + source inspection to prevent defects equals zero quality control).

The initial term was baka-yoke, which means 'fool-proofing'. In 1963, a worker at Arakawa Body Company refused to use baka-yoke mechanisms in her work area, because of the term's dishonorable and offensive connotation. Hence, the term was changed to poka-yoke, which means 'mistake-proofing' or more literally avoiding (yokeru) inadvertent errors (poka). Ideally, poka-yokes ensure that proper conditions exist before actually executing a process step, preventing defects from occurring in the first place. Where this is not possible, poka-yokes perform a detective function, eliminating defects in the process as early as possible.

Why is it important?

Poka-yoke helps people and processes work right the first time. Poka-yoke refers to techniques that make it impossible to make mistakes. These techniques can drive defects out of products and processes and substantially improve quality and reliability. It can be thought of as an extension of FMEA. It can also be used to fine tune improvements and process designs from six-sigma Define - Measure - Analyze - Improve - Control (DMAIC) projects. The use of simple poka-yoke ideas and methods in product and process design can eliminate both human and mechanical errors. Poka-yoke does not need to be costly. For instance, Toyota has an average of 12

How to use it?

Step by step process in applying poka-yoke:

1. Identify the operation or process - based on a pareto.
2. Analyze the 5-whys and understand the ways a process can fail.
3. Decide the right poka-yoke approach, such as using a
   - shut out type (preventing an error being made), or an
   - attention type (highlighting that an error has been made) poka-yoke
   - take a more comprehensive approach instead of merely thinking of poka-yokes as limit switches, or automatic shutoffs
   - a poka-yoke can be electrical, mechanical, procedural, visual, human or any other form that prevents incorrect execution of a process step
4. Determine whether a
   - contact - use of shape, size or other physical attributes for detection,
   - constant number - error triggered if a certain number of actions are not made
   - sequence method - use of a checklist to ensure completing all process steps

   is appropriate
5. Trial the method and see if it works
6. Train the operator, review performance and measure success.

What's on the web?

1. John Grout's Mistake Proofing Center
2. SawStop - a good example (we have no affiliation)
3. Benefits of Mistake Proofing
4. Circumventing Murphy - AssemblyMag
5. RealityPV - 3D Work Instructions

Pl let us know if you found this brief overview useful

Food for Thought !

"To be what we are and to become what we are capable of becoming, is the only end in life."

- Robert Louis Stevenson

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Apart from that we also learned about the we also learned about the MOVE ARROW. It is yet another policy followed by Schaeffler to ensure quality the document mentions the details of the policy and the function of the Move arrow. It is essential that all the employees be aware of the aspects of the move arrow. To promote the concept/philosophy of the same there are organized discussions.

DAY 12

Today, we worked on the Tappet line to understand the line and draw the process flow. We had to verify the cycle times and the working time and the preocess time of the machines and also verify the flow of the tappet. There are majorly two kinds of tappet which are of importance to the company. These are the ones made for ford and Maruti. A lot of engineering goes into making these tappets and hence their value stream is important. Unlike Maruti, ford's tappet are much more advanced in terms of the fact that they use only a single blank cut out and are imported from germany. These also, do not require any kind of heat treatment. The codes are .36 for Ford and .53 for Maurti.

Maruti has always been a budget car supplier or cost leadership. Hence,

their parts are imported from a local supplier. The rest is all the same.

Now, looking into the other aspects of designing.
There is a peculiar sorting machine in the plant dedicated to FORD which is sorts the tappets sorts the tappets based on their outer diameters.
Also, we learned about OEE and its importance in terms of production and the functioning of the plant. OEE.odt has all the important points and the formulas that are used to calculate it. Being an important measure the plant has an OEE of 60-65 %.

DAY 13

Today’s move discussion is about the takt time and what is the importance of this concept in order to synchronize the production rate at all instants of time. It ensures that there is just in time in effect. Moreover, it also helps in determining the bottle-neck operations and help in line balancing. That was mostly that I did

DAY 14

There is a need for changing the feeding of bush mechanism in the chain line. Apart from that I learned that the kanban cards are meant to store an inventory of two hours at any point in the line.

