CUBESAT PROJECT FEASIBILITY WITHIN ABSENCE OF REAL IMPLEMENTATION AND LAUNCHING IN DEVELOPING COUNTRIES

CASE STUDY:

UNIVERSITY OF KHARTOUM CUBESAT PROJECT
KN-SAT

Sara Mohammed Ali Ahmed

saratna.m.a@gmail.com

University of Khartoum CubeSat Project

Khartoum, Sudan

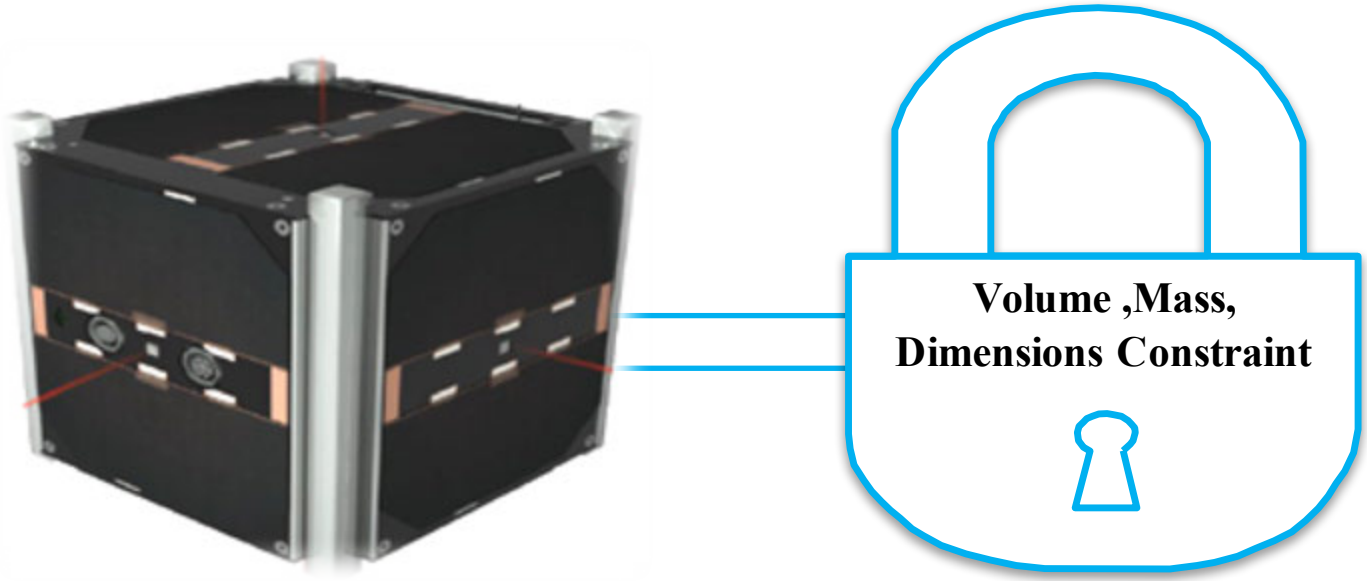
CONTENTS

KN|SAT

- Introduction.
- Benefits of Satellite Technology for Developing Countries.
- University of Khartoum cubesat project (start).
- Project Milestones and Phases.
- Problems faced the Project.
- How the team overcome some previous obstacles?
- What Does Project present to Students in the University.
- Project Influence.
- Conclusion.

INTRODUCTION

CUBESAT?



INTRODUCTION

- This standard platform had significantly reduced the cost and development time of the satellite therefore many Universities, Institutes and organizations had adopted it for research and education.
- In addition to the reduced time and cost the availability and openness had removed so many obstacles which faced the developing countries that have no previous space experience. They had offered them an opportunity to break through space technology and encouraged them to take a step to be within the developed nations.

HOWEVER!!

In spite of all that, establishing a space project or program even like a Cubesat presents economic and technical challenges for developing nations.

Some started projects there may not be after all capable of implementing and launching a satellite into orbit. Some programs may stop temporary or just end forever.

Why may a developing nation think of a space program ?

Have those countries had the cubesat project failed or lost its educational value?

How can a country start such a project without previous experience?

what is the feasibility for a developing nation to establish a Cubesat project if eventually it might not be able to construct and launch the satellite?

how to increase the value and the outcomes of the project and keep the continuity of the program in the absence of real experience or launching?

Benefits of Satellite Technology for Developing Countries

- "Why should we invest in space technology when there are starving people who could use that money? "

  Space enthusiasts in developing nations are often challenged with questions like that!!

  Such a question reveals an ignorance of how technology that is enabled by satellites and satellite applications have the potential to meet significant needs in developing countries "including food production".

- In fact there is a strong relationship between development, well-being of the citizens and space activities.

Benefits of Satellite Technology for Developing Countries

- Satellites have global view and can visit locations frequently.

Satellite based technology that can be of use in developing countries:

- Remote sensing.
- Communication.
- Navigation.
- Combine two or more of the above.

Satellite Remote Sensing

- **Urban Planning**: cities which grow quickly due to urbanization which happen much faster in developing countries than in industrialized ones. (better job and education opportunities). High resolution satellite imagery can provide the planners with needed information about the growth of the city.
- **Disaster Management:** (hurricanes, volcanoes, tsunamis, famines, fires and outbreaks) satellites can sometimes provide early warning about disasters. They can also do monitoring and provide backup infrastructure during and after the disaster.

Satellite Remote Sensing

- **Food Security:** Satellites can improve food production for starving people by improving information available to the agricultural sector.

Crop evaluation → use the data to understand the health of crops (estimates of rainfalls).

Weather forecast → help farmers making decisions about managing their crops as they grow.

Pet detection → alert farmers to the risk of pets.

Satellite Communications

- Satellites in general play a big role in providing phone, internet and broadcasting services. In case of a developing country, in addition to that, they can provide communication infrastructure that is faster to deploy and more useful in remote areas than a ground based one such as cellular network and fixed telephone lines specially where population density is low (satellite becomes cheaper approach).
- They can also improve access to **education and medical care**, **government services** and **economic efficiency**.

Satellite Communications

- **Education and medical care**: rural schools are often understaffed and lack basic resources (textbooks, boards..etc) and teacher absence is very common!! → satellite based communications can provide improvements to formal and informal opportunities by distance education for example. Also television, radio or internet for informal education.

  →satellite based communications can improve medical care by enabling telemedicine or transmitting valuable health-related data (patients can get diagnoses without travelling large distances and incurring great expenses via video conferencing or e-mails or pictures).

Satellite Communications

- **Government Services:** usually rural communities have poor access to government services (travel long distances for routine transactions and difficult to access up to date info).

  → e-government program

- **Economic efficiency:** markets highly inefficient, information about price does not travel as it should danger of arbitrage pricing and risk of being cheated. If people (e.g. farmers) can access Internet they can learn about market price.

Satellite Navigation

- **Aviation:** civil aviation can be a valuable source of economic growth. In some countries it is the primary mean for tourists to enter the country and stimulate the economy.

  air traffic management technology based on satellite navigation can be more affordable than traditional ground based and particularly useful in an infrequently used airports.

- **Wild life tracking:** wildlife in some developing countries it is a valuable natural resource and key challenge in many countries to manage it since many species are endanger due to human activities.

  → management can be facilitated using satellite based wildlife tracking. (special designed GPS receivers attached to animals without harm or impeding).

UNIVERSITY OF KHARTOUM
CUBESAT PROJECT

KN|SAT

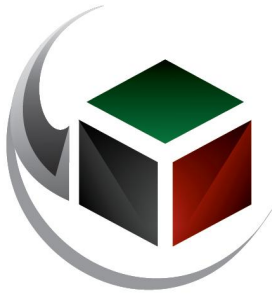
U OF K CUBESAT PROJECT (THE START)

- Sudan is one of those developing countries which had no space activities or space experience. Before this project a lot of proposals and studies of satellite projects have been carried out and presented but unfortunately they were just ink on papers!
- The University of Khartoum (U of K) Cubesat project is the "first" Sudanese satellite project.
- The idea of the Cubesat was brought to Sudan by Dr. Nader Abd-Elhamid Ali Omer ST2NH (a Sudanese international expert and an old ham radio) who presented his Cubesat proposal to many universities and Institutes in the country.
- They all thought the idea was far beyond Sudan limits and it was like a huge dream. However, the University of Khartoum had bravely adopted it realizing its benefits and following steps of other universities all over the world.

U OF K CUBESAT PROJECT (THE START)

- Dr. Nader Abd-Elhamid Ali Omer (ST2NH) (Team manager and project Co-founder).

Project Milestones and Phases



- The Cubesat project had been started with the main objectives of giving students knowledge and real hands-on experience in addition to designing, implementing, testing and launching a fully functional Cubesat.
- The university provided area for laboratory and two offices in addition to some electronic equipments and some other facilities, but the project needed a proper funding in order to afford the infrastructure and the salaries for the working force.
- Therefore a cooperation agreement between the Faculty of Engineering and Nile Center for technology researches had been signed in 2010, in order to support this project and other similar projects in the faculty.
- The idea was to start with project manager, team manager (Dr. Nader) and a research group.
- The research group was suggested to be composed of fresh graduate and under graduate students.

Project Milestones and Phases

- The group was supposed to conduct research in order to learn the basics about ground segment and satellite subsystems and design.
- Undergraduate students were to carry out their research having graduation projects related to different space and ground segments. The projects were: (OBC, ADCS, Satellite tracking and Telemetry decoder software).
- Graduate students went into a basic general requirements training course held in Istanbul Technical University, Turkey. Then upon that they conducted a research period.
- After that a small HF ground station was constructed using local available equipment (home made antennas + Radio + PC- SW).
- Meanwhile constructing the ground station and running it, the team started contacts with the cubesat companies and launching providers and constructed a schedule and timeline for the whole project cycles “satellite constructing, testing and launching +HR professional training”.

