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Design and Construction of an online System for Assessment of Radioactive and Chemical Materials and Meteorological Parameters at High Altitude

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ABSTRACT

In this research, the design and survey of the satellite (Kensett) has been addressed.The main mission is to study the atmosphere and eventually land on the air bag, and new designs and ideas were designed. The motivation for this design is to be native and affordable in comparison with foreign ones.

I. INTRODUCTION

In order to identify and trace radioactive materials in the air in different altitudes, portable nuclear dosimeter modules or nuclear detectors can be used on this satellite. This system also can be applied for the transferring fixed or portable ion and carbonaceous material detectors modules in different altitudes for facilities exposed to contaminations in various heights which are possibly due to air vents. The dose assessment of radioactive materials existed in the vented air from air vent towers of Isfahan uranium processing plant or Bushehr nuclear power plant can be used to identify the amount of radioactive material at any time and any desired point. If the amount of radioactivity exceeds the related standard value, a warning alarm will be set on.

Operational modules for this system are designed and constructed for many applications, including dose assessment of radioactive materials, radiocarbon-dating, acidimetry or alkalimetry, and etc. and if relevant standards being considered, it can be designed and constructed for detectors as well.

In this Kensett mission, it is necessary to measure the main parameters of atmospheric conditions during the operation with the help of sensors and provide ground station. Main parameters include temperature, pressure, geographic location (length, latitude and elevation) and humidity.These data should have acceptable accuracy. The information should be updated every second or faster and displayed on the ground. This mission has a successful level of storage and storage of data collected on the memory of the cache and its recovery after the operation is a special feature of it.

In this mission, Kensett must be able to safely land on his airbag and stay completely healthy. The air bag must be filled with Kensett before landing on the ground. The instantaneous opening of the air bag should also be transmitted immediately to the ground station. This mission has a successful level, and Kensett should be able to keep his airbag full of air for a few minutes after landing, and until the moment the experts have access to Kensett. Different parts of the landing umbrella provide sensor and receiver and transmitter software separately.

II. The design steps and testing

Kensett has a cylinder containing a chamber and a door that closes the door on the compartment. The compartment is also open on both sides. The main reason for this model is the freedom to choose parts for mounting. The body has three grooves for communication with the environment as shown in the figure. The mass of the compartment and the door, respectively, is 250 and 50 grams, respectively. The diameter and height are 120 and 190 mm, respectively.

Table 1. Specifications of the Kensettframe

Body Sheet Thickness	Height	Diameter	Internal volume	Mass	Price
1mm	190mm	120mm	2147.74cc	Less than 100 gr	620$

Based on the main mission of Kensett, namely the temperature, pressure, humidity and geographic position, it is absolutely certain that the Kensettshould be landed in such a way that it will have the time to measure, process, send and store information, and this at a speed less than Five meters per second. Secondly, the Kensettremains intact after dealing with the ground, which means that electronic components are not damaged while handling the ground. Because in this case, the operation of the door-to-door operation will be dealt with (in accordance with the team's mission, the crane will land on the bag to serve as an aid to safe landing). Therefore, to achieve any success in the main mission of this set of equipment should have an umbrella.

This is a complete system that will launch the umbrella at low altitude when it falls free. The Kensettsystem is designed to allow a free fall of about 30 kilometers. This height is sufficient for the Kensettto prepare input data for analysis and posting.

The pump motor is very small in total, and it fills the bag perfectly. This Kensettis used in medical digital barometers and fills the airbag with a voltage of 3.3 volts and a current of 280 mA with a pressure of 0.3 bar. [1-4]

Table 2 - Specifications of the motor pump

Length	Width	Height	Weight
24 mm	11 mm	37 mm	16 gr

According to the design-defined operation, we need a measurement that, in order to meet our needs, initially brings table 7 below, and then we will discuss each of them individually.

A) For the operation of the Kensett, 3 microcontrollers from the AVR family have been used. The task of one of these microcontrollers is to receive information from sensors and modules. We call this microcontroller "micro data."

The other microcontroller receives information from the microcontroller via the SPI protocol and sends it to the sender. In fact, this microcontroller is called the "transmitter microcontroller", and the last microcontroller is connected to the receiver of the information, and by receiving information through the receiver, that information is displayed to the computer and the information is visible on the screen. To this microcontroller, we refer to the microcontroller receiver.

B) For simulation of hardware, software installation of circuits, schematic maps and PCBs using Proteus software and Altium Designer software.

C) All programming was written and executed in C programming language.

Each of these sensors has problems such as: low accuracy, the outside of the measurement range from the required temperature range and so on, so they were not used. We then came to the conclusion that we use the HTS221 sensor, which is a high-precision industrial sensor and high-tech sensor based on MEMS. Now we are going to set up the hardware and software for this sensor.

III. Software Launch

In order to write a function that examines and reports the temperature of the environment, we will write a pilot program for setting up the HTS221 and test it in 2 real-world simulation and real-time software environments. The length of time we can give the HTS221 a chance to report the temperature to us is 200 milliseconds, which is a good time. The function for this sensor is given below:

```
h=0;
i=0;
for (j=0;j<5;j++)
{
i=read_adc(4);
h=h+i;
delay_ms(3);
}
g=h/10;
delay_ms(200);
```

The humidity of the environment can be achieved by using different modules, but the problem with almost all of these modules is that it takes at least 5 seconds to report the humidity to the microcontroller, while we only have 300 milliseconds to update our information about air humidity.

The HTS221 sensor, through its function in C, informs us about the humidity of the environment. To ensure proper operation, we first test this sensor on the main board individually, but due to the frequency of the sensor program, the simulator software cannot set it up unless changes are made to the frequency This mode also takes us away from the real situation. Interestingly, the update does not take more than 50 milliseconds. Because we have 300 milliseconds of time to get information about this sensor, we have more time with this sensor to better measure the moisture content.

Now we write the function of this sensor, which will be determined according to the basic definitions needed in the general program of how this function works:

```
TCCR0=0x06;
#asm("sei")
delay_ms(50);
#asm("cli")
in_freq=20*(timer0_ov*256+TCNT0);

sprintf(buff,"Freq=%d",in_freq);
TCCR0=0x00;
timer0_ov=0;
TCNT0=0;
humidity=(-0.075872)*(in_freq-7351);
sprintf(buff2,"Humidity=%d",humidity);
delay_ms(250);
```

One of the famous pressure sensors is the LPS series sensor from ST US, which can measure pressure at various times. We choose the LPS22HB according to the required range of 50 to 100 kpa. Of course, the LPS22HB sensor does not only provide the accuracy we need, but also has a good upgrade. To get the air pressure through the LPS22HB sensor, it's enough to use the circuit available on the sensor's data sheet (pic. ...). But there are two problems with this sensor, which is the SMD of this piece That is, except for one of the other components, we are not the rest of the SMD components, which is solved only with greater precision in the design and soldering, and the second is the problem of the absence of resistors, which, like the humidity sensor, with a row of resistances with a succession of resistors, we will achieve the desired resistance.

To be aware of the environmental pressures of the LPS22HB sensor, we need to use the existing relationship in the data sheet for this piece. An important point about the given relationship is the parameter in which the output voltage of the sensor is placed, that is, we must convert the digital microcontroller's number to the voltage on the microcontroller base and then put it in order to achieve the ambient pressure.

LPS22HB Sensor Program:

```
x=read_adc(0);
v =x*(0.00488); //(5/1024)=0.00488
s=(((v+0.0675)/5)+0.095)/0.009;
p=s+0.095;
delay_ms(150);
```

To run this motor-pump, we have to produce a 3.3 volt power supply, which is easy to use with the LM1117S regulator, and disconnect the base of the motor-pump through the microprocessor via the A733 transistor [5-6]

Once the air bag starts to fill the key below the umbrella, in fact when the umbrella is released and opened, the Kensett begins to send information and fill the air bag.

This memory card is of type mmc and connects to the microcontroller via the map shown in Figure 34. It's worth noting that the protocol used to communicate with the memory card and microcontroller is SPI information, and it's interesting to note that the transmitter microcontroller and memory card both are connected to the SPI-based microcontroller of the information.

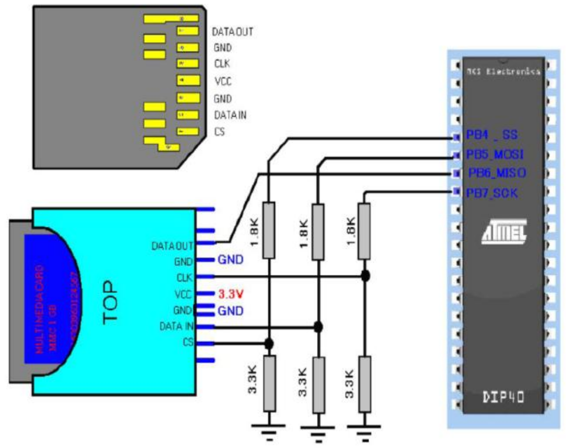

Figure 1: Microcontroller connection to memory card

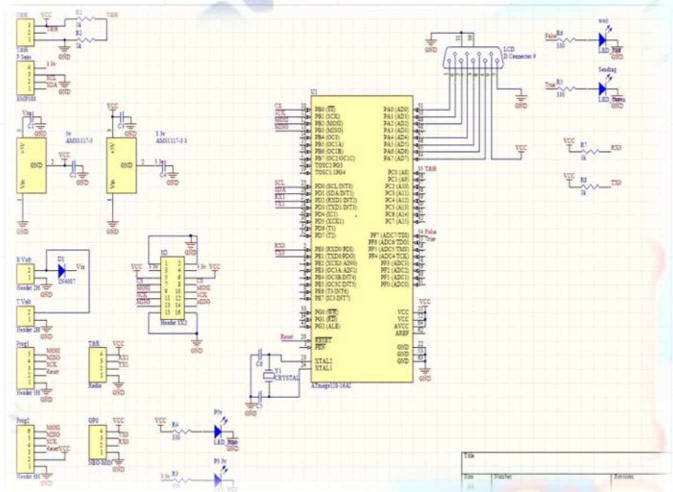

Figure 2 - Schematic of the circuit of the Kensett

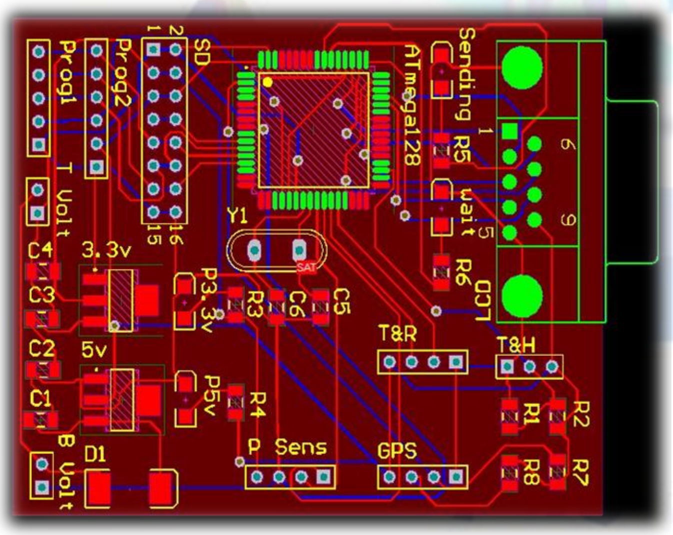

Figure 3 - Kensett PCB Map

A number of memory cards are included to store information when landing the Kensett on theoriginal board, and the information will be matched to the values sent by the sender at the end. The sender receives information through a serial port at a rate of 115,200, and transmits 9 sensor data into a packet and encrypts it securely. Then send this information and prepare the next packet for sending.

In the transmitter processor part, the AVR family microcontrollers and the ATmega8 model are used. Of course, the microcontroller is not used on normal market microcontrollers and has a military standard. The reasons for using the Atmega8 microcontroller are:

High security of this microcontroller in the AVR family, ease of purchase, easy assembly, passive military standard MIL-STD810 G models 516 and 517, low noise due to EMC and EMI considerations, and very low weight (about 3 grams).

Given that the transmitter's power supply must be 12.5 V (in the following sections), the input voltage will be connected to the microcontroller after passing through the regulator and supplying the energy it needs. The MAX232 IC has been used to receive or send information from the outside and other systems. In the case of communication protocols, the processor part can be explained as follows:

1- Sensors or computer RS232 2- Modulator SPI :

Given the importance of the security of communication at a distance of 30 km from the ground station and having the lowest amount of error in the data sent at 115200 data rates from the sender and receiver side, it was necessary that the calculations be done accurately. In this calculation, the transmit power and radiation pattern and antenna gain from the sender's side and on the receiving side of receiver antenna gain and receiver sensitivity, as well as figure noise, were calculated. For both sides, the downside of the signal was detected in the open space for a distance of 30 km.

To achieve a suitable modulator, two things have to be done, one is to calculate and obtain the details of a suitable module, and the other to adapt the details to the modules in the market. To get modulator details, you should calculate the link budget at 430 to 468 MHz and get the modulator's details accordingly.

Amount of receiving power to receive receiver:

Received power (dBm) = *Transmitted power (dBm) + gains (db) - losses (dB)*

- Transmitter power
- Antenna gains (receiver and transmitter)
- Antenna feeder losses (receiver and transmitter)
- Path losses

According to the generalizations of the above formula, we have exactly:

PRX = PTX + GTX + GRX - LTX - LFS - LP - LRX

- PRX = received power (dBm)
- PTX = transmitter output power (dBm)
- GTX = transmitter antenna gain (dBi)
- GRX = receiver antenna gain (dBi)
- LTX = transmit feeder and associated losses (feeder, connectors, etc.) (dB)
- LFS = free space loss or path loss (dB)

In the above formula, the amplitude of the outdoor signal amplitude is reduced by the following relation:

FSPL= 20 log (d) +20log(f) +20log(4π/C) -Gt –Gr

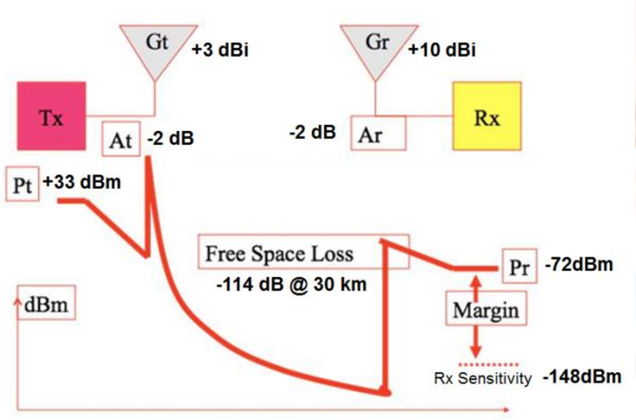

Figure 4 - Diagram Block Calculation of modulator details

Specifications of the strengths and weaknesses required at a distance of 30 km:

Transmitter power: dBm33 +, transmitter antenna gain: dBi3 +, transmitter transmitting lines: dB2-,

Total gain: + 42dB, weakens be at a distance of more than 10 km: -114 dB, amplitude of the received signal expected at the receiver: -72 dBm

This method is very good, but it was prevented from continuing this method due to the problem of the special and semi-industrial parts that were the heart of this modular circuit from the Aurelcompany in Italy. The output of this modulator is GFSK modulation with a power of 10 dBm in the frequency range of 430-470 MHz. After the field tests, the HC-12 module was selected. This type of module in the Iranian market is different in terms of originality of the goods, which, with the reviews, only one source of sales could sell the original product.

Some of the electrical parameters of non-original modules are:

Absence of sufficient RF power, having incorrect GFSK modulation coefficients, frequency instability, having disturbing signals with high amplitude along with the main signal at 300 kHz, having an impedance other than the manufacturer's claim (About 35 ohms instead of 50 ohms), instability versus return signal at 10dB, incompatibility with the next category at many frequencies, non-compliance with pre-amplifier class, loss of data at many frequencies, especially the range 400-432.5MHz, very low sensitivity in receiver mode (-50 dBm), which can not be expected with this burst of 500 meters. , A very key and very important parameter that these non-original modules could not handle: the inability to receive data at a data rate of 115,200.

In the design of the amplifier, it was concluded that a class C amplifier with an appropriate efficiency of about 50% should be used. Therefore, several MOSFET and MMIC transistors were examined and eventually the RA07H4047M piece (manufactured by Mitsubishi) was selected for the following reasons.

1-Supplying power in the frequency range of 400-470 MHz, maintaining power stability, producing a very low harmonic harmonic, supplying 7 watts of power at 12.5 volts direct voltage and 1 mW input stimulation, 50Ω input and output characteristic impedance Passing the standard MIL-STD2000 A, Electrical and Environmental Tested Parameters at Laboratory, Phoenix tactical equipment testing from Arizona State, a very low weight of about 50 grams.

According to the data obtained from the calculations section, an antenna with an all-directional radiation pattern and a vertical polarization with a four-lane electric length and a mechanical and incident length of 20 cm was designed and prototype, and to achieve the desired antenna in a way that also limits the space It should be considered that the stage should be designed and constructed in order to achieve the desired antenna.

The first antenna with VSWR = 1.2 has the ability to withstand up to 30 watts in the frequency range of 430 to 469 MHz. In addition, in the final sample, flexible and spring elements are used.

After field investigations, the Cross Diploe antenna with a λ/4-reflector reflector was considered and special considerations were made for choosing the type of transmitter antenna physically and electrically, as follows:

1- Considering the circular radiant pattern with the lowest amount of airborne radiation with a 90 degree degree of phase difference between any dipoles to communicate at a distance of 30 km
2- The minimum mechanical cross-section to reduce the mechanical noise caused by wind and earth gravity for the least amount of rotation in the Z axis.
3- Use of radiant elements without reactivity to the magnetic field of the earth (do not use stainless steel)
4- Use of electroplated and spring-loaded actinic elements to prevent oxidation caused by humidity
5- Altogether 180 degrees and half-page cover facing the ground with a minimum value of NULL of about 3dB at 120 degrees
6- Very low weight at 200 g and impedance characteristic of 50 ohms with return loss ≤ -23 dB

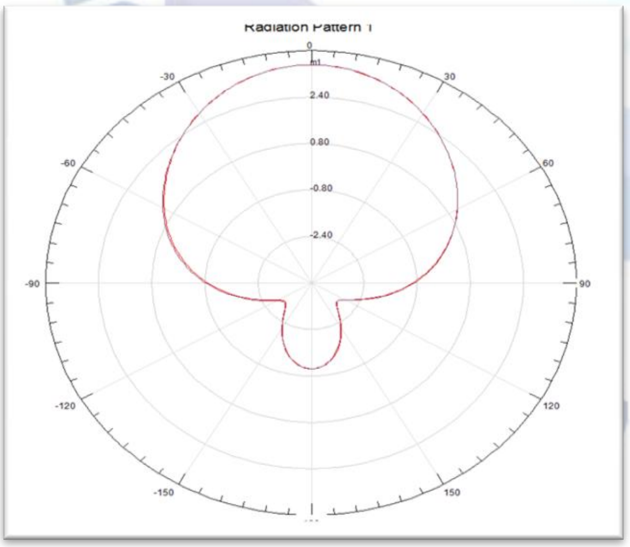

Figure 5 - Radiation pattern of this antenna

Simulation of this antenna in single and no reflector mode in Solid Works Software to obtain construction constraints in conceptual design phase:

Figure 6 - Final Sample of Transmitter Antenna

In this section, the code for the sender, written in the Vision code environment and written in C, is programmed on the microcontroller, is included in the appendix because of its large volume:

The receiver receives the information, decodes the encryption, and then sends it through the serial port embedded for another system that can be a processor or a computer.

The parameters and receiver parts are similar to the transmitter, so in this section only the schematic drawings of the PCB are presented in the receiver's design as well as the antenna examination.

In the receiver section, two radio frequency versions were also designed, and have good results in terms of noise figure and sensitivity, but due to blunt elements such as self-acting screw and ceramic filters if it is not able to neutralize the effect of shock and shock On them, in this section, the professional and industrial modules with GFSK modulation and the high range dynamical sensitivity have been used.

Considering the safe margin calculations for this one-way communication, in the design of the receiver antenna, it was concluded that we should use an antenna that uses the direct-radiation pattern, the so-called Direct. Therefore, we need to use a 10-dBi YAGI antenna.

Selection reasons, the ability to achieve over 10 dBi in this structure, impedance characteristic of 50 ohms, good positioning and direct to track the radiation signal from the transmitter antenna, low weight of about 3 kg and dimensions suitable for transportation. .

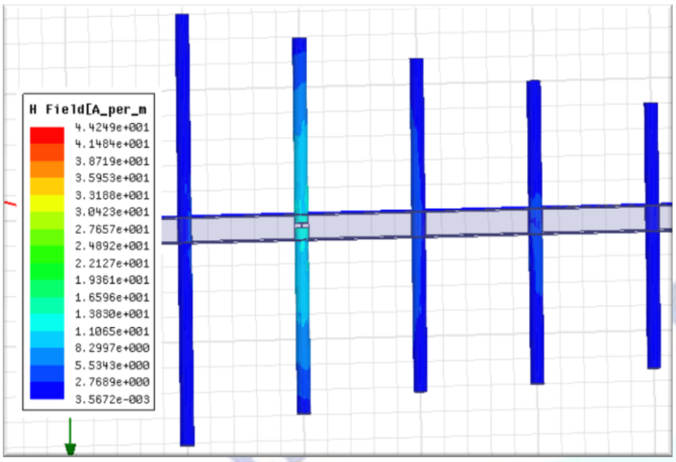

Figure 7 - YAGI antenna simulated in CST software

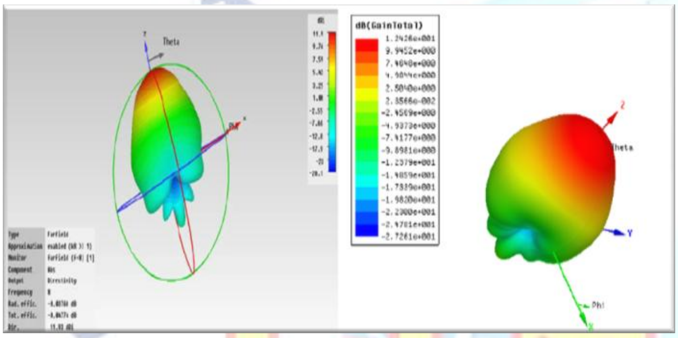
Figure 8 - Pattern of receiving the above antenna radiation

Due to the lack of restrictions in the antenna occupancy space, there was no need for any other changes in the antenna, and this kind of test in the test would well inform the amplifier.
In this section, similar to the sender, the code for the sender, written in the Vision code environment with the language C and written on its microcontroller, is included in the appendix because of its large volume.
Also, for a gas that fills the air bag when it encounters the set, the full gas equation is used. According to the design, the pressure in the bags reaches 0.232 bar, which is applied as the initial pressure to the gas simulator piece. For air, a density of about 1 kg per cubic meter, a molecular weight of 0.444 kg, and a molar thermal capacity of constant volume of 30 JW / kg Kelvin are assumed.
In this design, GPS and motor antennas are embedded on the bottom of the can. The batteries stick to the upper lid of the can (which can be detached). The original range is also attached to the body at a suitable distance from the top (for the upper door to be applied). The airbag is also located around the canopy around the environment, which, due to its long length, fully covers the body. [7-12]

IV. Result discussion

Following the simulation with the above conditions in Abacus Limited Elemental Software, the following results were obtained. It should be noted that the video and the main file modeling in this application (.Cae file), which shows the result of the simulation.
By plotting the kinetic energy diagram of a set, we can see the accuracy of the simulation and also the worst condition of the set in terms of tensions with the surface of the earth:

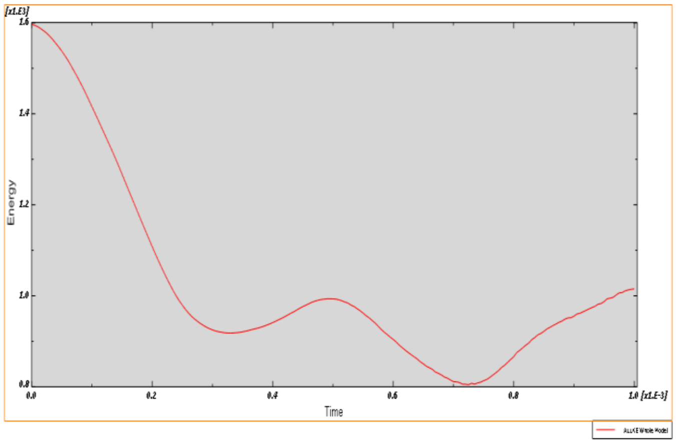

Figure 9 - Chart of speed and stop time

According to the figure, the set hits the ground at an initial speed of 5 m / s. In this case there is a maximum kinetic energy in the set. After about 0.0007 seconds, the object reaches its minimum kinetic energy. Due to the presence of the air bag, the set is not stopped and it will have oscillations of speed, and hence the kinetic energy will not be zero. However, at such a point, more kinetic energy will be converted into internal energy, and the maximum tensions and forces will be about 0.0007 at that time.
Basically, the main goal of this simulation was to examine these results because there are limits to the rules for maximum tension created in the components. This is especially important for sensitive components such as electronic wires and GPS systems. Given that we have already said that at the time of the complete stop, all kinetic energy has become internal energy, resulting in maximum deformations and tensions, the maximum pressure for the whole set and the electronic board and GPS at this moment are checked:

Table 3 - Specification of GPS components

Maximum equivalent stress (mega-Pascal)	Maximum pressure in the piece (mega-Pascal)	Case
386	88.4	Whole collection
32	15	GPS
2.07	1.36	Electronic board

In the following figures, the distribution of pressure on the set with its maximum value is visible:

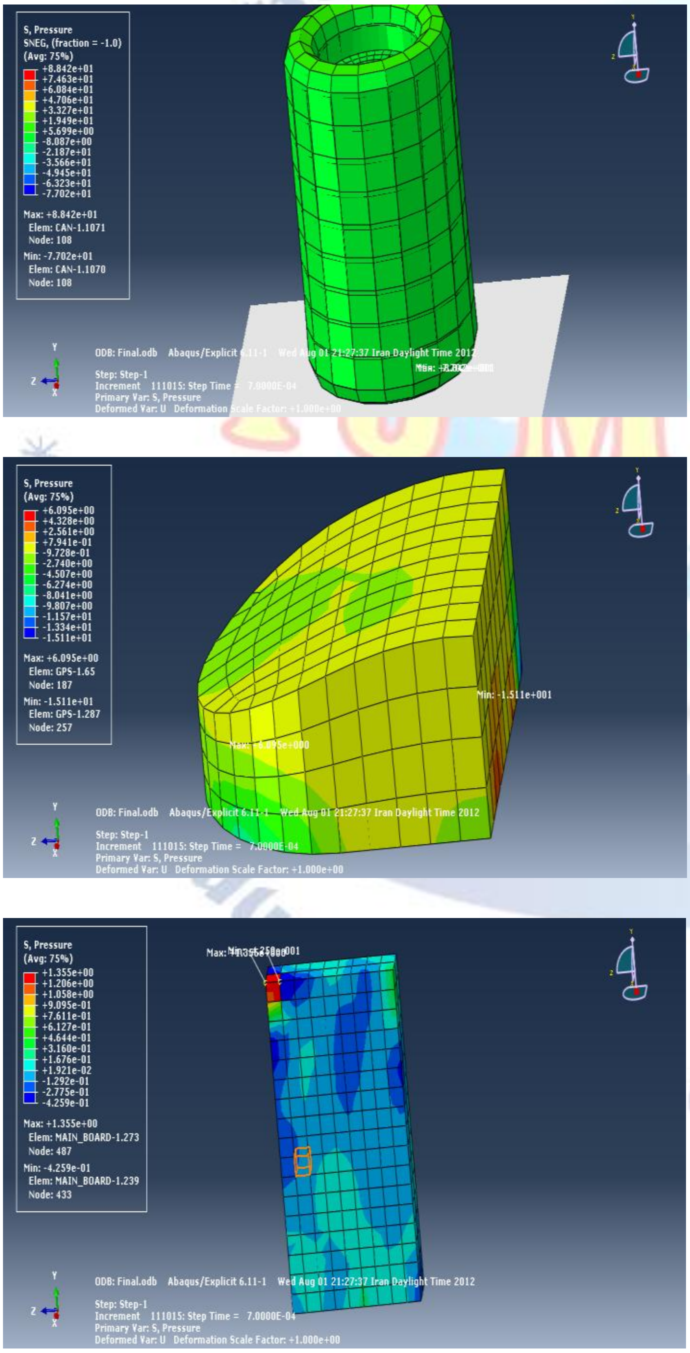

Figure 10 - Checking pressure and tension in components

The results seem reasonable; the main board, which is lower on the top of the installed canister, is affected by the impact. The bottom of the GPS system, which is closer to the shot, is under tension.

Up to now, the Kensett has been tested and flown four times, the first series is for testing the umbrella, and in the second stage the sensors have been examined. The major problem with the experiments is the need for altitude, which is practiced by launching the Kensett from an airplane.

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