DAY 15

We had to make the value stream for the chain line and start collecting the data for the data boxes. These details include the cycle time, change over time, scrap rate, working time, process time etc. In calculating the cycle time there is a glitch where we need to combine certain processes or not. Based on the processes since there is no pile up whatsoever between the processes the process has to be combined as a single process. While making the process box we need to consider the cycle time of a single process. However, when we need to consider the processes individually, we have to calculate and mention the machine time individually. Since it is close to a continuous process, we don’t have to concentrate the least on optimizing the process.

PROCESS	**CYCLE TIME**
LINK ASSEMBLY	0.0085 MIN

MOVE ARROW.

Customer satisfaction:

- Quality
- delivery services
- cost

Employees take personal responsibility >
Avoid Waste >
Error Free processes >
Synchronization with the customer >

KAIZEN FIT FOR QUALITY

they are the four pillars. these are the tools this is the target. TAKT principle we

in010013 datat-01 sw-ibi-p pv projects

four pillars are the ones mentioned in the arrow

the tools are the FFQ AND KAIZEN
direction is significant of continuous improvement.

There is a need to ask topsy turvy questions in order to make yourself acquainted with the process.
A leader must be always aware and must be answerable and must satisfy the question of the junior.

Customer satisfaction is the prime motive. If this is not satisfied he will buy from somewhere else. He judges the supplier based on the Quality, delivery, and the cost and also the after sales service. If this is not satisfied he will lose faith in you and will shut down the business.

The cost must be optimum.
How to achieve customer satisfaction.

- Everyone is responsible for the quality.
- Waste are of 8 types.
  - inventory
  - transportation
  - over production
  - delay
  - defects
  - space

    - motion
    - over processing
- error free processes- use of poka yoke. Proper setting. It should be the right at the first time. It must be 100% ok.
- Synchronization with the customer- Internal customers and the external customers these must be communication. They must be able to comprehend each other.
- Tool boxes- FFQ and KAIZEN are the ones who help us to
- tilted arrow is for continuous improvement and the three lines are significant of the INA LUK and FAG.

Our vision

We aim to be the best lean plant through our commitment towards quality, constant innovation and pride of ownership.

We constantly strive to reach high quality and high efficiency by harnessing the people and potential and continually improving our process, products and systems. We embrace a lean thinking, high performance work culture with innovative methods to achieve Zero Defects and Customer Satisfaction.

- The reason for doing this workshop is that we are having 22 to 23 products.
- We were only concentrating on a single product and how are we going to accommodate the products in this plant.
- Green Field layout implementation requires that **how my plant layout supports the value stream. Suggesting changes in the layout.**
- **Logistics concept should be defined.**
- **Only value added should be done by the operator. There should be minimum inventory and minimum space on the shop floor. The operator must not leave the workstation. The material should come to him.**
- COO review. Need to optimize the layout of the plant. REVISITING THE LAYOUT AND THE PLANT BASED ON THE VSD AND THE LOGISTICS TO PASS ANY RECOMMENDATIONS.
- **Foot print India 2020**.
- Participation is the most important aspect of the workshop.

PROCESS VISION 2020

orange represents the new product line that are going to be introduced in the plant in 2020

customers are new.
A lot of tools will be utilised. The purpose is to make the employees aware. It should reach a four star level by 2020. 1 star plant. Since all the three segments are at 1 star.

Value added per attendance hour = 1200 as per the vision. Currently, it is at INR 815. Delivery reliability should be 92%.

deliver x by date y+- 2 days if it is achieved then it is 100% reliable. Any deviation in the date or the quantity is not reliable and makes it less than 100%

plant level oee is 62% currently.
Road Map for a particular process. The focus of the workshop is on the operations.

PRINCIPLES OF THE MOVE.
FLOW TACT PULL 6-DEFECTS

flow- the product flow should be unidirectional otherwise movement will be more and it will be non-value added.

Tact- available time to the customer demand.

