

The GaugeCam system is only as precise as the uncertainties during the whole chain of measurements. Having the most expensive camera with the highest resolution and a great software cannot yield good results if the background target is not properly installed and on a stable fashion in the field. So it is very important to diminish all uncertainties everywhere possible, and particularly during installation.

- A very stable background is the first key. This means that the background itself is unlikely to expand or shrink very much with temperature and humidity variations. It also means that once installed in the field, its placement remains very stable, and changes less than 1 mm in elevation depending on the flow and temperature conditions.
- Second, it is essential to measure as precisely as possible the exact placement of the center of the bowties or fiducials. It is in the lab that the vertical and the horizontal distances between the fiducials can be measured most precisely. Ideally, measurements would be done with uncertainty of no more than 0.5 mm; doing better than that would require very special equipment which are probably beyond what can easily be done.
- Third, it is essential to install the background as vertical as possible, or if not possible at a precisely known angle. It is also recommended to install the background as horizontal as possible, although the software can accommodate for that to some extent. In the end, it is essential to be able to document as precisely as possible the coordinates of each fiducial in real world coordinates, i.e., against a known and stable benchmark in the field.

## Background configuration

In the current situation (Oct. 2013), our background is made of three columns, a white column in the center, and on the sides, two columns of four vertical bowties or in correct machine vision terms, fiducials (Figure 1). At the bottom of the background, there is a rather wider strip of white compared to the top. This is on purpose and has been added because during low flow conditions, where the water level would be within 10 cm below the bottom of fiducials, the background bottom may form a line in images of very clean waters which tend to trick our GRIM software (because of light refraction).

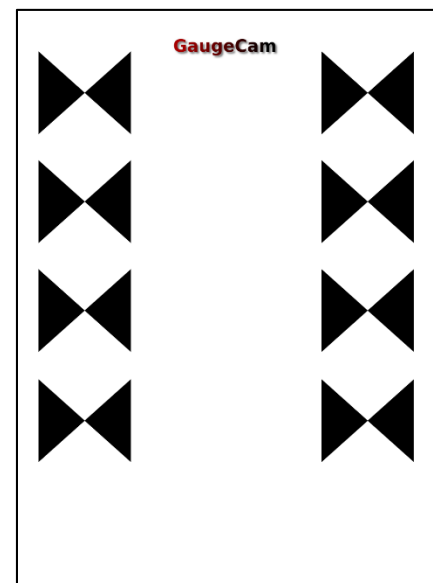
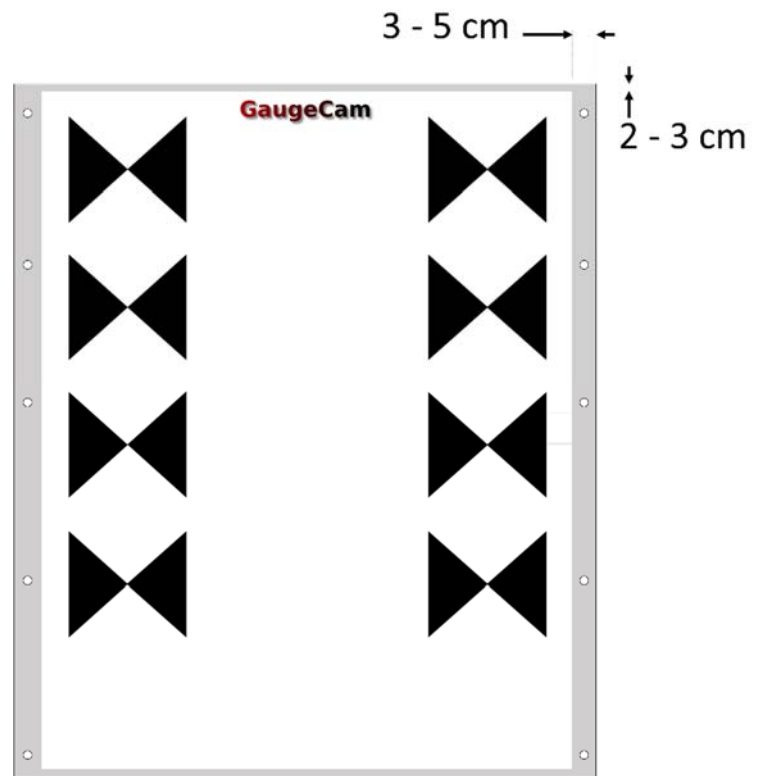


Figure 1: Configuration of the GaugeCam target background

You either received the background as such or you were sent a pdf file so that you may print and laminate the background yourself. In the second case, we recommend that you go to professional lamination companies, which make exterior signs. Their lamination techniques are usually very good, certainly a lot better than anything a non-professional could do. Ask for a plastic lamination for a durable exterior sign. Incidentally, our experience with these companies and their products is that the black ink used is visible in IR lights at night. We have observed that with some inkjet prints we did in-house, the black ink appeared transparent in these conditions.



*Figure 2: Recommended dimension of the laminating support for the background. Note the holes bored on the sides should also be counter sunk for better fit.*

Ideally, the background dimensions should not change regardless of the temperature and moisture conditions. We highly discourage for that reason the use of wood or metal as a laminating support. We have been quite successful with the use of Plexiglas, although we do not have definite data showing that the dimensions of the background did not change. Our subjective intuition is that the dimensions changed by less than 1 mm between winter and summer from the top to bottom in North Carolina, USA, with temperature variations ranging from  $-7^{\circ}\text{C}$  to  $+37^{\circ}\text{C}$ . After lamination, the background should be perfectly flat, sturdy and last a long time. It can be fragile to knocks, however, so protection against scratching during transportation and installation is highly recommended.

The Plexiglas support dimensions should be such that its dimensions are slightly bigger than the ones of the laminated background. We recommend about 2cm extra at the top and bottom and between 3 to 5 cm on the sides (Figure 2). The extra width is used to bore holes to attach the Plexiglas on its support in the field. The holes should be counter sunk for better fit.

## Installation in the field: theoretical considerations

In the field, the background must be installed parallel to the direction of flow and on the side to minimize its impact on flow (Figure 3). Install the camera as perpendicular to the background plane as possible (Figure 4).

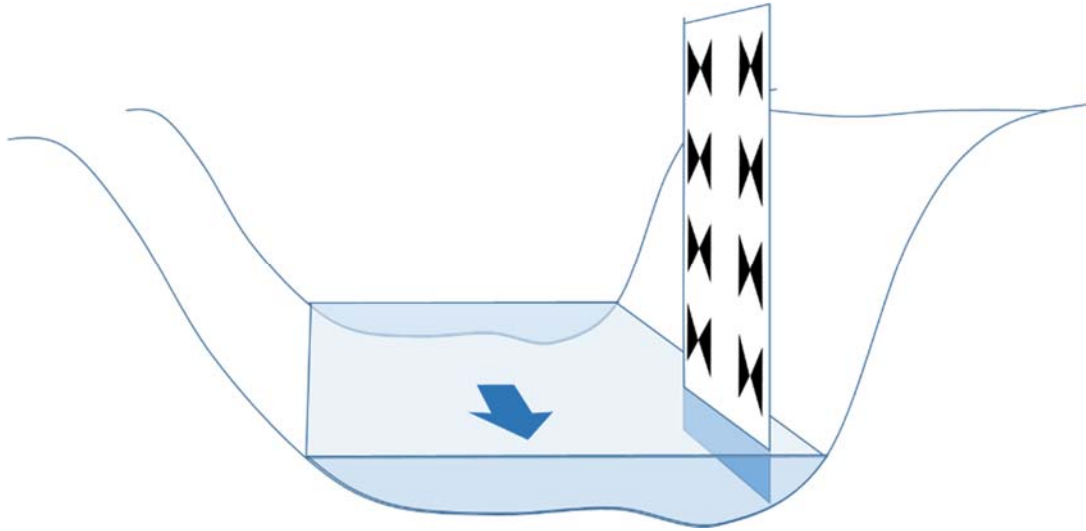


Figure 3: Place the background generally parallel to flow and on the side of the channel to minimize impact on flow

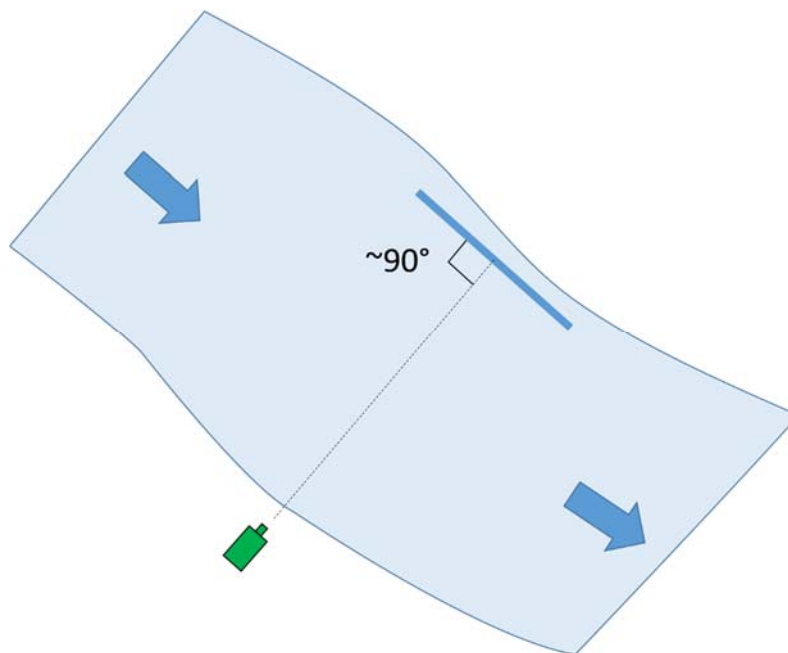
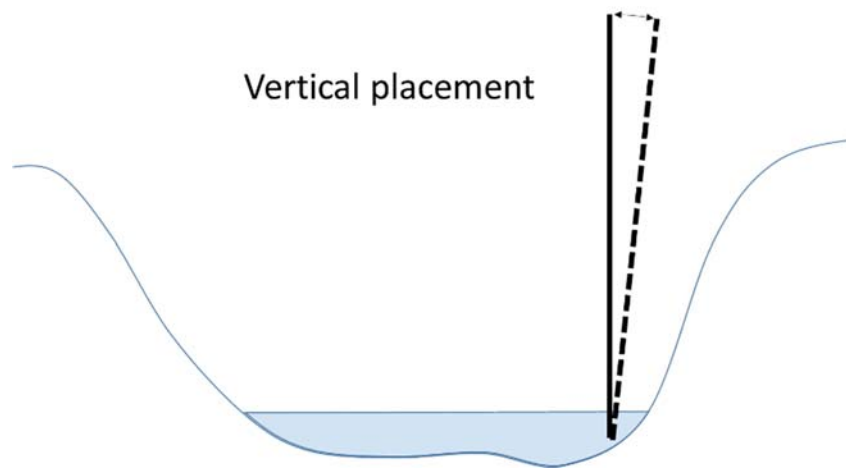
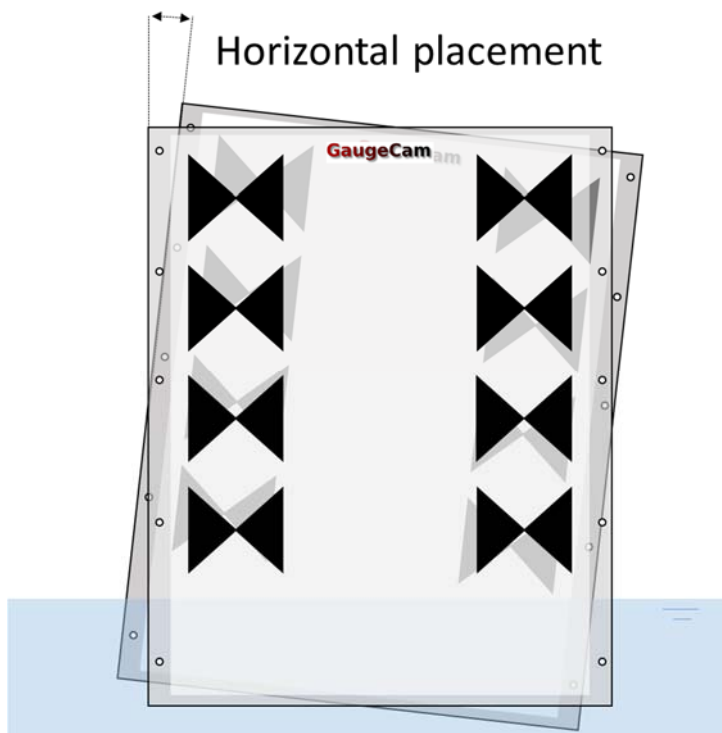


Figure 4: Top view of the background installation in relation to the channel and to the camera (in green)

It is very important to install the target background as horizontal and vertical as possible (Figure 5 and Figure 6). For this, you can use regular or laser levels. With a vertical background, the distance between fiducial centers will correspond to actual vertical distances. An uncertainty of 1 or 2° is not going to make much difference in the reading, actually. Should there be no choice but to install the background at a significant vertical angle (e.g. against a bridge pier, etc.) it is extremely important to precisely measure the angle so that linear distances between fiducials be transformed into vertical and horizontal distances.



