iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** V **Month of publication:** May 2025

DOI: https://doi.org/10.22214/ijraset.2025.71660

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Design and Implementation of an Intelligent Safety Helmet for Miners

Ravi Kumar[1], Leona Dutta[2], Sayandeep Das[3], Arghya Naskar[4], Saumyadip Pramanik[5], Partha Pratim Mondal[6], Koushik Pal[7], Palasri Dhar[8]
Department of Electronics and Communication Enginnering, Guru Nanak Institute of Technology, Kolkata, India

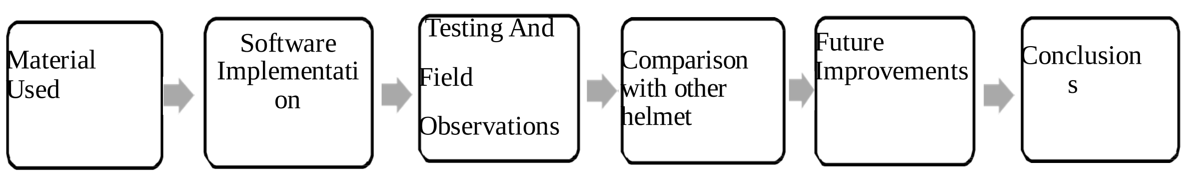
Abstract: Mining environments are among the most hazardous workspaces, where rapid response and continuous monitoring can spell the difference between safety and disaster. This paper presents the design, implementation, and testing of an intelligent safety helmet equipped with a suite of sensors—including an ultrasonic sensor to verify proper usage, a temperature sensor, gyroscopic motion detection, and atmospheric sensing—as well as an integrated SOS function for emergencies. The system leverages this sensor data to alert miners and supervisory systems of dangerous conditions. Future implementations propose integrating SIM card connectivity for direct emergency communication, thus reducing response times in critical situations.

I. INTRODUCTION

Mining poses inherent risks including fires, toxic atmospheres, structural collapses, and falls. Traditional helmets offer physical protection; however, they lack the capability to monitor ambient conditions or the wearer's status. In response, the proposed intelligent helmet enhances miner safety by embedding sensors that continuously validate helmet usage, monitor environmental hazards, and detect miner falls or erratic movements. An emergency SOS button further empowers the miner to initiate immediate alerts. This paper details both the hardware and software aspects of the helmet—illustrated by the accompanying Arduino code—and discusses avenues for future enhancement.

II. MATERIALS AND METHODS

A. *Workflow*



III. MATERIAL USED

A. *System Architecture and Hardware Overview*

The helmet comprises several key components:

1) Ultrasonic Sensor: Detects whether the helmet is worn properly by measuring the distance between the sensor and the miner's head. In our implementation, if the measured distance is less than a defined threshold (e.g., 10 cm), the system concludes that the helmet is worn correctly.
2) Temperature Sensor (DHT22): Monitors environmental temperature, critical for early detection of fire hazards or overheating in confined mine passages.
3) Atmospheric Sensor (MQ135): Evaluates air quality by measuring possible harmful gas concentrations.
4) Gyroscope (MPU6050): Measures changes in orientation and acceleration to detect falls or abrupt motions.
5) Pressure Sensor (BMP180): Measures ambient pressure, which can be correlated with altitude changes or environmental conditions underground.
6) SOS Button: A manual trigger that immediately sends an emergency alert via the communication module.
7) Communication Module (Optional): Uses a SIM card (or future SIM-enabled designs) to send SMS alerts containing sensor data and emergency notifications.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Fig (1)

Fig (2)

B. A simplified block diagram of the system is as follows

```
+--------------------------------------+
|      Intelligent Safety Helmet       |
+-----------------+--------------------+
                  |
          +-------+-----------+
          |  Sensor Array     |
          +-------+-----------+
                  |
    +-------------+-------------+
    |       |          |        |
Ultrasonic  Temperature  Gyro & Pressure  Atmospheric Sensor
  Sensor         Sensor          Sensors
    |               |                |
    +---------------+----------------+
                  |
               +--+--+
               | SOS  |
               |Button|
               +--+--+
                  |
      +-----------+------------+
      | Emergency Communication |
      |      (SIM Module)       |
      +-------------------------+
```

Fig (3)

IV. SOFTWARE IMPLEMENTATION

The following Arduino code snippet implements the sensor monitoring and emergency alert routines. The code uses multiple libraries (for LCD display, sensor reading, and SIM communication) to integrate data from each sensor and manage outputs via LEDs and a buzzer. Key functionalities include:

1) Helmet Detection: Using the ultrasonic sensor to check if the helmet is worn.
2) Sensor Data Display: The LCD shows temperature, humidity, atmospheric pressure, and gyroscope readings in timed segments.
3) Safety Alerts: If dangerous conditions are detected (e.g., high temperature, poor air quality, sudden movement), the system activates a buzzer and sends an alert.
4) SOS Functionality: Activation of the SOS button transmits an immediate alert via the SIM800L module.

CODE#

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <DHT.h>
#include <BMP180.h>
#include <Adafruit_MPU6050.h>
#include <Adafruit_Sensor.h>
#include <SoftwareSerial.h>

// Pin Definitions
#define DHTPIN 2
#define DHTTYPE DHT22
#define MQ135PIN A0
#define TRIG_PIN 8
#define ECHO_PIN 9
#define BUZZER_PIN 4
#define ALERT_LED_PIN 5
#define PANIC_BUTTON_PIN 6
#define STATUS_LED_PIN 7

// Initialize Components
LiquidCrystal_I2C lcd(0x27, 16, 2);
DHT dht(DHTPIN, DHTTYPE);
BMP180 bmp;
Adafruit_MPU6050 mpu;
SoftwareSerial sim800l(10, 11); // RX, TX
bool lastButtonState = HIGH;
unsigned long lastDebounceTime = 0;
const unsigned long debounceDelay = 500;

void setup() {
  Serial.begin(115200);
  sim800l.begin(9600);
  Wire.begin();

  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("Safety Helmet");
  lcd.setCursor(0, 1);
```

```
  lcd.print("IOT Based...");
  delay(2000);
  lcd.clear();
  dht.begin();
  if (!bmp.begin()) Serial.println("BMP180 Failed!");
  if (!mpu.begin()) Serial.println("MPU6050 Failed!");

  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  pinMode(BUZZER_PIN, OUTPUT);
  pinMode(ALERT_LED_PIN, OUTPUT);
  pinMode(PANIC_BUTTON_PIN, INPUT_PULLUP);
  pinMode(STATUS_LED_PIN, OUTPUT);
}

void loop() {
  int helmetStatus = getUltrasonicDistance();
  bool panicPressed = digitalRead(PANIC_BUTTON_PIN) == LOW;

  // Panic Button Handling with Improved Debounce
  bool currentButtonState = digitalRead(PANIC_BUTTON_PIN);
  if (panicPressed && currentButtonState == LOW && lastButtonState == HIGH && millis() - lastDebounceTime >
     debounceDelay) {
    lastDebounceTime = millis();
    triggerEmergency();
  }
  lastButtonState = currentButtonState;

  // Helmet Detection LED Logic Enhancement
  if (helmetStatus == LOW) {
    digitalWrite(STATUS_LED_PIN, LOW);
    displaySensorData();
    checkSafetyAlerts();
  } else {
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Pls Wear Helmet!");
    lcd.setCursor(0, 1);
    lcd.print("System OFF");
    digitalWrite(BUZZER_PIN, HIGH);
    digitalWrite(ALERT_LED_PIN, HIGH);
    digitalWrite(STATUS_LED_PIN, HIGH);
  }
  delay(2000);
}

void triggerEmergency() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("* EMERGENCY *");
```

```
  lcd.setCursor(0, 1);
  lcd.print("Sending SOS...");
  sendSOS();
    lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("* SOS SENT *");
  lcd.setCursor(0, 1);
  lcd.print("Help is coming!");

  blinkLED(STATUS_LED_PIN, 10, 250);
}

int getUltrasonicDistance() {
  digitalWrite(TRIG_PIN, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIG_PIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIG_PIN, LOW);

  long duration = pulseIn(ECHO_PIN, HIGH);
  int distance = duration * 0.034 / 2;

  return (distance < 10) ? LOW : HIGH; // Adjust threshold as needed
}

void checkSafetyAlerts() {
  float temperature = dht.readTemperature();
  int airQuality = analogRead(MQ135PIN);
  sensors_event_t accel, gyro, tempEvent;
  mpu.getEvent(&accel, &gyro, &tempEvent);
  bool dangerDetected = false;

  if (temperature > 40) {
    dangerDetected = true;
    digitalWrite(STATUS_LED_PIN, HIGH);
  }
  if (airQuality > 300) {
    dangerDetected = true;
    blinkLED(STATUS_LED_PIN, 5, 300);
  }
  if (abs(gyro.gyro.x) > 200 || abs(gyro.gyro.y) > 200 || abs(gyro.gyro.z) > 200) {
    dangerDetected = true;
    blinkLED(STATUS_LED_PIN, 3, 500);
  }
  if (dangerDetected) {
    digitalWrite(BUZZER_PIN, HIGH);
    sendAlert("Danger detected!", gyro.gyro.x, gyro.gyro.y, gyro.gyro.z);
  } else {
    digitalWrite(STATUS_LED_PIN, LOW);
    digitalWrite(BUZZER_PIN, LOW);
```

```
  }
}
void displaySensorData() {
  float temperature = dht.readTemperature();
  float humidity = dht.readHumidity();
  float pressure = bmp.getPressure() / 100.0;
  int airQuality = analogRead(MQ135PIN);
  sensors_event_t accel, gyro, tempEvent;
  mpu.getEvent(&accel, &gyro, &tempEvent);

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Temp: "); lcd.print(temperature, 1); lcd.print("C");
  lcd.setCursor(0, 1);
  lcd.print("Hum: "); lcd.print(humidity, 1); lcd.print("%");
  delay(5000);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Press: "); lcd.print(pressure, 1); lcd.print(" hPa");
  lcd.setCursor(0, 1);
  lcd.print("AirQ: "); lcd.print(airQuality);
  delay(5000);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Gyro X: "); lcd.print(gyro.gyro.x, 1);
  lcd.setCursor(0, 1);
  lcd.print("Gyro Y: "); lcd.print(gyro.gyro.y, 1);
  delay(5000);

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Gyro Z: "); lcd.print(gyro.gyro.z, 1);
  lcd.setCursor(0, 1);
  lcd.print("Helmet Secure!");
  delay(4000);
}
void sendAlert(String message, float gx, float gy, float gz) {
  sim800l.println("AT+CMGF=1");
  delay(100);
  sim800l.println("AT+CMGS=\"+918825252224\"");
  delay(100);
    sim800l.print(message);
  sim800l.print("\nGyro X: "); sim800l.print(gx, 1);
  sim800l.print("\nGyro Y: "); sim800l.print(gy, 1);
  sim800l.print("\nGyro Z: "); sim800l.print(gz, 1);
  sim800l.write(26);
}
void sendSOS() {
  sim800l.println("AT+CMGF=1");
  delay(100);
```

```
    sim800l.println("AT+CMGS=\"+918825252224\"");
    delay(100);
      sim800l.print("SOS ALERT! Emergency detected!");
    sim800l.write(26);
  }
  void blinkLED(int pin, int times, int interval) {
    for (int i = 0; i < times; i++) {
      digitalWrite(pin, HIGH);
      delay(interval);
      digitalWrite(pin, LOW);
      delay(interval);
    }
       }
```

In the code above, the function getUltrasonicDistance() checks if the helmet is positioned correctly. If not, a warning message is displayed and audible/visual alerts are activated. The displaySensorData() function sequentially shows sensor readings on an LCD screen, providing the miner with real-time environmental data. In dangerous conditions—as determined by thresholds set for temperature, air quality, and gyroscope readings—the system uses checkSafetyAlerts() to both activate a buzzer and send text messages detailing the incident via the sendAlert() function.

V. TESTING AND FIELD OBSERVATIONS

The prototype was evaluated in simulated mining conditions:

1) Helmet Detection: The ultrasonic sensor reliably distinguished between proper and improper wearing of the helmet.
2) Sensor Accuracy: Temperature, humidity, and pressure values were within expected ranges, and abrupt changes triggered the safety alert routines.
3) Emergency Communication: Although reliant on local network conditions for the SIM800L module, the SMS alerts functioned correctly, conveying sensor data and orientation details (Work in progress for future implementation).

The modular design allows for extension to incorporate additional sensors or modify thresholds based on miner feedback and environmental data.

VI. COMPARISONS WITH OTHER/ TRADITIONAL HELMETS

Feature	Traditional Helmet	Intelligent Safety Helmet
Protection	Provides basic physical head protection from impact and abrasion.	Offers the same physical protection while also incorporating electronic components to monitor environmental and user conditions.
Sensor Integration	None – relies solely on passive physical design.	Integrates multiple sensors (e.g., ultrasonic, temperature, humidity, atmospheric, gyroscope, and air quality) to detect hazards and ensure proper wearing.
Monitoring Capability	No real-time data monitoring or feedback.	Provides continuous monitoring of environmental conditions (temperature, air quality, pressure) and wearer status (helmet fit and motion) through real-time data capture.
Emergency Communication	No built-in communication; any alert must be generated externally.	Features an embedded SIM module (SIM800L) and an SOS button to send real-time SMS alerts and notifications on emergencies directly to safety control centers.
User Interface	Lacks digital displays; generally static with no interactive feedback.	Incorporates an LCD display that actively presents sensor readings and system messages, ensuring the user receives timely information on conditions and alerts.
Safety Alerts	Does not provide in-situ warnings; relies on external observation and manual intervention in safety systems.	Automatically triggers alerts (audible via a buzzer, visual via LEDs) and analytics-based actions when dangerous conditions are detected.
Future Adaptability	Limited to physical design improvements; no scope for software-based enhancements.	Opens avenues for upgrades such as advanced data analytics, predictive maintenance, AR-based guidance, and further integration of direct cellular communication.

Fig (4)

VII. FUTURE IMPROVEMENTS

A. SIM Card Integration for Direct Emergency Communication

While the current design uses a SIM module (SIM800L), future iterations will more tightly integrate SIM card connectivity by potentially embedding a dedicated cellular modem. This change would allow direct and reliable contact with emergency services, including geolocation tagging and real-time updates even in remote areas.

B. Enhanced Data Analytics

Incorporating machine learning algorithms to analyse historical sensor data could enable predictive maintenance and early hazard detection. Continuous monitoring might identify patterns that precede dangerous events, thereby informing proactive safety protocols.

C. Augmented Reality (AR) Integration

Future helmet designs could incorporate AR visors. With real-time hazard overlays and navigational cues, miners could receive context-sensitive guidance during emergency situations—further enhancing situational awareness.

VIII. CONCLUSION

The intelligent safety helmet presented in this paper goes beyond traditional protective gear by integrating a comprehensive sensor suite and communication mechanisms. Through continuous monitoring of environmental and physiological data, coupled with rapid emergency alerts, the helmet aims to reduce the response time and improve miner safety under hazardous conditions. The included Arduino implementation demonstrates a viable prototype that can be refined with further testing and enhanced features such as direct SIM communication and advanced analytics.

A. Additional Directions for Research

- Sensor Calibration and Reliability: Examining long-term sensor drift and calibration in rugged mining environments.
- Energy Efficiency: Designing low-power circuitry to maximize battery life during extended shifts.
- Ergonomic Studies: Collecting user feedback to optimize comfort and compliance with helmet usage protocols.

This integrated approach to design and implementation not only provides a blueprint for developing smart safety gear but also lays the groundwork for next-generation solutions in occupational safety.

IX. ACKNOWLEDGMENT

We would like to express our sincere gratitude to Mr Koushik Pal Sir for their invaluable guidance, continuous support, and encouragement throughout the duration of this research project. Their expertise and insights greatly contributed to shaping the direction and success of our work.

We also thank Guru Nanak Institute of Technology for providing the necessary resources, technical infrastructure, and an environment that fostered innovation and research. Special thanks are extended to the faculty members and staff for their assistance in various stages of the project.

Lastly, we are grateful to the open-source community and developers behind libraries such as Librosa, TensorFlow, Keras, and Scikit-learn, which made this research possible. We acknowledge the creators of the emotional speech datasets used in this study, whose contributions have significantly advanced research in the field of Speech Emotion Recognition.

REFERENCES

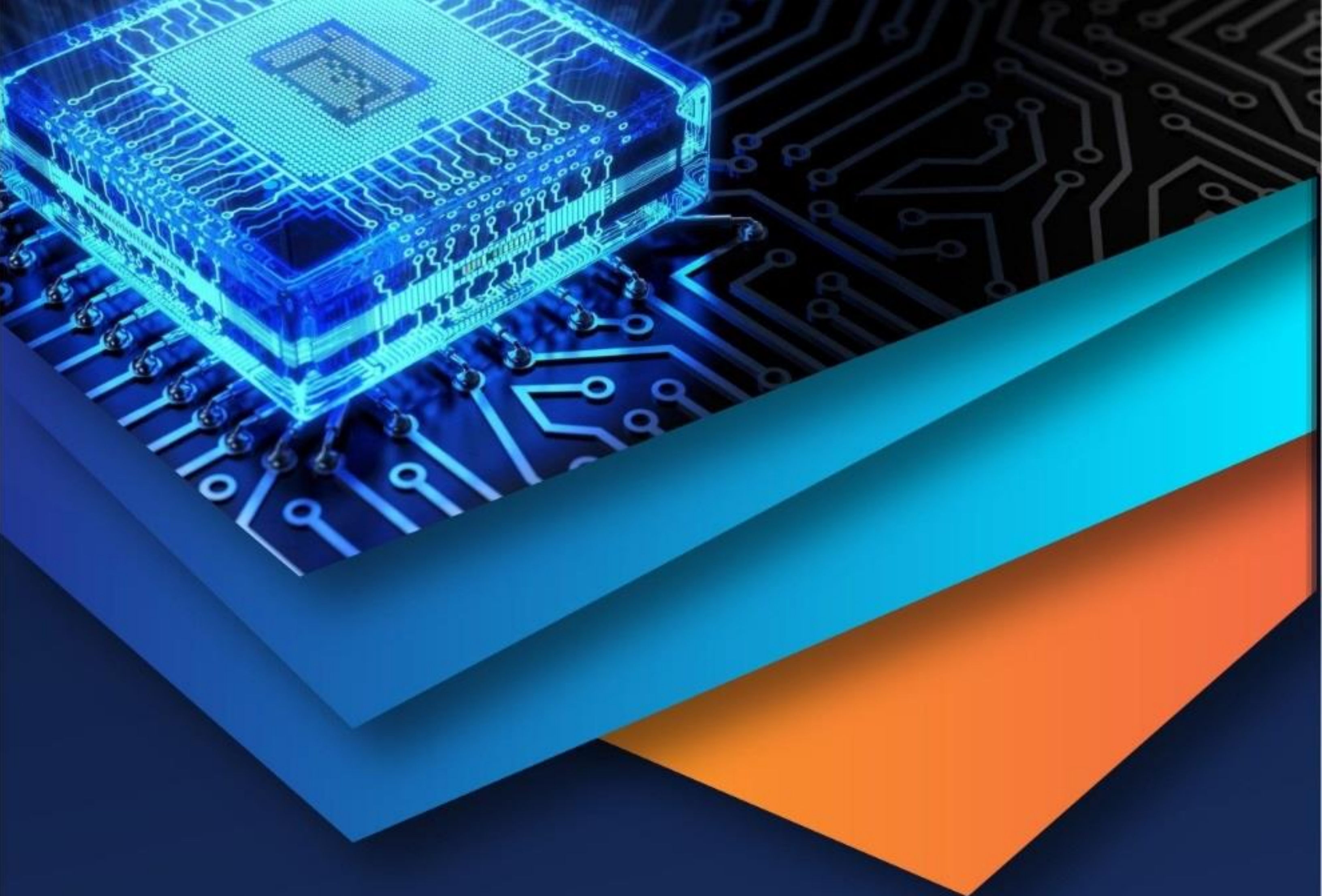
[1] Kamble, A. A., Deshmukh, A. R., Gawde, S. R., KulkarnI, G. S., & Biradar, N. S. *Research & Development of Safety Helmet Using Composite Materials.* International Advanced Research Journal in Science, Engineering and Technology (IARJSET), 2023.

[2] Akshatha, Anitha, Anusha, Prema, & Anjum, R. Smart Helmet for Safety and Accident Detection using IoT. International Research Journal of Engineering and Technology (IRJET). (Details such as volume/issue/year may be added if available.)

[3] Chandran, S., Chandrashekhar, S., & Elizabeth, N. Konnect: An Internet of Things (IoT) based Smart Helmet. Proceedings of the 2016 IEEE Annual INDICON Conference.

[4] World Health Organization. Helmets: A Road Safety Manual for Decision-makers and Practitioners, Second Edition. Geneva: World Health Organization, 2023.

[5] William, J., Padwal, K., Samuel, N., Bawkar, A., & Rukhande, S. Intelligent Helmet. International Journal of Scientific & Engineering Research. (If available, include further details on volume, issue, and year.)



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY