Anti-Hypothermia Jacket For Pro Climbers

ECE 445 Design Document

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1 Introduction

1.1 Objective and Background

ARACHI, Pakistan — Some climbers call it "the savage mountain." K2 stands as the world's second-tallest summit, after Mount Everest, and some climbers consider it even more perilous. Only last month did one group become the first to successfully scale it during winter, braving dangerously thin air and temperatures that can plunge past minus 70 degrees Fahrenheit.[3]

Many who have tried to climb it have lost their lives. In 2008, 11 lives were lost, while 13 climbers died over a two-week span in 1986, one of the worst disasters in mountaineering history. Mountaineering experts say climbers face a lack of oxygen, snow blindness and frostbite.[3]

Highland climbing is always dangerous because of extreme environments such as oxygen deficit and extreme low temperature. According to mountain-forecast, the average temperature from March 2 to March 14 is around -16 C at 6000m elevation. [4]

Many great explorers died because they are under Anoxia above 5000m and then lose their body heat unconsciously under Coma and Hypothermia. Therefore, a fully automatic system needs to be designed to monitor hazardous body temp loss and adjust the jacket temp to stop climbers' further health problems.

With that, we decided to integrate a traditional climbing jacket with a dynamic temperature adjustment & monitor package powered by detachable battery packages.

Our idea is to design a jacket integrated with TEC grids controlled by microprocessors and powered by detachable battery packages. The package has two modes. When body temp loss is not detected, users can use the package to deal with sudden temp drop and the temp adjustment is controlled by a microprocessor and each heating period is 15 minutes. Another mode is first-aiding mode. During this mode, the system will heat the inner temperature of jacket constant at about 37 C and give warning to climbers so that they can return to base within the battery limit or ask their teammates for help. For design overview, two TEC grids (about 20 pads) will be arranged in an efficient way to cover both fore-breast and back-breast and are controlled by a microprocessor and powered by detachable battery packages.

Currently, there is no outdoor company selling such first aiding products for professional climbers to protect their life. So, our product can provide future climbers a safer and more comfortable climbing experience.

1.2 High-Level Requirements

- The jacket with the whole system is designed compactly, incorporating the power supply, control unit, and TEC module systems with total weight lighter than 2kg.
- The whole system can heat the human body to designated temperature in 30 seconds after demands are made by body temperature or manual control.
- The whole system should be fully functional for 1 hour without running out of power.

2.2.4 Li-ON Batteries

The lithium-ion batteries must be able to keep all the TEC pads working at a certain temperature for at least 15min under manual model and at least 1H under first aiding mode. Besides, the battery also needs to provide 12V power for the Control Unit.

Requirement	Verification
1. The batteries must be able to handle at least 4A and at most 10A current at 12V voltage. The operation period is dynamically controlled by a 5V PWM signal.	1. Connect the battery package to TEC pads circuit. 2. Connect the I/O pin and Use the multimeter to verify the PWM signal is 5V. 3. Use the multimeter to measure the current and voltage of the battery package, ensuring the current I in the range of 4~10 A, the voltage stays with 5% of 12 V.

2.2.2 LED

The LED light is used to warn climbers when the system detects any abnormal body temp drop.

Requirement	Verification
1. Requirement1: The LED light has to be 450 lumens from 5m away during fog day. 2. Requirement2: The LED must use less than 20mA current.	1. a. Use 1-part glycerin and 3 parts distilled water to make 0.5-liter fog juice. b. Use a large soda can with fog juice we made to build a homemade fog machine. c. Pour fog juice into machine and wait until fog fill the whole room which is 5-meter long. d. Use a light meter to measure the luminance and ensure it within 5% of 450 lumens. 2. Use a multimeter to measure the current going through the LED when it's on, ensuring it is less than 20 mA.

2.2.3 Speaker

The Speaker will make a series of loud sounds to give both climber and teammates low body temp warning.

Requirement	Verification
1. Requirement1: The sound made by the speaker must be 65~120 dB from 5m away during a windy day. 2. Requirement2: The Speaker must use less than 20mA current.	1. a. Put the speaker 5 meters away from you and turn on an electrical fan near the speaker. b. Use a cell phone with dB volume meter app to measure the loudness of the speaker when it is turned on. Ensure the loudness is in the range of 65~120dB. 2. Use a multimeter to measure the current going through the speaker when it's on, ensuring it's less than 20mA.