Project Milestones and Phases

- Then they started making top level designs for the satellite and its subsystems and selecting proper components (subsystems boards) from online cubesat shops for EM and FM. The detailed part list was meant to be prepared after finalizing and approving the final design after undergoing a second more professional training.
- Since it was the first time for the team to construct a satellite, it seemed best to keep it simple as much as possible and buy most of the satellite subsystem except for the Beacon subsystem, Mission and some other parts (no testing facilities) and also in order to increase the success probability and decrease development time (due to the delay which happened in the project timeline).
- It was expected the project will turn out to be regular program run by university. So another philosophy behind the previous milestone was to take it step by step one at a time. Every time accumulate knowledge, skills and experiences and use low cost and rapid development strategy increasing the number of boards designed and built locally in every launch.

Project Milestones and Phases

The project had been divided into four phases:

- Establishing University of Khartoum educational Ground Station.
- Design, construct and build the different satellite's subsystems.
- Test and launch the satellite.
- Run and operate the satellite.

Ground station objectives :

- In addition to track and receive data from the satellite when it is launched, this phase was meant to make students familiar with the different tools (HW, SW) that are used in the ground segment to support the satellite in addition to receive and analyze its data.
- Put the university's name among the educational space community and make relationships with other universities by helping tracking and receiving data of other universities satellites.
- Inspire other institute in the field of space science.
- Support curriculums teaching satellite, wave and antenna theories in the University.

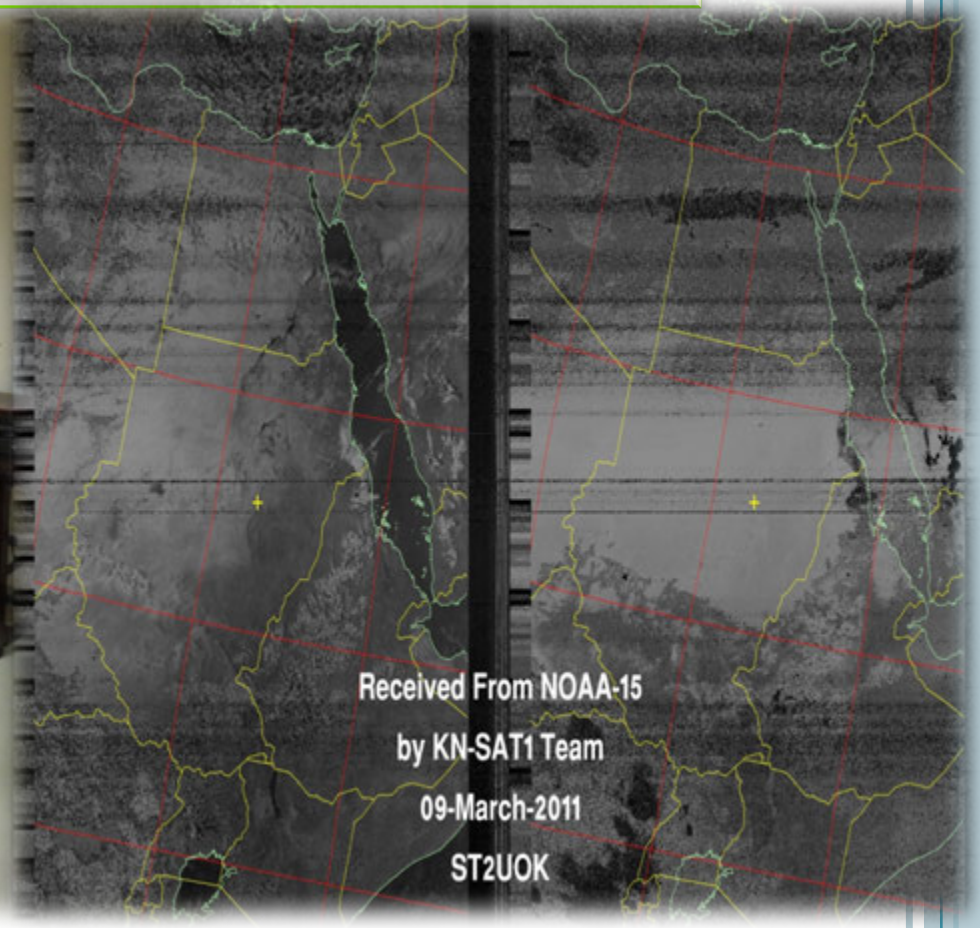
Project Milestones and Phases

ST2UOK Professional Ground Station:

- A real time satellite tracking ground station (ST2UOK) up to the standards was established in 2011. It was designed, built, calibrated and operated by the team members.
- It is capable of receiving and transmitting signals in the HF, UHF, VHF, L and S bands. The team successfully received and decoded data so many times from other CubeSats as well as other amateur satellites, the (ISS) and the (NOAA) satellites.
- ST2UOK has become a very important ground station and that is due to the lack of ground stations in Africa as well the fascinating capabilities which it have. The ground station reputation has grown tremendously among the Cubesat and amateur satellite communities and a lot of requests come to it in order to assist tracking the newly launched satellites and receiving their data. The team was always happy to contribute and help.