TARGETS

- increase productivity and reduce logistics cost
- reduce throughput time
- transparency of logistics structures and processes
- implement stable and lean processes
- reliability of logistics
- Hollistic view of the complete supply chain
- motivated and qualified employees
- flexibility on repeatedly changing requirements

PRINCIPLE METHODS

- reduce handling costs
- ensure higher transport frequency of small quantities
- separate value added and non-value added terms
- tacted wellness and synchronized processes
- measurability in all processes and reliability of supply
- line back-from inside to outside
- standardization of all equipments
- flexible structures

VALUE STREAM METHOD

Today, we had to plot the data boxes of the products in the segment 3 and segment 4. Based on that, the demand and the takt time were obtained from the scm and the ppc. Furthermore, there was the inventory and the stock that was divided into three parts:

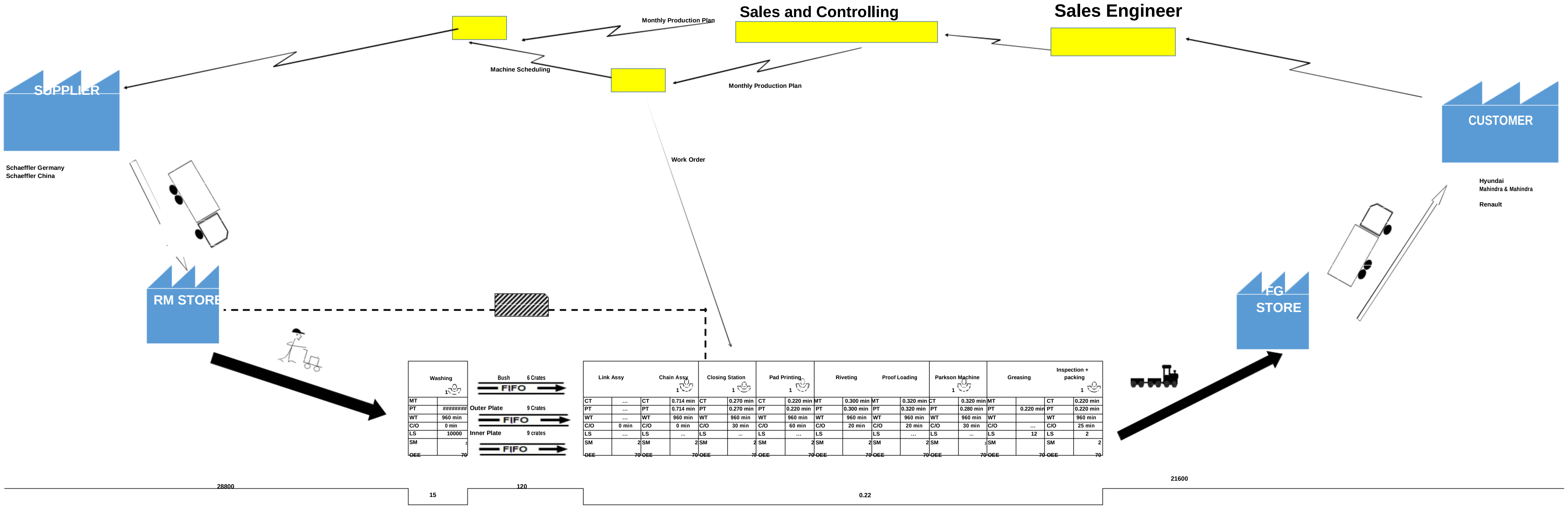
1. Plant Stock
2. Transit Stock
3. Warehouse Stock

There are total of three warehouses in the country of the plant. Gurgaon, Kolkata and Chennai. North South and East.

The finished goods are sent to these ware houses where they are kept for a certain period.

The following data will summarize the same.

