SHAKO — Smart Helmet Arduino Kindled Optimization

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Abstract. The life of a trained pilot is too precious. Many pilots lose their lives in combat or during training while encountering serious medical conditions due to flying stress, combat action or inability to eject timely due to exceeding ‘G’ tolerance limits. This project is a synergy of sensors and software to actuate pilot ejection system when the physical/health condition of a pilot does not permit to actuate it manually. This invention is much simpler and economical to be installed with a purpose to take critical decision to ‘eject’ at crucial juncture of flight based on the health parameters of the pilot when he/she is unable to take the decision. This device can be a safeguard for the pilots by overriding the incapacitated pilot’s decision-making action, and self-actuating the ejection system to save invaluable lives. Soviet Yak-38 had been installed with automatic actuation of pilot seats in case of failure of one of the two engines while take off or roll exceeding 60 degrees. This system had a preset condition and overrides the skill / capability of the pilot to handle the adverse situation. Whereas, this invention primarily focuses on the health parameters of a pilot by monitoring with help of various sensors and initiates the critical decision to eject when the life of a pilot is threatened. It is an improvement over previous such attempts because the self-actuation of ejection is based on the physical health parameters of an incapacitated pilot rather than based on rigid preset threshold of flying parameters. This invention overtakes the crucial decision-making capability of an incapacitated pilot to eject timely at a minimum safe altitude. This is the reason we have made the best used of our resources to calculate the physical parameters and have optimized to a compact level for easy communication and pilot interface.

1. Introduction

Smart Helmet is a new way to combine the biomedical engineering and aerospace to know about the physiological changes in the human body during post-flight operations. The previous attempts to design self-actuating ejecting systems were based on the various parameters’ viz attitude, altitude, speed and ‘G’ load of an aircraft to initiate self-ejection. This can lead to premature / unwarranted ejection based on the perceived state of an aircraft whereas; it might be otherwise due to handling of an aircraft by pilot at that point of time. As on date there are no self-actuating ejection system known to be installed in any aircraft except the Russian Yak-38. Body parameters changes when a pilot becomes unconscious due to ‘G’ [1, 2]. The proposed invention monitors all the vital parameters of the pilot viz blood pressure, SPO2, blinking rate of eyes, sweat, pulse rate etc to determine the health condition of the pilot for correct decision making to ‘eject’. When the sensors evaluate the health parameters of the pilot incapable of taking the critical decision to eject, it overrides the
manual ejection and actuates it at the safe altitude for the safety of the pilot. However, the pilot goes under a series of physical parameters which are measured by the sensors to avoid early ejection. The results of this proposed device were tested using a simulation which was incorporated by a Flight Simulator Game [3–5]. The results obtained from Pulse sensor and GSR sensors were filtered to get a clear output and then fed into the algorithm. Some of the advantages of SHAKO are enlisted below which supports its use and application. (i) No pre-fed flying parameters for ejection, thus negates unwarranted ejection during extreme flying maneuvers. (ii) Based on actual health parameters being monitored constantly through sensors. (iii) Health parameters can be transmitted to ground stations for monitoring. (iv) Provides adequate prior warning to the pilot for necessary corrective measures to be adopted in time by pilots. (v) Overtakes the inability of an incapacitated pilot to actuate ejection at safe altitude. (vi) Acts as one of the primary lives saving devices for pilots. (vii) Extremely beneficial for single pilot aircraft. (viii) All weather functionality at all altitudes up to the operating ceiling of aircraft. (ix) Very low power consumption. (x) Sensors can be easily housed on the helmet. (xi) Lightweight compact mechanism and can be easily fitted in the cockpit without weight penalty. (xii) Extremely economical and cost effective. (xiii) Simple to operate and reliable.

As many of as 22 fighter jets of Indian Air Force crashed since 2017-18 and human error were the main reasons for most of the accidents as informed by Rajya Sabha. This invention can be extensively used for the safety of pilots. This is more useful for single pilot seated aircraft compared to twin seated, as the other pilot may assist the incapacitated pilot to eject on time. This can be very useful for all combat aircraft and single seated civil flying training aircraft. It can provide the benefit of saving a pilots’ life in case of any unforeseen eventuality. By installing this device in all the combat / civil aircraft the Government / aviation authorities can display the concern for the safety of aircrew and can also acknowledge the great service to the nation provided by the pilots [1, 2]. The scope for this project can be vast can be used for the upcoming generations who are in the aviation industry. The major aim and objective of this project is to safely land the new trainee pilots who might experience fatigue due to ‘G’ and eject the pilot solely on the basis of his physiological and flight factors.

2. Methodology

2.1. Cognitive Helmet
The helmet has been synchronized using various sensors which are placed at a particular location to collect data. The helmet will also be connected to the explosive cartridges. The physical parameters of the pilot will be executed in a synchronized order using an algorithm [3]. In case the pilot is unconscious due to heavy ‘G’ force the algorithm will activate the ejection mechanism. The seat is stabilized by a drag parachute and falls along with the pilot. At a predetermined altitude calculated by a barometric unit, the seat is separated and pilot descends with the main parachute with his PSP hanging below. If the pilot regains consciousness at an early stage, the helmet will be able to identify the pilot’s physical state and the auto eject mode can be overridden by the manual mode. To demonstrate the working model, a simulation was carried out using a Flight Simulator game and ejection was carried out actuating a servo motor placed below the seat of the pilot. The detailed approach has been discussed to measure the physical parameters and link them in a synchronized manner to make SHAKO efficient [2-5]. The block-diagram of the SHAKO helmet is shown in figure 1.
2.2. **Block-Diagram Description**

The block-diagram is a representation of our system and how will it perform during real action. When the pilot is not in a state to fly the Jet due to medical conditions, our system will measure the above parameters in a synchronous order. Starting with eye and ending with the altitude check this system will ensure the safe ejection of the pilot. However, as it is mentioned that if the pilot regains its control over the aircraft then he can over-rule the system for manual flying. The SHAKO system will be connected with the ejection system and will only help in initiating the ejection. The after-ejection protocol will be continued as it is imposed by the aviation governing bodies [6, 7].

2.3. **Sensors**

2.3.1. **Pulse Wave.** The heart rate of the pilot rapidly increases between 135-152 bpm when he/she experiences a 5g force before crossing the tolerance limit and getting unconscious. The pulse sensor/Heart-Rate sensor Arduino module is placed near the carotid artery which measures continuous heart rate and SpO2 to calculate the g-force [8, 9].

2.3.2. **GSR Sensor.** The Galvanic Skin conductance sensor (Grove-GSR v1.2) is used to measure the stress and anxiety. This sensor is placed in left and right of the chin strap to measure the skin conductance continuously.

2.3.3. **Eye Blinking Sensor.** The RoboCraze Eye Blink Sensor is used to track the eye movements and keep a check on the unconsciousness stage of the pilot. It is an infrared sensor that can monitor the REM (Rapid Eye Movement) and is mounted on the visor of the helmet.

2.3.4. **Electrocardiogram (ECG).** The ECG patterns of a pilot can give the rhythm patterns of the heart and can simultaneously record the ECG of the pilot if he suffers from cardiac arrest, arrhythmia and unconsciousness (Black out/Red out).
2.3.5. **Buzzer.** The Buzzer is used to precede the ejection procedure after the above parameters are checked by the algorithm in the sequential manner. The ejection procedures carry out after 2-seconds of the sounding of buzzer [10].

2.3.6. **Sound Detection Sensor Module.** This LM393 sound detection sensor is used to monitor the altitude when the pilot has lost control over the aircraft. In all modern aircraft there is a buzzing system which tells the pilot to ‘Pull Up’ the aircraft to avoid crashing. This sensor will capture the noise and will initiate the ejection procedure.

2.3.7. **Other Sensors.** Some of the sensors have been proposed to use in the helmet like Respiratory Rate Sensor (TGS4161), Silicon Impact Gel and EEG monitor to increase the performance of the helmet shown in figure 2.

All the sensors have been integrated with the main unit and has been placed in the desired locations of the helmet. Some of the sensor values are raw data which have been processed into clear data using LabView Software [11].

![Figure 2](image_url). The placement of various sensors in the SHAKO helmet. The Anti-ejection gel and respiratory sensors, are in testing phase for future implications.

2.4. **Processor**

The processor in the helmet should be lightweight and compact to be used to be fitted in the helmet ergonomically without posing any discomfort shown in figure 3. The Arduino Nano is used to increase the robustness and high specificity [12]. It uses the ATmega328P’ which can support more than 4 sensors and can be programmed to do a specific task. The processor has been installed at the back of the helmet which records all the parameters in an SD card. The micro SD card module is used to store information in the SD card that can be analyzed later. The pulse rate and ECG can be analyzed in pulse sensor ‘Amped visualizer’ where the ECG can be monitored at different time intervals. The wires connected to the sensors and servo has been lined properly within the helmet. The power source given to the processor is through a 9V
battery [13-15].

Figure 3. The above figure is a basic circuit diagram for the processor. It has been divided into following main components 1) Eye Blinking sensor 2) Arduino nano 3) servo motor 4) GSR sensor 5) Heart Rate and ECG sensor.

2.5. Algorithm
The algorithm used for the processing and the synchronized output is Arduino IDE. It has been written in such a way that the health parameters which have been mentioned above, will be executed in a 'First Priority, First Check' manner. The algorithm continuously carries out checks on the various physical parameters. To depict the result of this project a simulation was carried out using a Flight Simulator. The results obtained and procedure are as follows [16].

- A working model has been fabricated by installing various sensors in a helmet.
- A successful actuation of ejection has been simulated by using alarm and buzzer to indicate ejection. This has been resorted to, due to non-availability of ejection seats.
- The subject was asked to sit on a chair and was depicted as pilot. He had a joystick and a game simulator was played in the projector for the demonstration to audience.
- The subject was asked to crash the plane in the simulator and the various health parameters were recorded which includes- blood pressure, heart rate, galvanic skin conductance and sensor to measure the eye movement.
- We asked the subject to close his eyes which depicts the state of unconsciousness of pilot due to ‘G’ force. It was recorded via Eye blinking sensor and was programmed to detect it instantly. (f)After 5 seconds of rapid health parameters and unconscious state of the subject the alarm was generated.
- With the alarm, the servo motor which was placed under the seat rotated at an angle (270º) to depict the ejection of seat from the cockpit.
- After 5 seconds of rapid health parameters and unconscious state of the subject the alarm was generated.

In actual ejection procedure the seat is propelled out of the aircraft using a cartridge explosive which is activated mechanically. To simulate the ejection the servo motor was used to initiate the cartridge explosion procedure.
In order to analyze the data after storing it in SD card, ‘LabView’ software was used to process the baseline signals to extract processed data. For the purpose of diagnosis, data is required to be extracted from the various inputs like QRS intervals, ECG data, QRS amplitudes, QT intervals, PR intervals, etc. These extra features provide information about the heart rate, the velocity of conduction, the condition of tissues within the heart as well as various factors which resulted in the pilot being unconscious. Resistance was calculated by passing very small amount of electric current to the subject. The resistance value decreases when the subject is active and the resistance value increases when subject is in stress. Accordingly, the analog output from the amplifier varies and frequency was set to 50 Hz. The half-wave value appeared every 35.25 ms. By comparing these values, the program can be achieved [17]. The experimental setup is shown in figure 4.

![Experimental Setup](image)

**Figure 4.** The experimental set up of the SHAKO helmet.

### 3. Results & Discussions

The data were stored in the SD card module which is connected in the signal conditioning unit. The data recorded in the SD card were later analyzed in Pulse Amp software to amplify the signals. Various test subjects were used to analyze the different data in both normal and excited state. The excited state will give 70% similar data to the condition of pilot during ejection and will help us to evaluate and set the parameters of different subjects. The different waves obtained from the subjects were clipped at the highest excitation level of both Heart rate and GSR values. The above graph shows 2 different cases of the pilot and can be analyzed easily. However, various subjects were tested for different parameters which can be listed below. Each subject showed some variability and the stability of the system was tested. The major factor which defines a system’s credibility is its accuracy and precision. The following table 1 shows the various subjects. A total of 35 subjects were used to gain the physiological values and here are some of the values of random subjects shown in figure 5.
Figure 5. The Heart rate and GSR parameters of the pilot condition.

Table 1. Physiological Parameters of the subjects.

| S.No | Normal Heart Rate (Bpm) | Excited Heart Rate (Bpm) | GSR Rate (Bpm) | Excited GSR Normal (nS) | 'G'/ Load Value (nS) |
|------|-------------------------|--------------------------|----------------|------------------------|---------------------|
| 1    | 78                      | 120                      | 182            | 597                    | -3.2                |
| 2    | 75                      | 116                      | 172            | 590                    | -4.2                |
| 3    | 82                      | 132                      | 154            | 596                    | -3.1                |
| 4    | 77                      | 131                      | 159            | 597                    | -3.3                |
| 5    | 78                      | 125                      | 155            | 596                    | -4.2                |

In turning jet, the load factor or 'G' is normally greater than +1. For eg in a turn with a 75° angle of bank the load factor is +2. Again, if the similar turn is performed when the aircraft inverted, the 'G' becomes -2. In general, in a well-balanced turn, the angle of bank is θ, the load factor n is related to the cosine of θ by the formula-

\[ n = \frac{1}{\cos \theta} \]

In the Flight Simulator, the aircraft level was calculated by recording the Artificial Horizon indicator in the game while the subject was playing the game. The values recorded were inserted in this above formula to know the load factor or 'G'.

4. Future Work
The scope of SHAKO is to well research the other parameters and imbibe the Anti Ejection Gel and Respiratory gas sensors to strengthen the physiological check before ejection. This project can give the vast safety and post-flight synopsis of the pilot's health. However, the ongoing work will yield fruitful results and the paper with new systems will be published to increase the efficiency of SHAKO system. The anti-ejection gel will be made of silicone gel which will
absorb the ejection shock and the respiratory metal oxide gas sensors will calculate other factors. The new generation jets have a gas analyzer inside the mask for O2 measurement but these gas sensors will measure the relationship between respiratory rate and stress.

5. Conclusion
Training a combat pilot entails huge expenditure of Government revenue and even more precious human hours. Losing a pilot in combat is an acceptable operational hazard. However, losing an invaluable trained pilot in avoidable accidents needs to be minimized. Often, due to extreme combat maneuvers and adverse physical conditions a pilot can lose consciousness causing inability to eject timely. This innovation can be successfully used to reduce accidental death of combat pilots who are unable to eject themselves at crucial decision-making juncture. By installing this self-ejecting system, the pilot is ejected automatically by sensing and evaluating critical health parameters. The overall data of 35 subjects helped us to identify the key features of this system. However, the results were completely evaluated in programmable software via the Flight Simulator game. Throughout the study it was observed that the pulse rate of the pilot while flying in the cockpit was 85 bpm, but it increased to 112 bpm during medical condition like. Similarly, the skin conductance of the pilot during normal condition is 182 nS which increased to 550 nS during 'freeze' or 'unconsciousness'. The altitude for self-ejection was noted at 2500 ft and the 'G' force fluctuated from -2 to +2. The buzzing sound of the cockpit was recorded by sound sensor module and ejection height was recorded. The IR sensor responded and printed 0 for closed eyes and printed 1 for open eyes. This system can prove to be boon in saving the extremely valuable human resource and also be a great morale booster to the combat pilot fraternity.

6. References
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