Project Milestones and Phases

ST2UOK Ground Station



Problems Faced the Project

After constructing the U of K ground station the project suffered various issues which caused it to stop:

National/ Public Awareness

- Most developing countries in general do not have sufficient awareness towards benefits of scientific research and probably they assign a small portion of the national budget to it (if they did).
- It becomes worse when it comes to space related researches because they are often expensive (space proven components, testing facilities and launching cost which is proportional to the satellite weight) cost is often higher than other researches.
- The problem becomes even worse when those researches are not profitable or do not have tangible outputs!!
- The cubesat project had neither profitable return nor scientific or commercial applications (cubesat programs aim to develop a human resource that is active and capable of earning and implementing space and satellite technology from inside educational institutes), so some thought that investing money in this project is just useless.

Problems Faced the Project

Funding Delays

- The project suffered several delays in the amount of fund since its beginning which leaded to delay in its progress of course (time line delays).
- The infrastructure which included a clean room, a thermal vacuum chamber and shaking table in addition to the space proven components list for EM and FM had not been purchased.
- In 2013 the project considered as a failure from project management point of view (the satellite has not been built or launched) and no longer fund assigned to it.
- No other financial resources were available.
- The project was to be shut downed.

The reasons behind the above:

1) Lack of awareness about the project benefits as stated earlier which made the decision makers in NTC hesitate to continue support the project.
2) Increasing of the inflation rates.

Problems Faced the Project

ITAR/ Sanctions:

- The ITAR regulations until 2013 prohibited some countries from gaining software, hardware and data about satellites.
- The team faced several rejections from several entities around the world for their request acquiring cubesat hardware and software! Although their requests did not included any military sensors and the cubesat was to be used for totally educational purposes (cubesat is educational satellite in the first place!).

Human Resources Problems:

Students and graduates working in the project faced lots of issues:

1) Lack of knowledge and hands on experience.
2) Low income and lack of job security.
3) Career risk. since it was new field (no market for it)→ if failed they will be far away from the market requirements in the country + lost the opportunity of accumulate years of experience in the existed market which increases the chance of getting good job (after two years they are considered fresh graduates compared to their colleagues in the market).
4) The project is no longer attractive for new graduate students to enroll (so many obstacles will face them).

HOW THE TEAM OVERCOMED SOME PREVIOUS OBSTACLES?

Introducing Prototyping Concept

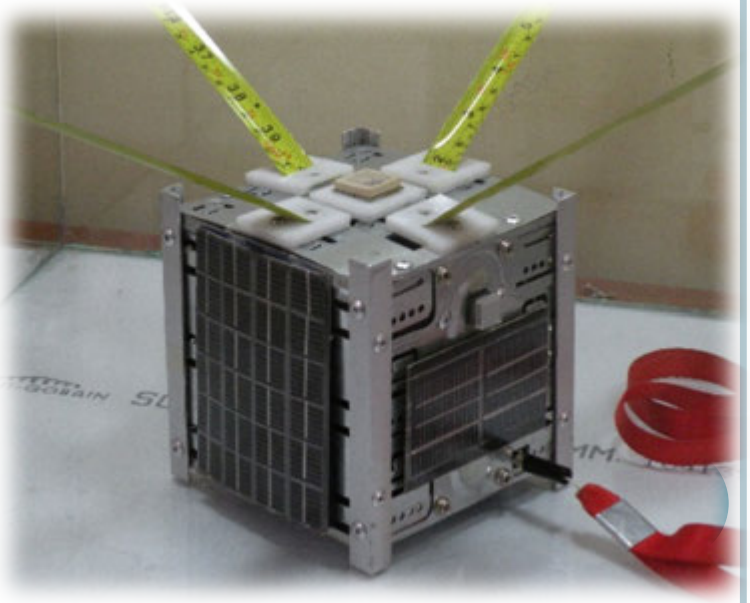
- A prototype is an early sample, model or release of a product built to test a concept or process or to act as a thing to be replicated or learned from.
- With lack of funding, resources, electronic components and experience in space field the team at the University designed and built -from scratch two fully functional cubesat prototypes.
- The objectives of the prototype were to:

1) breakthrough the technology and obtain the necessary skills and experience by exploring the design process, testing the theories and executing activities and development of a whole system that carries most of the sub-systems exist on real cube-satellites which will prepare them to fulfill the University's Cubesat using space proven components for future launch (self training).
2) Produce functioning model will serve as a tangible evidence of the team capability of constructing a real fully functional satellite (convince decision makers and community).
3) Challenge the team busy and keep their hands wet.
4) Inspire young students and graduates to join the program and encourage them carry out researches along with earning hands on experience (cubesat prototype as philosophy for research and education).

KN-SAT P1

- KNSat-1 Prototype 1 is the first model designed and built from scratch by the cubesat team at University of Khartoum using local materials in 2011.
- The prototype was fully functional. It had been assembled and tested successfully by the team members.
- It had a Mission of sending GPS data in addition to the house keeping data (CW beacon).