VSD CHAIN KNITTING LINE 2017



Process	Operators	CT / MT	PT	WT	C/O	LS	SM	OEE
Washing	1	MT:	########	960 min	0 min	10000	2	70
Link Assy		CT: ...	...	...	0 min	...	2	70
Chain Assy	1	CT: 0.714 min	0.714 min	960 min	0 min	...	2	70
Closing Station	1	CT: 0.270 min	0.270 min	960 min	30 min	...	2	70
Pad Printing	1	CT: 0.220 min	0.220 min	960 min	60 min	...	2	70
Riveting		MT: 0.300 min	0.300 min	960 min	20 min		2	70
Proof Loading		MT: 0.320 min	0.320 min	960 min	20 min	...	2	70
Parkson Machine	1	CT: 0.320 min	0.280 min	960 min	30 min	...	2	70
Greasing		MT:	0.220 min		...	12		70
Inspection + packing	1	CT: 0.220 min	0.220 min	960 min	25 min	2	2	70

PER ANNUM BASIS	DAYS	MINUTES
AVAILABLE TIME	286	386100
TOTAL DEMAND	436160	

	MINUTES
TAKT TIME	0.885226
NON-VALUE ADDED	50520
VALUE ADDED	15.22

OEE

oee stands for overall equipment **EFFECTIVENESS.** Superficically, it is the operator's efficicency to do/complete a job. Also, there is a particular formula to calculate OEE. There is a range of percentage which determines the grade of your mahcine. According to the discussion which is going on right now a value above 85% is world class.
There is a difference between efficiency and the effectiveness. There is a **degree of utilization which is efficiency** however, in actuality **it was working should also be considered(effectiveness)**

KEYWORDS:
1 Setup time reduction
2Rejection control
3Rework control
4Degree of utilization
5Losses

There are three aspects to it.
Availibility= NET RUNNING TIME/ NET AVAIL. TIME
Performance = TOTAL PROD. QTY X CYCLE TIME/ NET RUNNING TIME
Quality= TOTAL PROD QTY REJECTION (NUMBERS)/ TOTAL PROD. QTY

Once, these three factors have been calculated we can calculate oee by multiplying these three figures.

IMD is a
SAP

- 85% is considered class
- machine utilization and its capacity
- steel cage is having a oee of 65-80%
- NET RUNNING TIME IS THE TIME DEDUCED FROM THE TOTAL AVAILABLE TIME FOR UNPLANNED BREAK DOWN, KNOW BREAK DOWN and the other time where the machine was not working.

The performance of the machine can also be calculated based on the number of parts produced actually to the planned production number.

In case the machines are working on a number of parts then their individual cycle times should be taken.

TAKT TIME

The definition of takt time is net working time divided by the customer's demand.

- Customer satisfaction
- Delivery
- takt time helps in line balancing
- this is basically a process to maintain
- decide the bottleneck
- Work load and combining the operations in one machine
- optimise the man power
- Available time/customer demand

CHAIN LINE POKAYOKE DETAILS

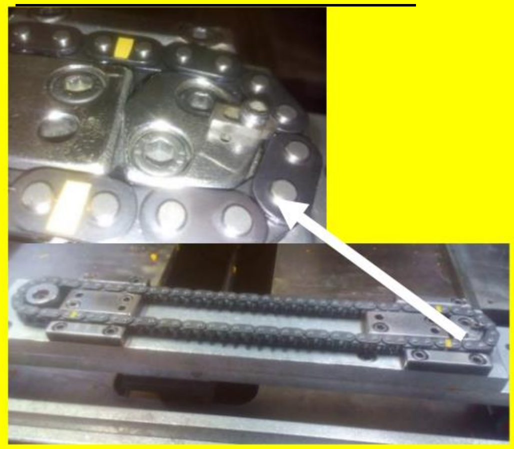
STATION 1: Link Assembly

POKAYOKE DETAILS:
Camera is installed on the machine to ensure proper orientation and angle of the bush.
PHOTO REFERENCE:

CHAIN LINE POKAYOKE DETAILS

STATION 4: Pad Printing

POKAYOKE DETAILS:
A fixture to ensure the proper **alignment of chain and the right location of the marker** to be placed on the chain.
PHOTO REFERENCE:

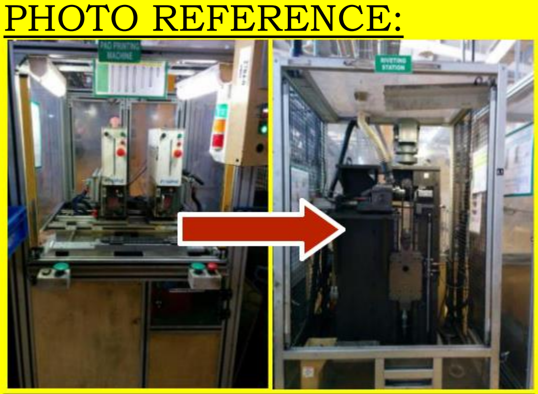


CHAIN LINE POKAYOKE DETAILS

STATION 4: Pad Printing

POKAYOKE DETAILS:
Interlocking between the Riveting Station and Pad Printing. Pad printing starts only if the Riveting machine is working.

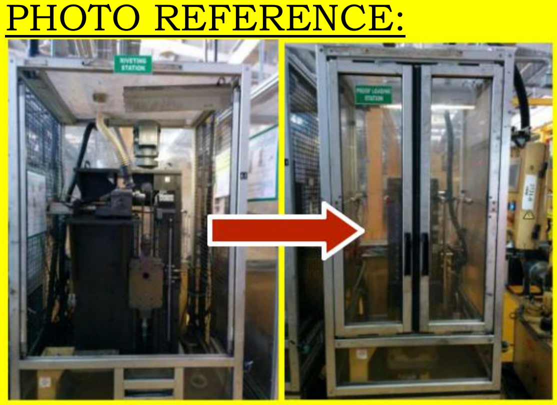
PHOTO REFERENCE:



CHAIN LINE POKAYOKE DETAILS

STATION 5: Riveting Station

POKAYOKE DETAILS:
Interlocking between the Proof Loading Station and the Riveting station.
Riveting does not start if Proof loading machine is not Started
PHOTO REFERENCE:

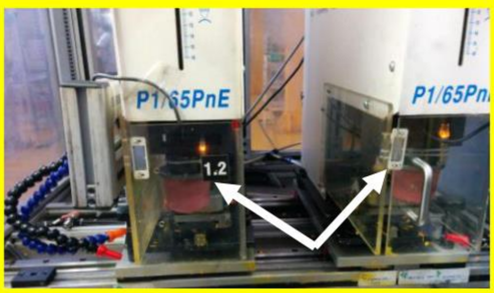


CHAIN LINE POKAYOKE DETAILS

STATION 4: Pad Printing Machine

POKAYOKE DETAILS:
Printing pad presence sensors installed on the machine to ensure the Pad is present. If the Pad is missing the machine won't start.

PHOTO REFERENCE:



CHAIN LINE POKAYOKE DETAILS

STATION 6: Proof Loading Station

POKAYOKE DETAILS:
Interlocking between the Parkson Machine and the Proof loading machine.
Machine starts only if the Parkson machine is working.

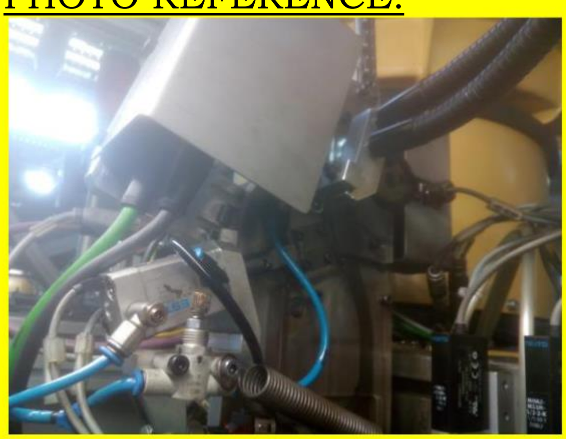
PHOTO REFERENCE:

CHAIN LINE POKAYOKE DETAILS

STATION 2: Chain Assembly

POKAYOKE DETAILS:
A camera system to ensure the bush hole orientation while feeding the link.

PHOTO REFERENCE:



CHAIN LINE POKAYOKE DETAILS

STATION 4: Pad Printing Machine

POKAYOKE DETAILS:
Sensors to ensure the proper position of the printing head and the marking on the chain.

PHOTO REFERENCE: