Apogee Components

PEAK OF FLIGHT

NEWSLETTER

Feature Article:

Educator's Plan: Build An Accelerometer

Cover Photo: Starlight Rocketry's Sparrow glider rocket kit. To get one today, visit:

www.apogeerockets.com/Starlight_Sparrow.asp

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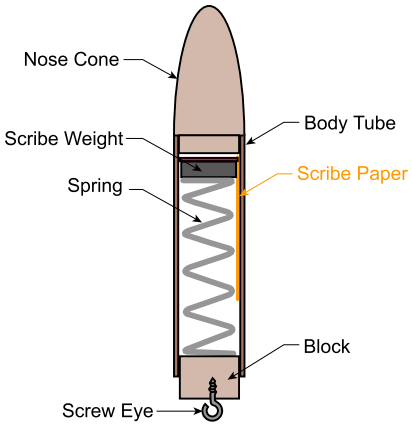
ISSUE 246 OCTOBER 20, 2009

Geeeeeeee! What an awesome ACCELERATION!

Written By Pierre Boivin

Editor's Note: Pierre Boivin is an educator living in Quebec, Canada. His native language is French, so please bear this in mind as you read this English edition of his curriculum. We left this mostly untouched so you can get a taste of the international flair of this article.

As space educator, I frequently read the Apogee Components literature. With the *Model Rocket Propulsion* (www.ApogeeRockets.com/mod_rocket_propulsion_bk.asp) publication, a companion comes freely, *Activities for Model Rocket Propulsion*. On the second page, Tim wrote "Measuring acceleration is hard to do". Hmmm! It is hard to believe, because I have measured acceleration for many years….. so easily. Let me show you!



The first of these onboard accelerometers for measuring the maximum acceleration was built and perfected by Lindsay Audin, of Hillside, New Jersey, in the early 1960s. Stine (1976)

AMROC company commercialized the onboard accelerometer in 1969. Stine in the 4th edition of his Handbook of model Rocketry presents the instrument. Essentially, it was a triangle lead mass, on a compression spring, scratching a *scribe paper* inside the instrument as a recorder.

Kranich introduced in 1995 a model with a rubber band and a centering ring as the recorder.

An accelerometer is used to measure how fast a rocket changes its speed in the vertical direction.

Our accelerometer uses a lead weight suspended by a rubber band to sense changes in the rocket motion. It is a modified Kranich concept.

It is a mechanical (Inertial-mass) accelerometer; mono axial (vertical); exclusively for positive acceleration; ranging from +1 g to +25 g.

You will learn to build your own accelerometer for pennies. Tim loves that too. This is so simple that everyone can build their own, launch it and calculate his rocket peak acceleration.

Material and Design

The list of material is quite simple and easily available:

10 cm of Airframe Tube 18/18 (Apogee Cat No 10086) (BT-20);
DO NOT use a blue motor mount (Estes), it's too weak!
2 centering rings 13-18 (Apogee Cat No 13028) (BT-20);
2 cm of an empty motor case 18 mm;
1 screw eye small size;
1 fishing sinker size (20 g);
1 micro torch (Micro-jet® from Solder-It®) using disposable lighter;
1 paper clip;
4 to 6 orthodontics rubber bands (Apogee Cat No 24002) and many spares;
Wood glue, of course; X-acto® and calliper.

Building the Accelerometer

Glue a centering ring (support) at one end of the body tube section. Let it dry.

Drill a tiny hole (the diameter of the paper clip) through the diameter of the glued centering ring.

Cut a 4 cm x 50 mm slot lengthwise on the body tube section at the opposite end of the centering ring.

Cut a 2 cm section of the 18 mm empty motor case. Put this section on a dish plate. With the micro torch melt the fishing sinker *(please take adequate precautions melting the lead...)* inside the section of the motor case. In a minute, screw the screw eye at the center of the melted lead. Let it cool. This is your inertial mass.

Hang your rubber band(s) to the screw eye.

Introduce this setup inside the tube;

Introduce a straight section of paper clip throughout the hole at side of the tube, throughout the rubber band, and

Continued on page 3

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Newsletter Staff

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Layout / Cover Artist: Tim Van Milligan
Proofreader: Michelle Mason

Continued from page 2

Build an Accelerometer Payload

through the hole at the opposite side of the tube! Understand!? OK

Introduce an Indicator-centering ring by the bottom of the tube, close, very close, to the bottom of the Inertial-mass.

Glue a centering ring (stopper) at bottom of the body tube section. Let it dry.

You are ready.

Calibrating the accelerometer (finding the spring constant – K)

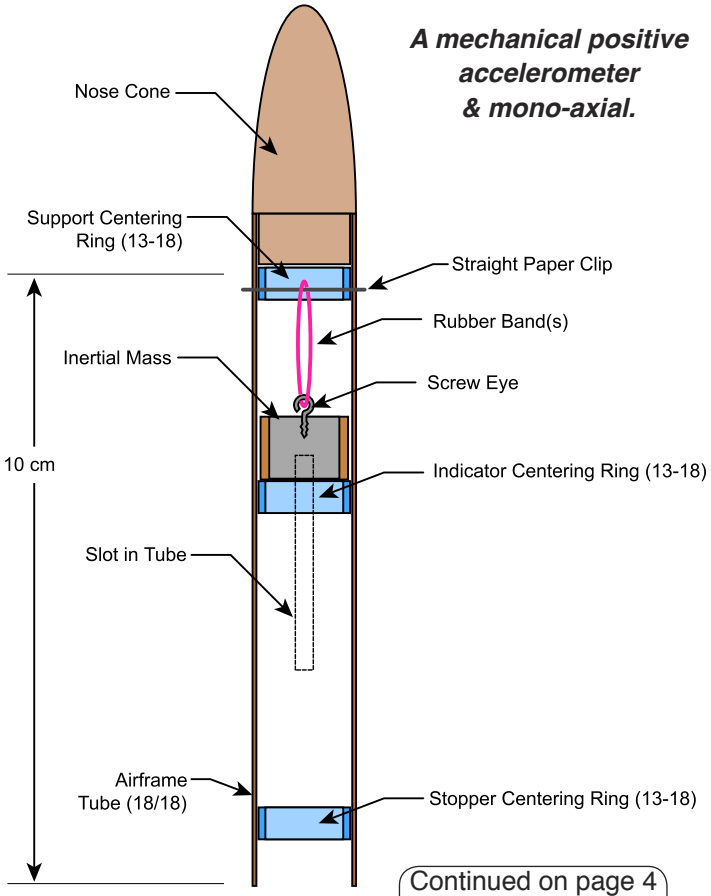
Assumption: We assume the rubber band stretch is linear (a constant amount for each increase in weight/g force).

Protocol

As shown in Figure 3, measure and note the length of the rubber band at rest (l).

Hang 50 g on the rubber band, simulating acceleration. Measure and note the length of the rubber band under tension and the force (in Newtons) on the dynamometer (L).

Hang 100 g on the rubber band. Measure and note the length of the rubber band under tension (L).



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Build an Accelerometer Payload

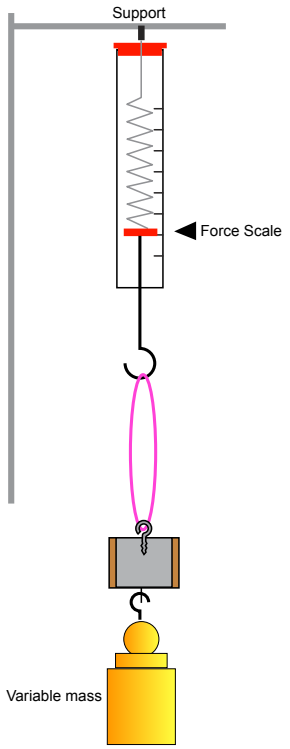

Figure 3: Calibrating the accelerometer (finding the spring constant - K).

Measure and note the length of the rubber band at rest (l).

Hang 200 g on the rubber band. Measure and note the length of the rubber band under tension and the force (in Newtons) on the dynamometer (L).

Measure and note the length of the rubber band at rest (l).

Hang 500 g on the rubber band. Measure and note the length of the rubber band under tension and the force (in Newtons) on the dynamometer (L).

Measure and note the length of the rubber band at rest (l).

And so on, up to 1,000 g (1 Kg).

Fill up the table and graph length (independent variable) vs force (dependent variable).

Mass (g)	Length (cm)	Force (N)
50		
100		
200		
500		

Table 1: Collect data on the length of the rubber band with different weights attached.

Compute the spring constant - K. It is **EXCLUSIVE to EACH rubber band** or set of rubber bands or spring. So, do it with every one. The **spring constant** is demonstrated by the following equation:

If **F = m * a** then **F = k * length** and **M * a = k * length**; so **K = (m * a) / length**. But, it's easier to get K graphically by the slope of the curve.

Using the accelerometer

Newton's first law of motion

Yes, I know … one more time; but it's so fundamental.

A body in motion will stay in motion and a body at rest will stay at rest unless an external force acts upon it.

As our rocket is launched and accelerates, a mass at rest wants to stay at rest. The rocket accelerates upright

Continued on page 5

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Continued from page 4

Build an Accelerometer Payload

from this Inertial-mass stretching a rubber band or a spring (an extension spring). As the rubber band stretches a tension is developed which increases more and more by the accelerating rocket. The tension in the rubber band (or the extension spring) is proportional to the acceleration of the rocket and the Inertial-mass used.

When the rubber band stretches during acceleration, the Inertial-mass pushes against the Indicator-ring.

The Indicator-ring, pushed by the Inertial-mass, slides freely inside.

As the acceleration decreases at burnout, the rubber band contracts and pulls the Inertial-mass back up to his original level.

The Indicator-ring stays at the furthest level by the friction between the ring side and the inside of the accelerometer.

With a metric calliper (or a ruler), **measure the distance, in millimetres, between the pencil marks** (L & l). The measuring is the difference between the TOP of the Indicator-ring at rest (on the launch pad) and the TOP of the Indicator-ring at the recovery.

With the **mass** of the mass and the **Force** in the accelerometer you can get the **acceleration!**

Experimentation

You have a big, big choice for the loader: Quest Payloader One®, Sky Dynamo®, Quest Magnum Sport Loader® or Quest Zenith II® are fine.

Protocol

1) Make a general mechanic verification of the accelerometer.

2) Check the free motion of the Inertial-mass.

3) Introduce the Indicator-ring in the bottom of the accelerometer.

4) Slide the Indicator-ring as close as possible under the Inertial-mass.

5) **Make a pencil mark of the start position** of the Indicator-ring with a sharp & dark pencil, easily spotted after the flight. Use the TOP of the Indicator-ring as a start position.

Identify this mark as 1 g.

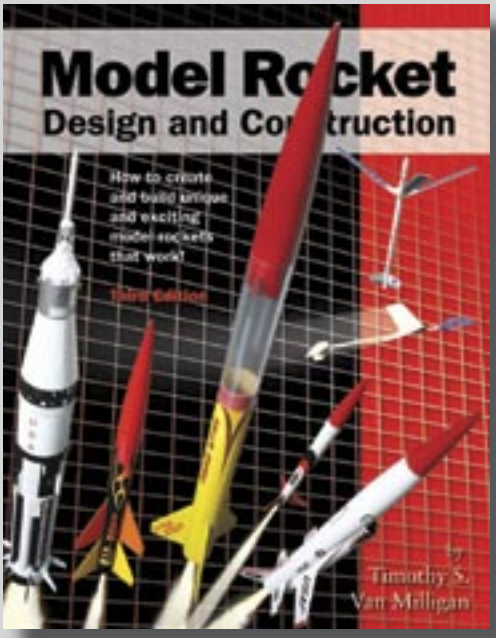
*** This mark is a frequent source of mistakes. Make the mark very precisely, it's the position (**L**) where every measurements will start, so ….*

6) **Introduce the accelerometer vertically in the payload** section of the rocket.

Use bubble wrap or Kleenex® to secure vertically the instrument if you are putting it inside a larger diameter rocket. Check the fitting of the nose cone.

7) **After the flight**, extract the accelerometer with care. DON'T move the Indicator-ring, **mark its position**. Use the TOP of the Indicator-ring.

Continued on page 6



Model Rocket Design and Construction

By Timothy S. Van Milligan

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This new 328 page guidebook for serious rocket designers contains the most up-to-date information on creating unique and exciting models that really work. With 566 illustrations and 175 photos, it is the ultimate resource if you want to make rockets that will push the edge of the performance envelope. Because of the number of pictures, it is also a great gift to give to beginners to start them on their rocketry future.

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Continued from page 5

Build an Accelerometer Payload

*** This mark is a frequent source of mistakes. Make the mark very precisely; it's the position (**I**).*

8) With a metric calliper (or a ruler), measure the **distance, in millimetres, between the pencil marks** (L & I).

9) Make a general mechanical verification of the accelerometer.

Results

Newton's second law of motion

Yes, I know … one more time; but …. OK OK.

A force is equal to the mass times the acceleration or **F = m * a.** As our rocket is launched and accelerates the force in the rubber band equals the acceleration of the rocket times the mass we used. So the mass is measured easily, and if we can measure the force in the rubber band, BINGO we get the third parameter, the acceleration.

The friction force between Indicator-ring and the body tube is assumed to be zero.

If **F = m a**,

so F / m = a, then

[K * (L – I)] – p / m = a

Example:
K = rubber band slope = 3.92 N/m
L = Length of rubber band at rest = 0.5 cm
I = Length of rubber band on tension (cm)
p = weight of inertial-mass = 0.196 N

[3.92 * (0.5 – I)] – 0.196 / 0.020 = acceleration

and the number of gees is g = a * 9.81

The g's unit is computed by the following equation:

g = a * 9.81 m/s²

g (gravity) is a unit of acceleration. It is based on terrestrial gravity (9.81 m/s²) as a unit, so:

1 g = 9.81 m/s²

2 g = (9.81 m/s²) * 2 = 16.62 m/s²

3 g = (9.81 m/s²) * 3 = 29.43 m/s²

And so on .....

Applications

In 1969, AMROC designed many experiments for mechanical accelerometers. Let me summarize some of them.

1) **The best way to connect and ignite a cluster of motors.**

An application of your mechanical accelerometer is to setup the best way to connect & ignite a cluster of motors. Many have tried but no one got a real and complete solution. So, knowing the maximum acceleration, you can assess if all motors were perfectly ignited.

If the max acceleration doesn't equal the total thrust /rocket's weight, then motors weren't ignited in synch. TADAAAAAA !

2) **The thrust of the ejection charge.**

One more application of your mechanical accelerometer is the measuring of the thrust of the ejection charge. A lot of precautions should be taken:

To prevent burning your launch pad, boost the level of the rocket by 15 cm;

Tape tightly the rocket to the rod with electric tape at 2 places on the body tube;

Take care for a free ejection;

Continued on page 7

Continued from page 6

Build an Accelerometer Payload

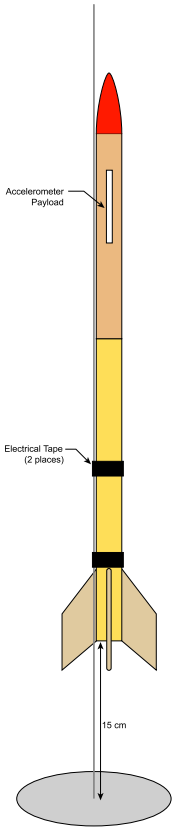

Figure 4

Take care for a frictionless moving between the launch lug of the payload and the launch rod;

Take care for a frictionless nose cone – body tube junction.

3) **My rocket's drag**

One more application of your mechanical accelerometer is the measuring of drag; so useful to the optimization of a rocket *design*. Use this equation to compute drag (D):

$$D = P - (g * m)$$

D = Drag (N)
P = average thrust (N)
g = number of g
m = mass of rocket (g)

Discussion

When you analyze your own data, don't forget the fact that it is an approximation.

With an elementary instrument like a *home-brewed* mechanical accelerometer, your data represents ***a relation*** between variable x and variable y.

A series of trials should be performed for the assessment of the precision level of your accelerometer. A ***mean*** (based on 10x trials, at least) with the ***standard deviation*** generates ***a fair approximation***.

NEVER ASSUME ONE RESULT AS
A FAIR AND ACCEPTABLE RESULT!

Check & re-check the **perfect** ***return to 0*** of the rubber band at rest. So, **NO residual constraints** should be on the rubber band.

Some low acceleration can generate imprecision relate to an **imperfect** ***return to 0*** of the accelerometer.

If your data is weird, ***re-check your assumptions***: without spin, vertical flight, frictionless launch lug, …..

Now, a general call to everyone, let me know : How can this accelerometer be redesigned so it is more sensitive or more accurate? My email address is: marielaurenceb@sympatico.ca.

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Continued on page 8

Continued from page 7

Build an Accelerometer Payload

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About The Author:

Pierre Boivin, of Quebec, Canada, is a former infectious diseases epidemiologist, microbiologist, economist & bioethician. He is currently retired, and has been a full time space educator (trained at the Canadian Space Agency) at the Quatre-vents High school for 8 years.

Reader Questions and Answers

Responses By Tim Van Milligan

Just finished the Apogee Saturn 1B about two weeks ago. Took it for a walk and here is the pic! -- Bill Perretti

VERY COOL!!! I love it. I'd say you did an excellent job on building the kit. Keep up the good work.