- The main objectives of this prototype were :
  - Introduce the project to the national community (increase the awareness)
  - Give students basic hands on experience.



KN-SAT P1 Specifications

- **Dimensions and Weight:** The module measures 13x13x13 cm3 .Weight 1.3 Kg.
- **Structure:** The prototype structure was made of scrubs of computer power supply cases.
- **Frequencies:** The module used VHF for packet and HF for beacon.
- **Bus:** USART Protocol.
- **Subsystems**

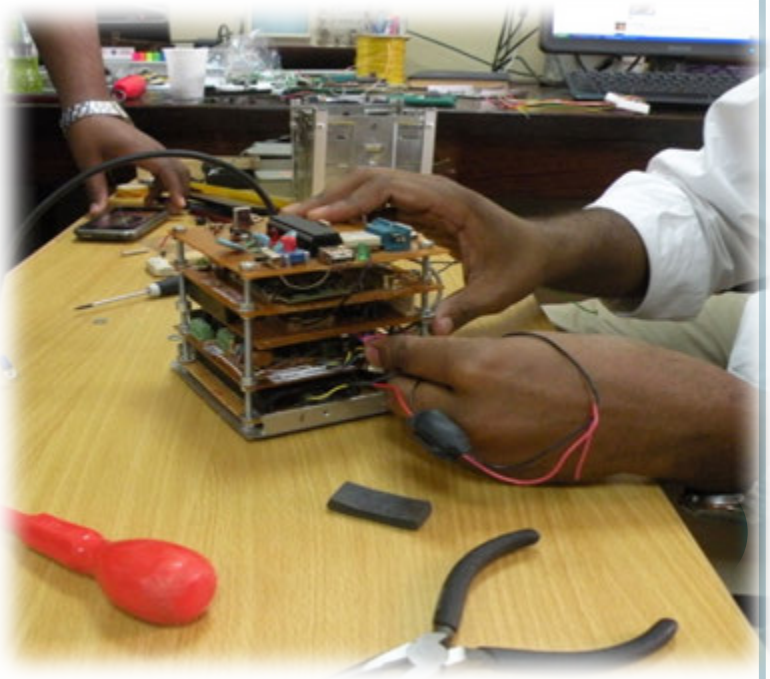
  Electrical Power System (EPS)

  Communication System (Transmitter)

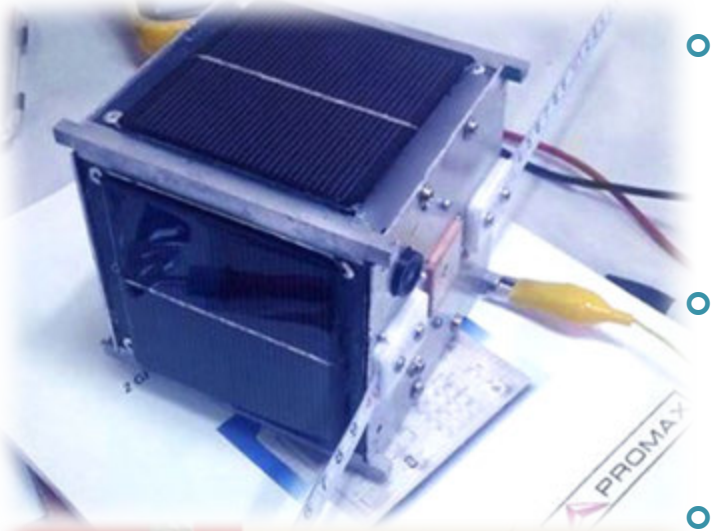
  Terminal Node Controller (TNC)

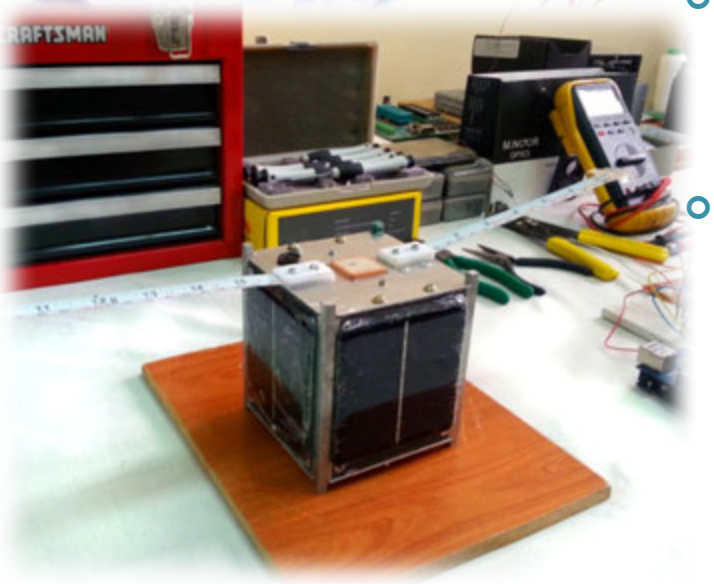
  On Board Computer (OBC)

  Beacon System



KN-SAT P2





- KNSat-1 Prototype 2 is a sophisticated model designed and fabricated by the cubesat team at University of Khartoum from scratch following the cubesat standards and using local materials 2012.
- The main goal of this prototype is to make realistic and reliable cubesat design with high capabilities up to cubesat standards in addition to give the team hands on experience.
- The prototype is fully functional and fulfills its predefined mission. It had been assembled tested and operated successfully by the team members.
- Its Payload is JPEG Color Camera that takes a picture at stored predefined location (determined by the GPS on board the module) then send it to the ground station.

  Send the housekeeping data (call sign+ text, GPS data, Temp and Voltages) using beacon RTTY mode.

KN-SAT P2 Specifications

- The module is also capable of receiving Tele-commands from Ground Station and executing them. Tele-commands include:

1) Set Image GPS Location.
2) Take and Download Picture.
3) Reset the satellite.
4) Change Passwords.

- **Dimensions and Weight:** The prototype is complying with the Cubesat standards measuring 10x10x10 cm3. Weight 912 gm.

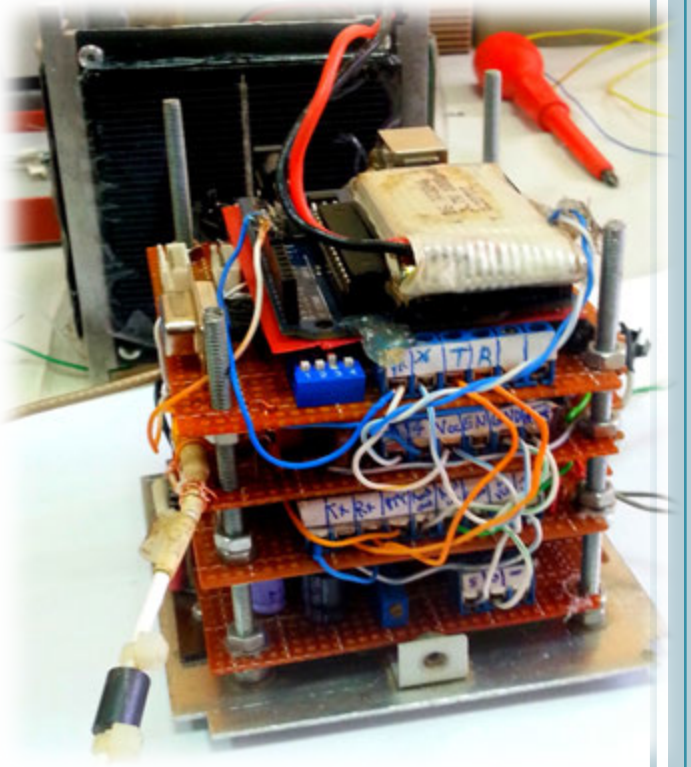
- **Structure:** The prototype structure was made of the aluminum AW 7075 as suggested in the VEGA launcher's specification. Numerical simulations (FEA) by software (Thermal and Dynamic Analysis) have carried out to meet these specifications.

- **Solar cells:** Commercial solar cells.

KN-SAT P2 Specifications

- **Frequencies:** The module use FM VHF frequency at 144 MHZ.
- **Bus:** For the first time IC2 and SPI protocols + USART Protocol.
- **Software:** For the first time Using Interrupt requests. The requests are handled by priorities.
- **Sensors:** Temperature and humidity sensors.
- **Subsystems**

1) Electrical Power System (EPS).
2) Terminal node controller (TNC).
3) Communication System (Transceiver).
4) On Board Computer (OBC).
5) Beacon System (Ardiuno).
6) Payload System .



KN-SAT P2 Results/ Outputs

First Picture ever been taken sent and received in Sudan.

- For the first time **Taking a shot** remotely by the payload subsystem (using **Telecommands**),

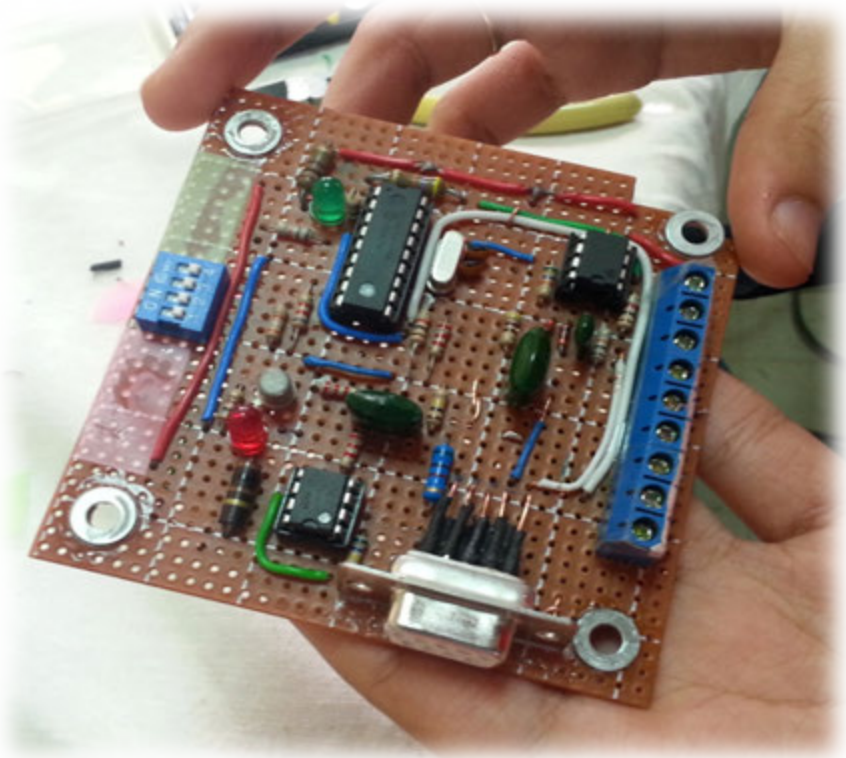
  process it, and

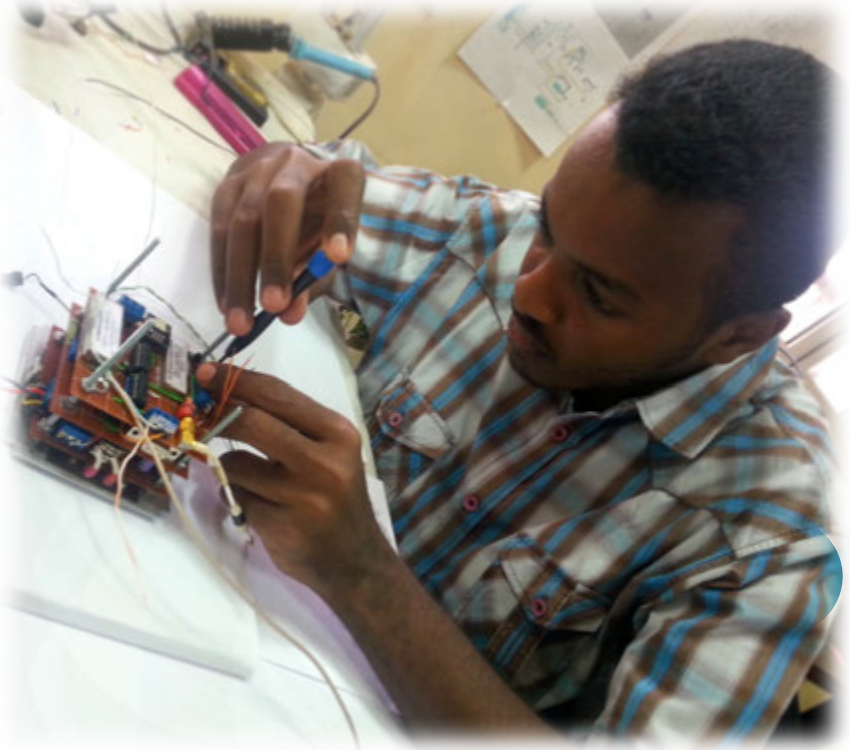
  Sending it from the prototype.

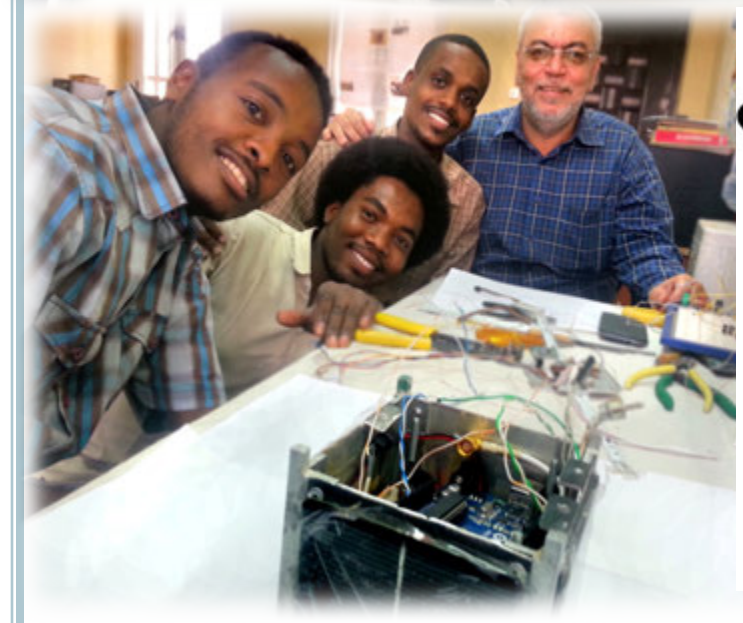
  then **Receive** it and **Decode** It using ST2UOK Ground Station.
- Developing software and hardware for the TNC.

KN-SAT P2 Results/ Outputs

- Confidence, achievements and hands on experience.
- Challenge: this time the team insist to follow the cubesat standards using available commercial components (although they are big and heavy) but they managed to make a module following the standards.