2.2.4 Manual Control Button

The button is used to start manual mode of the system. During manual mode, the system will work for 15min/cycle to help users get rid of sudden weather change.

Requirement	Verification
1. The button should be capable of being pushed in a temperature range of -30℃ to 50℃.	1. Place the button in a refrigerator with temperature below -20℃ to make sure the button works as it does in the standard room temperature. 2. Use a TEC grid to heat the button up to 50℃, ensuring the button is pushable.

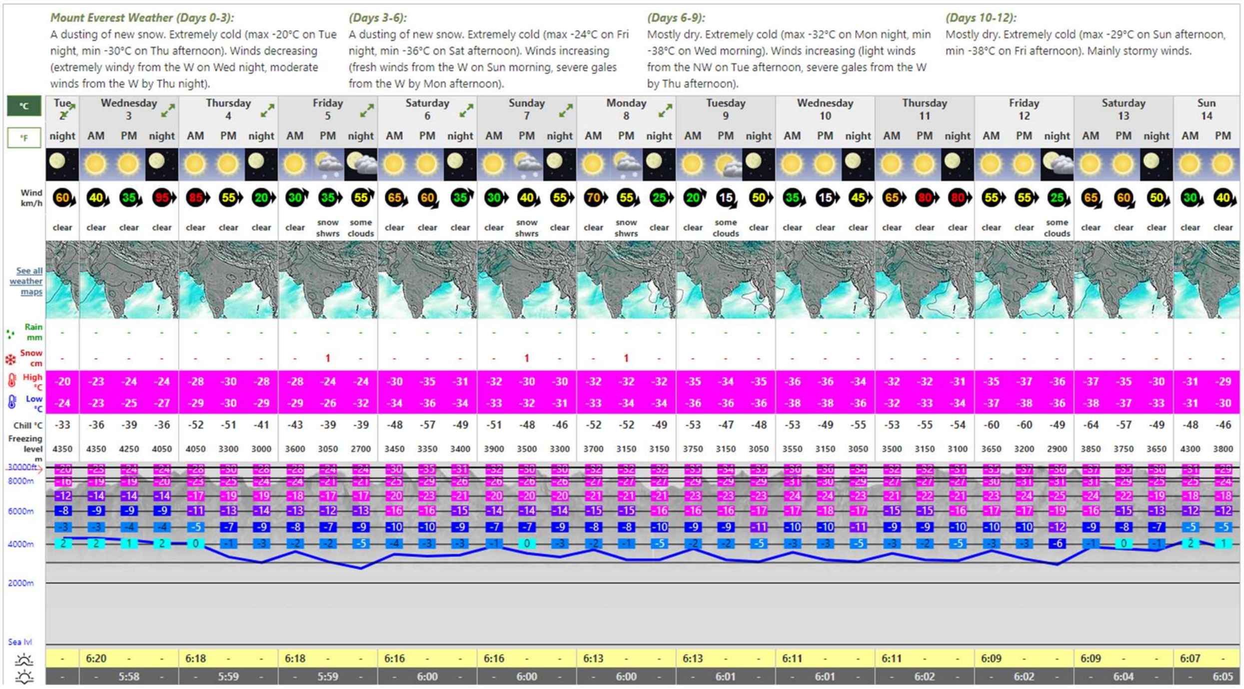

Figure1. Temperature Diagram [4]

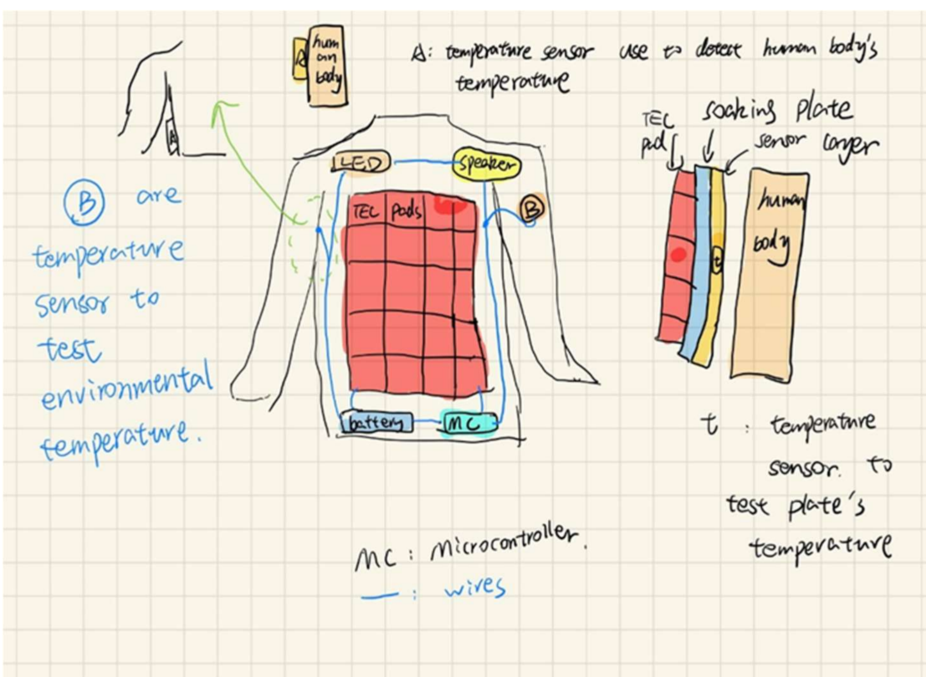

Figure2. Physical Diagram

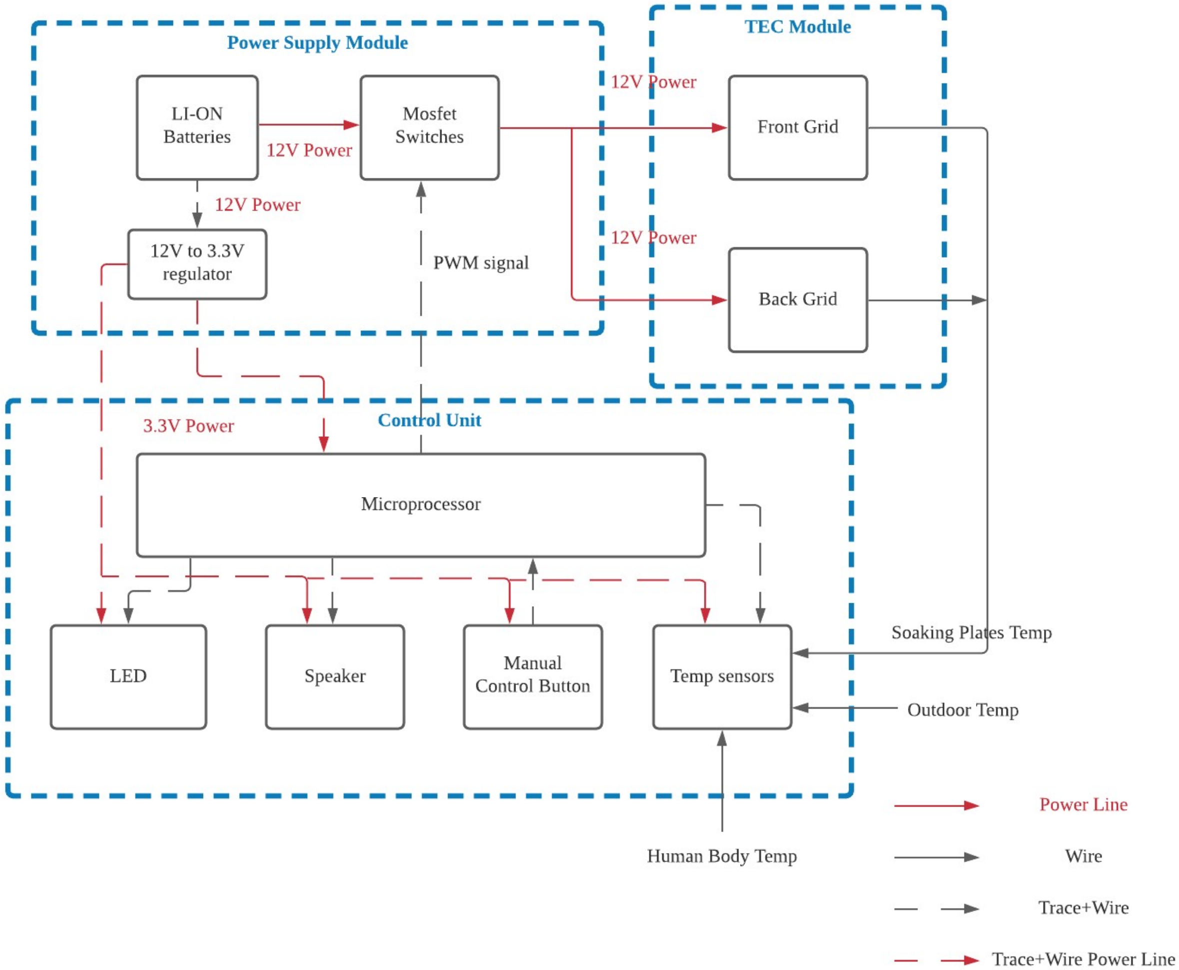

Figure 3. Block Diagram

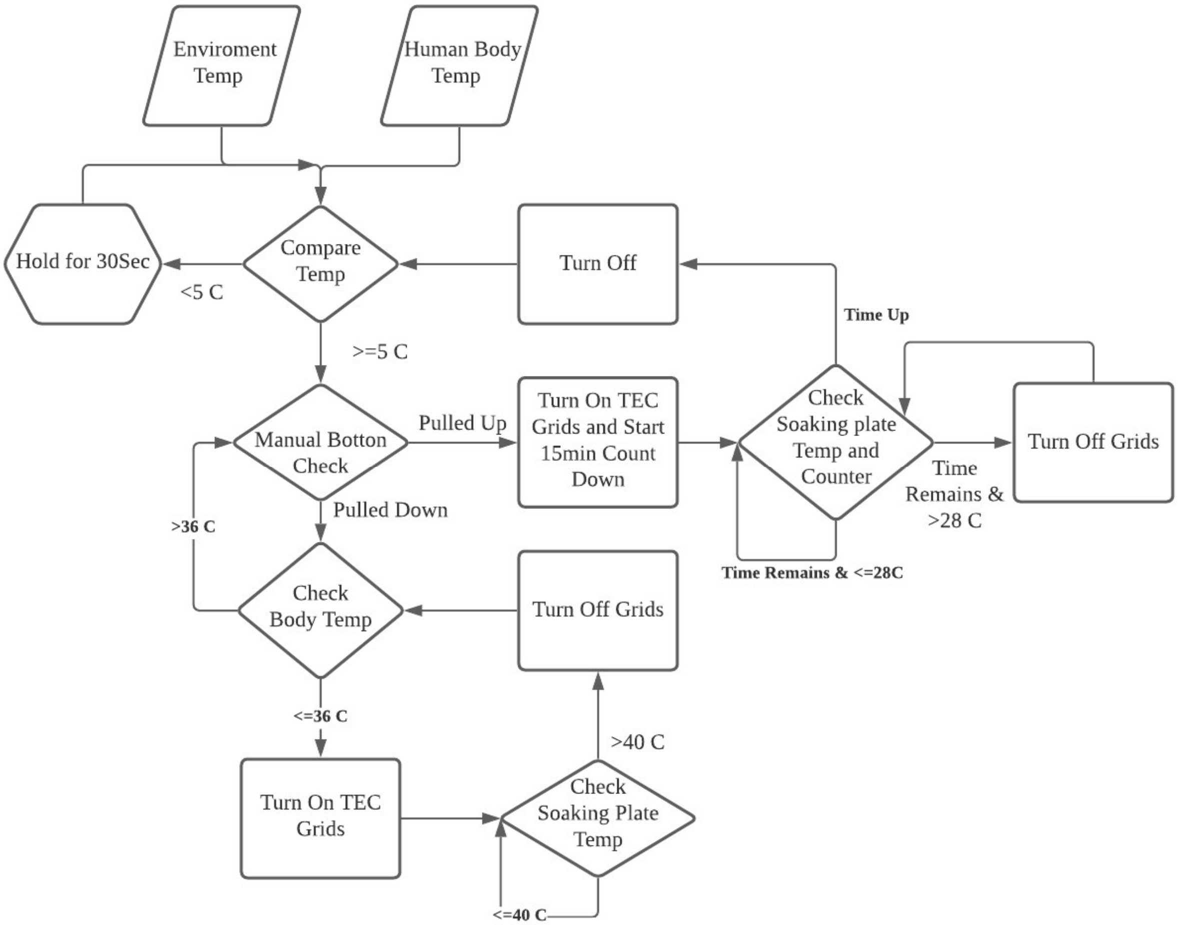

Figure 4. Microcontroller Algorithm

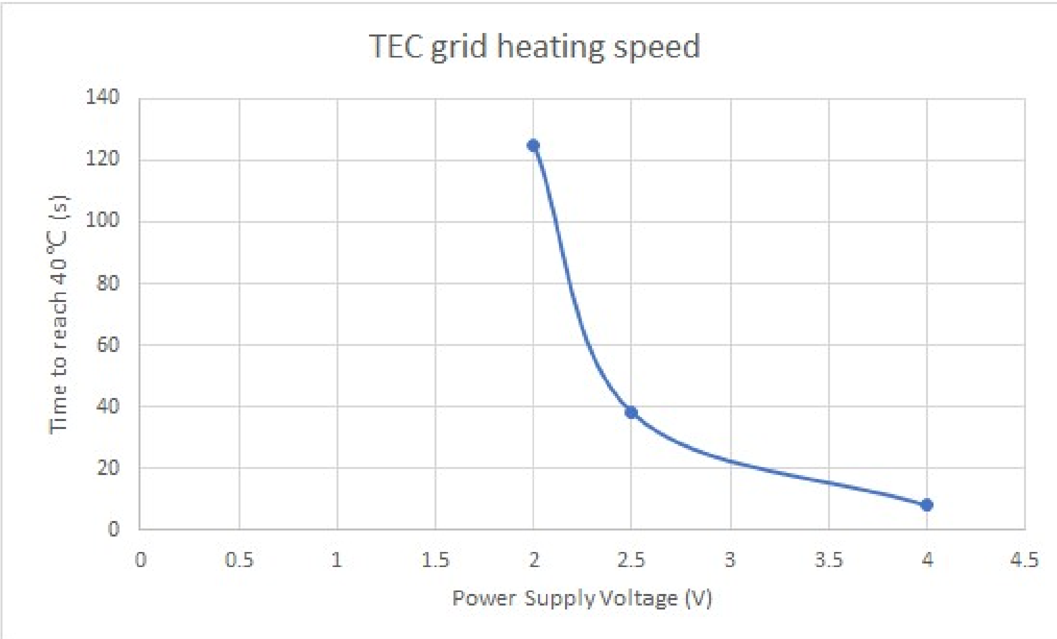

Figure 5. Power Supply Voltage vs. Time for TEC Grid to reach 40°C(experimental)

For power supply of 1V, it takes 210s for the TEC grid to be heated up from room temperature 26.7°C to stable 31.5°C and for power supply of 1.5V, it takes 111.45s for the TEC grid to be heated up from room temperature to stable 34.5°C.

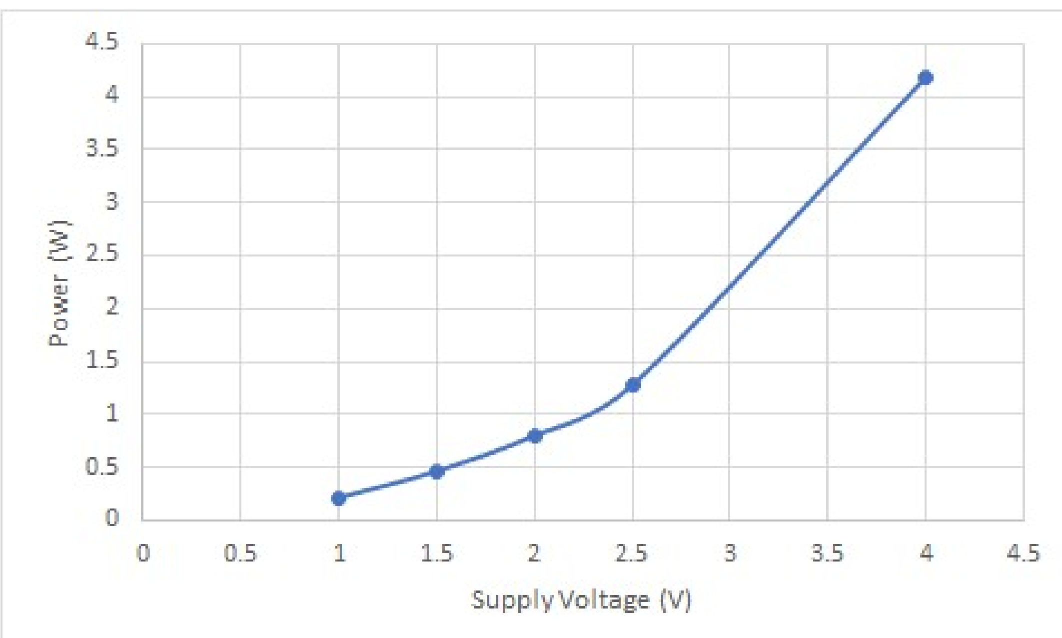

Figure 6. Power of TEC Grid vs. Supply Voltage(experimental)

2.4 Tolerance Analysis

Mosfet tolerance:

We use Mosfet switches to control the pass through current of our pads. One of the most significant tolerances is the current variation caused by the TEC pads. We have tested the pads from 1V to 4V input voltage and calculated the variation of resistance at each voltage and found 17.5% to 30.2% current decrease when the pads heat up to 40 C and achieve steady state. Therefore, the Mosfet should be able to tolerate higher than steady state current consumption at the beginning of heating. Because each grid will contain 9 pads which totally consumes 3.138A current, we need a Mosfet to have at least 4.14A saturation current at Vgs=5V.

Tolerance analysis

Temperature sensor:

In the microcontroller's algorithm, the temperature sensors in different places are aimed to detect changes in temperature and give feedback to the microcontroller in terms of voltage. The resistance of a temperature sensor will be changed due to the variance in temperature and we utilize a voltage divider and monitor the voltage across the temperature sensor to reflect changes in temperature. Ideally, we are able to monitor the exact temperature at a temperature sensor if its resistance strictly depends on the environment temperature. In reality, errors may occur due to internal resistance of power supply, accuracy of the resistance of the temperature sensor at a given temperature, and internal resistance of the microcontroller's internal logic components. We would expect the temperature monitored by the microcontroller to be within 0.5 ℃ away from the desired temperature (+/- 0.5 ℃).

Tolerance analysis:

Power storage: our goal for the device is to make it last for at least 1 hour. Due to our measurement, 3 TEC pads connected in series will consume around 12.6 W under 12 V voltage. Also, it takes around 8.5 seconds to increase the temperature of TEC pads from 26.8 celsius degree to 45.0 celsius degree. We have 18 pads in total,so the total power for TEC pads is

75.6W. So, at least, we need one 100 Wh batteries to supply our devices and ideally it can support 1.3 hours. However, the actual battery power storage may change with the temperature changes. We would expect three batteries can support our device working for 1.0 ~ 1.3 hours.

2 Safety and Ethics

There are potential safety hazards in our project. Lithium-ion batteries can be damaged or even explode due to physical impacts such as crushing and dropping and extreme cold temperatures [1]. If the TEC grid cells keep heating, it may cause burning of the circuit system and the jacket. To prevent those safety hazards, we will design a negative feedback loop to avoid excess heat. We would take all aspects of potential safety problems into consideration in our design and try our best to obey the IEEE Code of Ethics, #9: “to avoid injuring others…” [2].

In our design of the anti-hypothermia jacket, we aimed to save climber’s lives and protect their safety during climbing experiences. This purpose is coherent with the IEEE Code of Ethics, #1: “to hold paramount the safety…” [2].

In the process of designing and testing our project, we will consult teaching assistants and professors when we encounter troubles and we are open to criticism which would help to improve our project. Our attitudes align with the IEEE Code of Ethics, #5: “to seek, accept, and offer honest criticism…” [2].

3 References

[1] “UNITED STATES DEPARTMENT OF LABOR,” Safety and Health Information Bulletins | Preventing Fire and/or Explosion Injury from Small and Wearable Lithium Battery Powered Devices | Occupational Safety and Health Administration. [Online]. Available: https://www.osha.gov/dts/shib/shib011819.html. [Accessed: 19-Feb-2021].

[2] “IEEE Code of Ethics,” IEEE. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 19-Feb-2021].

[3] “Hopes Dim for Three Climbers Missing in Winter K2 Attempt,” Zia ur-Rehman and Sameer Yasir, the New York times. [Online]. Available:

https://www.nytimes.com/2021/02/08/world/asia/k2-climbers-dead-winter.html

[4] “Mount EverestWeather Forecast, NepalIssued: 10pm Tue 02 Mar Local TimeUpdates in: hr min sUpdate imminent ,” Mountain. [Online]. Available: https://www.mountain-forecast.com/peaks/Mount-Everest/forecasts/8850. [Accessed: 02-Mar-2021].