



# Tech Report 3

## Single Station Tracking

In this activity we will create a Single Station Tracking altitude calculator. We will be using the spreadsheet in LibreOffice called "Calc" (this was done in Version 6.0). Earlier versions of Calc should also work. You should also be able to use this activity in other spreadsheet programs such as Excel.

A spreadsheet is a good way to start using the power of a computer to perform number calculations. In fact a spreadsheet is designed primarily for number crunching.

### The Math of Single Station Tracking

Before we jump into creating the spreadsheet, we first need to understand the math behind calculating the altitude.

The basis of optical tracking in model rocketry is the triangle. We know a triangle consists of three

angles (labeled A, B and C) and three sides (labeled a, b and c), for a total of six parts.

The symbol  $\angle$  denotes an angle. In trigonometry, capital letters always represent angles, with lowercase letters representing the side opposite the angle. Two capital letters together represent distance. AC would represent the distance from the angle A to angle C.

There are several more terms you need to know before we get started. The triangle displayed in Figure 1-1 is a special type, known as a *90-degree* or *right triangle*. We know this is a right triangle because of the square shape at the  $\angle C$ . This shape always indicates you are looking at a right triangle.

The next term is the *hypotenuse*. This is always the longest side of a right triangle (labeled as side c in the figure 10-x above).

The last term to understand is *tangent* which is simply a ratio or a numerical relationship. The symbol 'tan' is used when seen in equations.

Another thing to remember is that when you are working with any triangle, knowing the values of two angles and the length of one side allows you to calculate the remaining sides and angle. This is important to us in calculating altitude.

When working with a right triangle, the tangent is the ratio between the length of the opposite side and the length of the nearest side. So the tangent of  $\angle A$  is the ratio of the length of side a to the

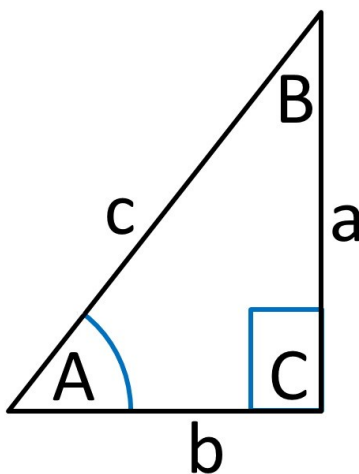


Figure 1-1: Six parts of a right-angle triangle

length of side b. To write this out as an equation, it would appear as follows:

$$a = \tan A (b)$$

To determine the length of side a, take the length of side b and multiply it by the tangent of  $\angle A$  (The ratio of the length of side a, to the length of side b). In a right triangle, there is no need to be constantly calculating the tangent of  $\angle A$ . This is a consistent number so it is easy to calculate using a calculator or spreadsheet that includes the tangent function.

In single station tracking you have one person using a tracking scope that observes the model during its flight. Like other forms of optical tracking, the altitude calculations are based on the triangle.

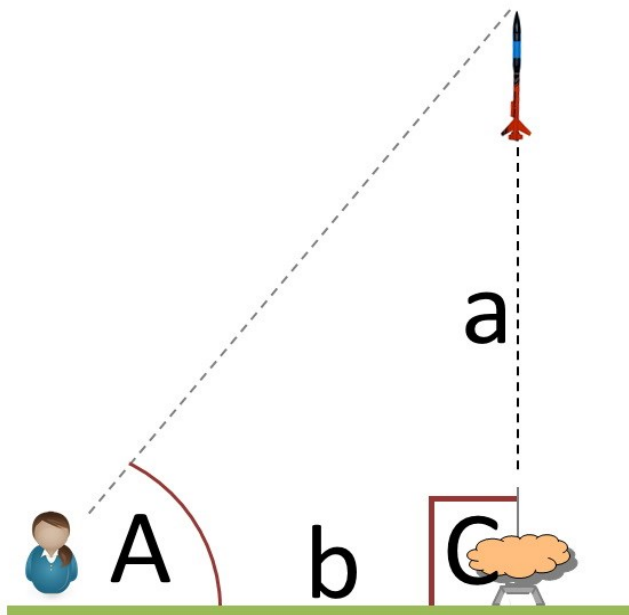


Figure 1-2: Tracking a Model Rocket

When tracking a model (see Figure 1-2), you watch the model during its flight from point A. The distance from the launch pad to your location is AC, and in rocketry this is referred to as the baseline. If you have a fairly good idea how high

the model will go, you would want to be about the same distance from the launch pad. The rocket is tracked to its highest point, or apogee, and this is point B. The line of sight is AB. The angle on the tracking scope at apogee is  $\angle A$ . To find the length of BC, the altitude of the rocket, we multiply the baseline times the tangent of the angle at apogee. If we were to write this out as an formula it would look like this:

$$\text{Altitude} = (\text{Baseline distance}) \times (\text{Tangent } \angle A)$$

For example, let's say we are using a 100-meter baseline. The model is launched, and the tracking scope shows an angle of 57-degrees at apogee. The tangent of 57-degrees is 1.53986 (obtain this from a Table of Sines and Tangents at [www.mymathtables.com/trigonometric/tangents-0to90-tables.html](http://www.mymathtables.com/trigonometric/tangents-0to90-tables.html)). Therefore to calculate the altitude, we multiple 100 meters times 1.53986, for an altitude of 153.986 meters.

$$100 \times 1.53986 = 153.986$$

## The Spreadsheet Layout

Now that we know the math, we can look at converting the math formula into one that a spreadsheet can use. But first let's take a look at how a spreadsheet is laid out.

When looking at a spreadsheet, you will notice that there are letters going across the top (the blue row) and numbers down the left side (the gray column). These are your coordinates in the spreadsheet. When referencing a cell, we use a combination of the letter (to identify the column) followed by the number (to identify the row). The baseline entry for Station A is located in Cell C4. The elevation entry for Station A is located in Cell C5 (see Figure 1-3 in the next column).

	A	B	C	D	E
1	<b>Single Station Altitude Reduction</b>				
2					
3	<b>Station A</b>				
4		Baseline			
5		Elevation			
6					
7	<b>Results</b>				
8		Altitude		meters	
9				feet	
10					
11					

Figure 1-3 Single Station Calculator Spreadsheet

In our sample we have highlighted in yellow the numbers entered by the user, in this case Cells C4 and C5. The altitude figure is calculated by recreating the math formula in a way the spreadsheet can understand and reuse.

## Creating the Altitude Calculator

Open LibreOffice Calc and create a spreadsheet that looks like Figure 1-3. All we have done so far is to create a form. The spreadsheet doesn't do anything yet. For that we must convert our formula for single station tracking into something the spreadsheet can recognize and use. Our formula for single station altitude reduction is:

$$\text{Altitude} = (\text{Baseline distance}) \times (\text{Tangent } \angle A)$$

## Creating the Formula

The 'trick' to having this work in a spreadsheet is to break down the equation and convert it into a calculation that is usable by the spreadsheet. In this case, we will recreate the entire formula and insert it into Cell C8.

Click on Cell C8. A cursor will appear in formula entry box at the top of the sheet. When creating a formula in a spreadsheet you start with the equal

sign (=). This lets the spreadsheet know that you are now entering a formula. We want our spreadsheet to display the results in Cell C8, and this is where we will enter our formula. Therefore, in Cell C8 we would start with "=".

Next we tell the spreadsheet where it can find the data for our baseline. In this case it is located in Cell C4. So our formula at this point looks like this:

$$=(C4)$$

The next part of the formula has us multiply the baseline by tangent of  $\angle A$ . On a spreadsheet we indicate multiplication using the star symbol (\*). So our formula now looks like this:

$$=(C4)*$$

The data for the angle of A is found in Cell C5. In this case we are going to use the Arc-tangent of the elevation so on the spreadsheet we will enter "ATAN". Now our formula looks like this:

$$=(C4)*(ATAN(C5))$$

### **Why Arc Tangent?**

*For every trigonometry function, there is an inverse function that works in reverse. The inverse functions have the same name but with the prefix 'arc' in front. The inverse of tan is arctan. When we see "arctan A", we understand it as "the angle whose tangent is a".*

In the screen shot on the next page (Figure 1-4) you can see that Cell C8 has been selected and the formula has been entered. Because no data has been entered for Baseline or Elevation, the results are shown as 0.

C8					
	A	B	C	D	E
1	<b>Single Station Altitude Reduction</b>				
2					
3	<b>Station A</b>				
4		Baseline			
5		Elevation			
6					
7	<b>Results</b>				
8		Altitude	0	meters	
9				feet	
10					

Figure 1-4: Formula entered into Cell C8

Next we will use the same entries as in our earlier example. Enter the baseline of 100 into Cell C4, and the elevation of 57 into Cell C5. If we have entered everything correctly, it should look like the following:

C5					
	A	B	C	D	E
1	<b>Single Station Altitude Reduction</b>				
2					
3	<b>Station A</b>				
4		Baseline	100		
5		Elevation	57		
6					
7	<b>Results</b>				
8		Altitude	155.3254267	meters	
9				feet	
10					

Figure 1-5: Initial results in meters

Congratulations! You now have a working altitude calculator. But let’s do just a little more coding to make it a bit more useful.

### Convert Meters to Feet

There are times when we want to see the results in feet, rather than meters. This is especially true in the United States where the metric system isn’t in wide spread use. To accomplish this we have added Cell C9 for that use. First, however, we need to know the formula for converting meters to feet. Here is that formula:

$$feet = meters \times 3.2808$$

As before we will enter the formula in Cell C9, starting with an equal sign. Next we want to take the answer in Cell C8 (which is in meters) and multiply it by 3.2808. Our formula in Cell C9 should appear as follows:

$$=C8*3.2808$$

Our spreadsheet should now look like the one below (Figure 1-6):

C9					
	A	B	C	D	E
1	<b>Single Station Altitude Reduction</b>				
2					
3	<b>Station A</b>				
4		Baseline	100		
5		Elevation	57		
6					
7	<b>Results</b>				
8		Altitude	155.3254267	meters	
9			509.5916598	feet	
10					

Figure 1-6: Altitude results converted to feet

### Cleaning Up the Results

The results displayed in Cells C8 and C9 are taken out 12 decimal places. For our purposes we really don’t need anything that precise. By reducing the visible decimal places we can make the results more readable. To do this we are going to use the *Format Cells* dialog.

Begin by highlighting Cells C8 and C9. Right-click and select “Format Cells…” from the pop-up menu. You should now have a dialog box displayed on the screen. Make sure you are on the Numbers tab.

About half way down the box you should see “Options” and directly below “Decimal places:” with a number box just to the right. Increase the number of places to “4” (it should look like the dialog box in figure 1-7 in the next column), then click the “OK” button.

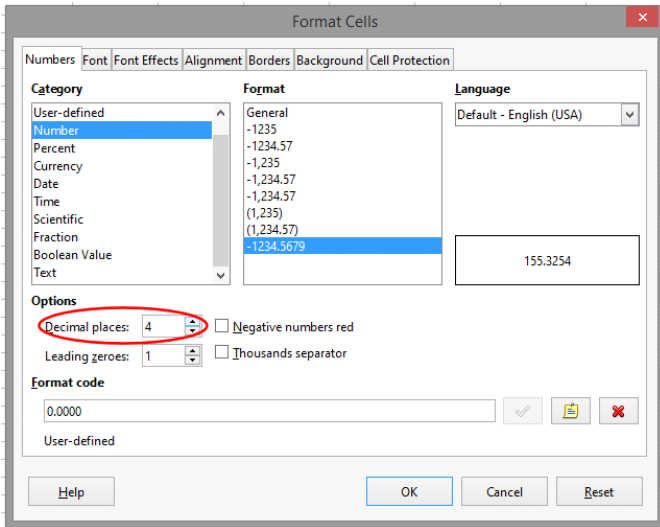


Figure 1-7: Format Cells dialog box in LibreOffice Calc

The spreadsheet should now look like the following (Notice that it rounded up the altitude in Cell C9):

	A	B	C	D	E
1	<b>Single Station Altitude Reduction</b>				
2					
3	<b>Station A</b>				
4		Baseline	100		
5		Elevation	57		
6					
7	<b>Results</b>				
8		Altitude	155.3254	meters	
9			509.5917	feet	
10					

Figure 1-8: Altitude results reduced to four decimal places

You can adjust the formatting of the results to meet your needs. If 4 decimal places is too many, reduce it to 2 places or even zero decimal places. This formatting doesn't change the actual results of the calculation, but only how it appears.

## Organize Your Spreadsheets

The last thing we want to look at is how to organize your spreadsheets. Most spreadsheets today allow you to have multiple spreadsheets in a single file. In this case, we could save the one spreadsheet under the file name "Single Station

Tracking." However, we can create additional spreadsheets to do other types of altitude calculations (such a Two Station Elevation Only). By organizing our spreadsheets, we can have all of these spreadsheets in a single "Altitude Calculator" File.

The easiest way to organize your spreadsheets is through the use of tabs. At the bottom of the spreadsheet is a tab (see figure 1-9 below). Double-click on the tab and in the dialog box, rename the sheet "Single Station Altitude Reduction" and then click the "OK" button.

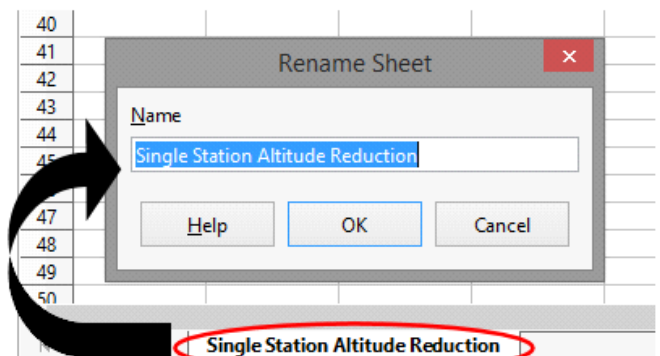


Figure 1-9: Rename tab

Finally, click on the "Save" button and save the spreadsheet as "Altitude Calculator.ods".

## Finishing Up

You can use this calculator at any time to determine how high your model flew. Simply enter your data for the baseline and elevation into the yellow cells. The results will be displayed automatically in the Results section.

## If You Enjoy Rocketry, Consider Joining the NAR

If you enjoy model rocketry and projects such as the Arduino Launch Control System, Project:Icarus, The Dyna-Soar and others, then consider joining the National Association of Rocketry (NAR). The NAR is all about having fun and learning more with and about model rockets. It is the oldest and largest sport rocketry organization in the world. Since 1957, over 80,000 serious sport rocket modelers have joined the NAR to take advantage of the fun and excitement of organized rocketry.

The NAR is your gateway to rocket launches, clubs, contests, and more. Members receive the bi-monthly magazine “Sport Rocketry” and the digital NAR Member Guidebook—a 290 page how-to book on all aspects of rocketry. Members are granted access to the “Member Resources” website which includes NAR technical reports, high-power certification, and more. Finally each member of the NAR is covered by \$5 million rocket flight liability insurance.

For more information, visit their web site at <https://www.nar.org/>

