Investigation of Modern Equipment for Launching and Testing of a Sounding Rocket

John Bawa*

*National Space Research and Development Agency, Obasanjo Space Centre, Airport Road, P.M.B 437 Garki Abuja, FCT Nigeria

Abstract: Sounding rockets are developed for scientific research, they are an excellent means of taking measurement at very short notice of transient phenomena. And many space agencies in the world continue to depend on sounding rocket for their research work for example in meteorology, ionosphere physics, aeronautical engineering and etc. Beside sounding rocket afford the opportunity of making measurement on the way up and back down through the atmosphere. Sounding rockets are simpler, recoverable, and temporal flexible. If the proper care for the rocket is not taken and insufficient prelaunch checkout is performed the rocket has failure due to human factor. After launching, sounding rockets experience extreme variations in temperature, acceleration, atmospheric pressure and vibration. All these can be well taken care off if adequate testing policies are done and well examine with the appropriate equipment.

Keywords: sounding rocket, launch, test

1. INTRODUCTION

The most important innovation provided by sounding rockets for space science activities was related to the fact that the study of many atmospheric and ionosphere phenomena requires measurement taken through the vertical cross-section of the atmosphere and the ionosphere. Therefore, sounding rockets have been utilized for scientific research since the late 1950s and were originally implemented in meteorology and upper Atmosphere studies, such as the composition temperature density of the atmosphere and ionosphere, ultraviolet and roentgen radiation of the sun, cosmos radiation and particles with low energy, magnetic and electrical fields, the flow of the micro meteors, anomalies, and atmospheric gravitational waves. These rockets take their name from the nautical term “to sound,” which means to take measurements, and are made up of essentially Three major parts, i.e. a single or two–stage solid-fuel propulsion system. Sounding rockets are sub-orbital carrier, which means that they do not go into orbit around the Earth. They are an excellent means of taking measurement at very short notice of transient phenomena. They also provide several sub discipline with result that constitute a high scientific return in themselves. This is especially the case for short duration experimenting to investigate combustion behaviors in low gravity conditions, and for various field of fluids sciences and the solidification of metallic melts.

Sounding rockets are projectile that are launched into the upper atmosphere to reach an altitude of between 40 and 200 km. They are developed primarily for Space and Earth sciences research activities. Sounding rockets as important to space sciences as ever, furnishing our most powerful means for obtaining vertical profiles of atmospheric properties. Many Space Agency in the world continue to depend on sounding rockets for research in aeronomy, meteorology, ionospheres physics, and many other disciplines. In order to meet up the challenges scientifically, in my paper work, I wish to investigate the modern equipments use for launching and testing of sounding rockets in order to gain more information that could be help to our scientist and engineers to minimize failures and cost.

The sounding rocket is a scientific vehicle that will carry a lot of instruments (a few kilograms to a few hundred kilograms) to almost any altitude he desires between a few kilometers and a few hundred kilometers. Besides affording the opportunity of making measurement on the way up and back down through the atmosphere, the sounding rocket can provide several minutes of observation

2. THE IMPORTANT OF SOUNDING ROCKETS

Sounding rockets are excellent platform of independent investigations, preparatory experiments for long duration flight opportunities, and for in-flight verification of scientific innovations, especially in cases where no prior microgravity exists. In scientific community over the world the sounding rockets exploration is less expensive than alternative units. Such as;

SIMPLICITY: Sounding rockets are much simpler than satellites, with fewer interfaces to match and far less complicated launch facilities to deal with the rocket interface.

RECOVERABILITY: Payloads from film packs to small animals can be recovered for study or reflight.

GEOGRAPHIC FLEXIBILITY: Sounding rockets can be launched almost anywhere , making them ideal for studying
eclipses, solar flares, polar-cap absorption events, the aurora, the equatorial electro jet, etc.

TEMPORAL FLEXIBILITY: Sounding rockets and experiments can be prepared in a matter of months to take advantage of scientific targets of opportunity; or, they can be kept in readiness for firing during the passage of a satellite or comet to obtain vertical profile and orbital data at the same time.

The development of sounding rocket technology continues to serve as a low-cost test bed for new scientific techniques, scientific instruments and space craft technology. In the field of education, sounding rockets provide invaluable tools for education and training. They provide opportunities for wide range of students from undergraduate to PhD candidates and post Docs. Career opportunities range from engineering to scientific research and development with industry, academia, and government.

3. THE PROBLEM STATEMENT

When a sounding rocket is being designed, built, and tested well, we expect it to have a successful launch, but just our vehicles can fail in our unforeseen ways, so too can sounding rocket occasionally fail.

Failure is usually attributed to problem associated with a subsystem, such as propulsion, separation/staging, electrical, or structures etc. And in some case failure is ascribe to problem in another area altogether (e.g., launch pad, ground power umbilical, ground flight control, lighting strike), or to unknown causes (usually when subsystem failure information is not available).

Failure is an unsuccessful attempt to place a sounding rocket payload into its intended place due to human error, poor workmanship, in adequate designs and component tests, improper handling in manufacturing and repair process and insufficient prelaunch checkout. In order to minimize cost and to achieve the desired objectives. It is necessary to use modern equipments for a successful launch.

4. METHODOLOGY

A sounding rocket experiences extreme variations in temperature, acceleration, atmospheric pressure, and vibration during flight. These conditions are hostile to the proper structure, mechanical, electrical and aerodynamic functions of the payload. All of them should be tested before launching to ensure that all on board system can withstand to impact and avoid failure.

Information gathered from failure studies of past sounding rocket indicates that following certain work practices could greatly enhance the reliability of the sounding rockets. It is necessary to incorporate Preventive measures in all aspect of system development, from deign, testing and operations. My research work will examine all the testing policies and the testing equipments involve for pre launch system of a sounding rocket. Such as;

5. ENVIRONMENTAL TESTING POLICIES

Under it I will take a study of the following tests:
Acceptance Test
Principal Investigator Test
Plan Test
Assembly and Qualification Test
The testing of azimuth angle
The testing of angle of jump
The testing of gyro stabilization system
The testing of the radio telemetry and
The testing of the accumulator

ASSEMBLY AND QUALIFICATION TEST: Assembly and Qualification tests expose items to environment that are more severe than those experienced throughout the mission. This ensures that the design is sound and that there is high confidence that failure will not occur during mission.

ACCEPTANCE TEST: Previously qualified components and all fully assembled payloads (new or re-fly) must undergo acceptance testing, which exposes test items to the environments that mimic those experienced during a mission. These tests are the final gauge for determining the launch worthiness of a component or payload.

TEST PLAN: The Mechanical Engineers are responsible for developing a test plan for a particular payload and its related components. The test plan entails;
1). Determine exactly which tests are required.
2). Scheduling time frame for testing with the Environmental Testing and Evaluation group.
3). Generating test request for each test.

6. TESTING EQUIPMENT AND CAPABILITIES

Sounding rocket components must be tested before launching and this is done with specifics equipments meant for testing them. In my research work I intend to examine a lot of equipments for testing sounding rocket. Such as

Mass properties measurement
Static/dynamic balancing
Vibration test
Bend test
Thermal vacuum test
Magnetic calibration
Wind Measurement Instrument, etc.

MASS PROPERTIES MEASUREMENT: The payload’s mass properties i.e. (weight, centre of gravity, moment of inertia) are determined by test or calculation with special equipment. Final measured properties are always determined during payload test and evaluation. Requirement for moment of inertia are necessary to determine suitability of trajectory, predict Altitude control system performance and to calculate stability. For example to calculate the position of the centre
of mass of a sounding rocket can be calculated using the formula below.

$$\Delta m = m_{\text{initial}} - m_{\text{final}}$$  \hfill (1)

STATIC AND DYNAMIC BALANCING: All payloads must pass flight acceptance test to determine launch vehicle stability, both static and dynamic. The payload configuration and structural bending characteristic must be adequate for acceptable flight parameters to be satisfied. All these are done during pre launch activities with design equipment to perform the function.

For example let $M$ be the total mass of the rocket mechanism ($m = m_1 + m_2 + m_3$). The centre of mass $C$ is:

$$C = \frac{1}{M} (m_1 F_1 + m_2 F_2 + m_3 F_3)$$  \hfill (2)

Where $F_1, F_2, F_3 \in \mathbb{C}$. Therefore in dynamic balancing, if the mechanism remains stationary for infinitely many configuration (i.e infinitely many choices of the angles). From equation (2) above, this condition can be formulated as:

$$F = F_1 + F_2 - C$$  \hfill (3)

Where, $C = CM - F_2$

VIBRATION TEST: Vibration test is equally important during prelaunch testing. Vibration test specifications are determine by the type of engine used for launching the payload. The payload reaction depends on the size, weight and weight distribution (harmonic frequency) of the payload. Vibration transmission problem can create excessive motion of sensitive electronic parts; components are, therefore, vulnerable to failure from vibration; they must be rigidly attached to prevent abrasion and subsequent shorting. Mathematically, dynamic balancing can be calculated by determining the position of the centre of mass.

BEND TEST: Every sounding rocket payload is subjected to a bend test in order to determine the overall stiffness of the body during pre launch testing. This will help to verify payload stability during flight. This is also done with special equipment to help verify the stiffness. Bend test is necessary in order to determine if the sounding rockets can withstand the loads. The loads are defined according to the following equations:

$$L_N = \frac{1}{2} \rho V^2 C_D r_0 \alpha$$  \hfill (4)

$$L_T = \frac{1}{2} \rho V^2 C_L r_0 \alpha$$  \hfill (5)

$$L_{\delta} = \frac{1}{2} \rho V^2 C_L E \delta_0$$  \hfill (6)

$$L_{\theta} = \frac{1}{2} \rho V^2 A \frac{E_{\theta}}{V} C_L$$  \hfill (7)

$$T = T(\theta)$$  \hfill (8)

\[ T_L = T_{\alpha \beta} \]  \hfill (9)

THERMAL AND VACUUM TEST: The thermal test, determines the component’s sensitivity to elevated temperatures and relatedl, it is needs to isolate it from projected heat source.

While the vacuum tests; when the payloads rapidly ascend in the atmosphere during launch, ambient atmospheric pressure drops quickly to zero. Payloads are generally designed to vent internal air. Barometric switches are often utilized for switching functions in payloads electric subsystems. The two most common undesirable effect of vacuum are reduced heat transmission and corona. Both can be easily addressed when identified by vacuum test during pre launch testing. In sounding rockets, thermal and vacuum test is necessary for any given temperature. For example, for a melting temperature range $(T_L, T_U)$, the equivalent specific heat capacity is given by:

$$c_p = \frac{1}{T_L - T_U}$$  \hfill (10)

The variation of the specific heat capacity with temperature is:

$$c_p(T) = \begin{cases} c_p & T < T_L \\ c_p(T_L) & T \geq T_L < T_U \\ c_p(T_U) & T \geq T_U < (T_U - 1) \end{cases}$$  \hfill (11)

When the temperature increases.

$$c_p(T) = \begin{cases} c_p(T_L) & T \geq T_L < T_U \\ c_p(T_U) & T \geq T_U < (T_U - 1) \end{cases}$$  \hfill (12)

When the temperature decreases.

MAGNETIC CALIBRATION: Special equipment is used to conduct magnetic calibration of magnetometers on sounding rocket payloads and to perform functional test on magnetic attitude control system during prelaunch testing.

WIND MEASUREMENT INSTRUMENT: Wind measurement is of paramount important during launching of a sounding rocket, but for prelaunch activities is less important. But however, high accuracy and precision of wind measurement and world wind coverage are the major advantage. Various meteorological instruments are available to measure wind speed direction. These instruments can be divided into two categories based on sensing techniques. First group are local sensing techniques which includes Anemometer, Rawinsonde, Weather balloon, Weather vane and Windsock. For example, a weather balloon is a special type of high altitude balloon which is used in the measurement and evaluation of atmospheric conditions. Weather balloons, which are made of latex material or rubber, are filled with hydrogen or helium. The weather balloon may reach up to 40 km before it burst. Wind data is obtain by tracking the weather balloon by radar or navigation system. Meteorological balloon’s know parameter are needed
to find all the forces acting on the balloon. Mathematically, for a given balloon, the following parameters are known or can be calculated.

**FRICTIONAL FORCES:** Friction is a force that acts upon moving objects. It acts in the opposing direction to that of the moving object. The frictional force is determined by using this formula.

\[
F_f = \frac{1}{2} \rho v^2 A C_d,
\]

where

- \( F_f \) = Drag force \([\text{kg} \cdot \text{m/s}^2]\)
- \( \rho \) = Air density \([\text{kg/m}^3]\)
- \( v \) = Velocity \([\text{m/s}]\)
- \( A \) = Cross sectional area \([\text{m}^2]\)
- \( C_d \) = Drag coefficient \([\text{dimensionless}]\)

**BUOYANCY:** Buoyancy provides an upward force on the object. It can be determined by using the formula below.

\[
F_B = \frac{1}{2} \rho g V D D F
\]

where

- \( F_B \) = Buoyant force \([\text{kg} \cdot \text{m/s}^2]\)
- \( V \) = Balloon volume \([\text{m}^3]\)
- \( \rho \) = Air density \([\text{kg/m}^3]\)
- \( g \) = Acceleration due to gravity \([\text{m/s}^2]\)
- \( D \) = Cross sectional area \([\text{m}^2]\)

**BALLOON FLIGHT ANALYSIS:** for a given balloon, the following parameters can be calculated.

Normal inflation diameter, \( d \)

Volume of balloon, \( V \)

Mass of balloon, \( m_B \)

Lift of Helium in standard air:

Density of Helium

\[
D_{\text{He}} = 0.18 \text{kg/m}^3
\]

Density of air

\[
D_{\text{air}} = 1.30 \text{kg/m}^3
\]

Buoyancy force

\[
F_B = (D_{\text{air}} - D_{\text{He}}) V g
\]

(17) Lift per volume can be calculated using the following formula;

\[
L = (D_{\text{air}} - D_{\text{He}}) g
\]

(18) The drag force can be calculated by using the following equation:

\[
F_D = \frac{1}{2} \rho v^2 A C_d
\]

(19)

Where,

- \( C_d \) = Drag coefficient \([\text{dimensionless}]\)
- \( \rho \) = Air density \([\text{kg/m}^3]\)
- \( v \) = Velocity \([\text{m/s}]\)
- \( A \) = Cross sectional area \([\text{m}^2]\)

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7. CONCLUSION

The technology of sounding rocket has been developed for space applications and their spin-offs have dramatically improved human life, and no doubt continue to do so. In coming years for commercial and national defence space-related technologies are expected to multiply in many areas: propulsion, guidance and control, communications, navigation, tracking and data relay, weather forecast, remote sensing, surveillance, and interplanetary exploration.

As more launching are to be conducted, more possibilities for failure will be present themselves. The need for developing reliable launch systems will continue. My research work is to examine the appropriate tests that should be carried out in order to avoid failure and minimize cost and appropriate equipments for every test needed to be done.

**REFERENCES**


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