Scientific work and Conferences

- The team members have participated in many conferences and workshops inside and outside the country and they have published a number of scientific papers.
- The objective were ones were to introduce the project to the space and scientific community and play an active role by publishing researches.

Conferences and workshops:

- African Telecommunication minister's Conference (Oct 2012, Sudan)
- University of Khartoum Post Graduate Studies Annual Conference (Feb 2012, Sudan).

Scientific work and Conferences

- International Conference for Computing, Electrical and Electronics Engineering (ICCEEE), Sudan

  "The Unscented Kalman Filter Applied to Satellite Orbit Determination; Using Only Publically Available Two-Line Element Sets "

- United Nations/United Arab Emirates Symposium on Basic Space Technology "Small Satellite Missions for Developing Space Nations" (Oct 2013)

  "Nano-satellite Development Issues in Developing Countries/ Case Study Sudan"

Scientific work and Conferences

2nd IAA conference on University Satellites Missions and Cubesat Winter Workshop (Feb 2013)

- The Papers titles were:
  - VHF Transmitters for CubeSats
  - Brief Guideline to CubeSat Antennas.
  - Android Smart Phone as an OBC.
  - Hot Down Cool Up Effect.
  - Satellite Tracking Software.
  - Design, Implementation and Impact of Educational Satellite Ground Station, Case Study: University of Khartoum, Sudan

Spread Awareness and Space Science

- Organizing visits to the ground station ST2UOK and seminars for different students from different institutes with different age's categories (even kindergarten).
- The team participated by a talk in TEDxKhartoum with the title "Sudanese Satellite" that inspired many audience to come and visit the project and know more about it.
- The team had introduced the Cansat competition to the University undergraduate students which is considered the first competition of this kind in the country in order to bring space systems and satellite sciences closer to students, raise their awareness, explode their creativity and polish their skills.

UofK CanSAT Competition (2012)

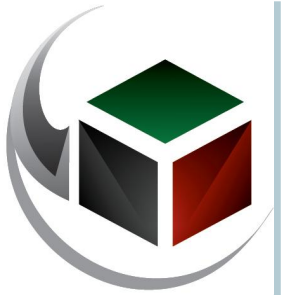
The First Sudanese CanSAT Competition

Other Contributions / Achievements made by the Team

- The team had developed their own decoding software to be used by the Indian University, SRM for their satellite.
- The team had participated in HF armature radio CQ contest for the first time and received a large number of calls from radio amateurs from all over the world.
- They also participated in the QB50 project in which their proposals had been accepted and they started working on it however due to the funding issues they could not proceed in it anymore.

QB50, an FP7 Project

What Does Project present to Students in the University

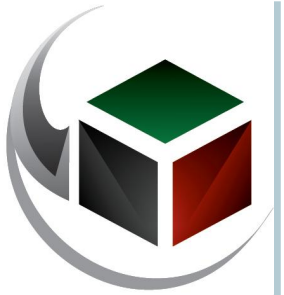


- The team give technical support to students on their projects and to the last year undergraduates in their final projects.
- Every year, a couple of the final year projects affiliate to the project is presented and the team provides the students with guidance and technical assistance.
- Last year, a master degree research affiliated to the project had been presented.
- Some of the project staff work as part time teaching assistant teaching courses and laboratories specially those courses related to satellite or ground station.

Project Influence

- The team members started to peruse higher education degrees and many of them enrolled a space related degree programs in foreign universities around the world.
- After three years of struggling and trying to spread the awareness, a hope light has finally appeared. The need for a satellite program had finally got the attention and had been addressed by the government which started to make some moves:
- It started establishing national satellite research center (Institute of Space Research and Aerospace (ISRA)).
- The NTC decided to establish the project again and assigned a full budget for it for this year 2014.

Conclusion



- Cubesat programs is a small step but could lead to a giant leap. So it is recommended to use it as the first step into space break through, especially in developing countries which have no space experience before, since this program and other small satellite ones aim at developing a human work force at the first place. Many universities around the world succeeded in developing and launching cubeats into orbit as first satellites to their countries.
- Even though the U of K CubeSat project has not built or launched the actual satellite yet, the project has made lots of achievements. It can be concluded that, The long development time in satellite programs is not a big issue if the project still makes successes.
- Keep the sustainability of the program even in the hardest times is very important. Prototyping and making small projects are very helpful. They can be useful tools for education and gaining technical skills. Adding to that a tangible practical module is more convincing and can explain the new ideas better.

Conclusion

- Spreading awareness is a very effective factor specially in developing countries which have never experienced a space project before. This project motivated young graduate and undergraduate students to enroll and earn knowledge and hands on experience and then spread this knowledge and awareness about the importance of satellite and space sciences within a community that has no knowledge or experience about this new field which did not exist before except in theories and references. This is rather clear that even the government was motivated by the project to make real steps towards a national satellite program.


CRAFTSMAN
M.NOTOR
OPTICS
THANK YOU

Questions ?