*Figure 5: Longitudinal view showing that the background should be installed as vertical as possible.*



*Figure 6: Side view of background illustrating that the background should be installed as horizontal as possible*

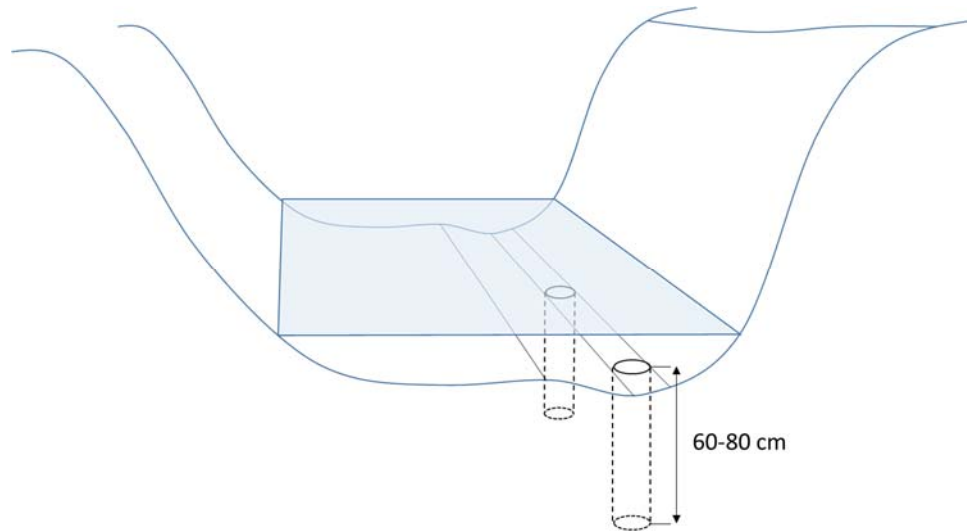
Perfect horizontality is nearly impossible to obtain in the field (see below). The software creates a grid using the center of the fiducials as benchmark to extrapolate water level values to real world coordinates. The real world coordinates (X and Z; see last page) of each fiducial must be carefully measured and consigned and sent to GaugeCam ([team@gaugecam.com](mailto:team@gaugecam.com)). Having the background almost perfectly horizontal allows for much easier calculation of the coordinates. After installation (see below), we recommend to survey the installation, and carefully measure and consign the exact X and Z coordinates of each fiducial point. Having measured the placement in the lab, should make extrapolation of the coordinates of each fiducial easy from the measurement of the bottom and top two fiducial centers.

## Installation in the field: practical considerations

So far, we have been successful with the use of 10×10 cm sharpened and treated (still as wet as possible) wooden posts buried at least 60-80 cm in the sediment, serving as a support for the background on its up- and downstream sides (Figure 7). We have not had to deal with gravel, yet. If gravel were to be the substrate for your station, we suggest to pound in thick pieces of metal such as rebar 2.5 cm in diameter, almost 1 m in the substrate and 1 m above the substrate. Then attach 10×10 cm wooden posts to the rebar as tightly and along as many points as possible. The background would then be attached to the wood itself rather than directly to the rebar.

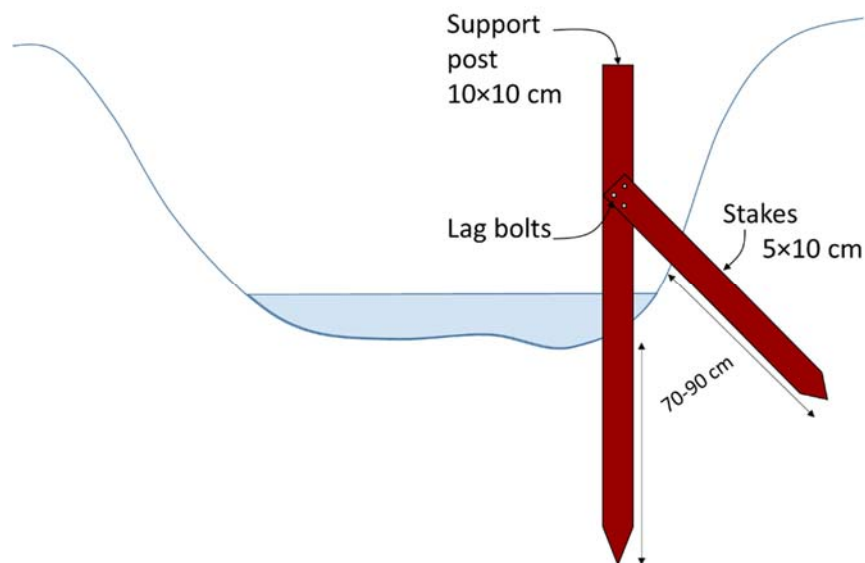


*Figure 7: general view of a background installed in a salt marsh in North Carolina*



*Figure 8: Bore holes in substrate using a handheld auger down to at least 60 cm before pounding wooden posts*

In relatively soft sediments, we have used slightly undersized augers to make the first part of the hole and then used sledge hammers to drive them in further (Figure 8). Ideally these posts need to be as vertical as possible and as wet as possible so that they will not twist too much after installation. To install and maintain them as vertical as possible, we suggest to add braces to the side using 5×10 cm stakes driven into the bank using sledge hammers (Figure 9). Clamp the stake to the support post using e.g., C-clamps when the support post is adjusted vertical. Then use lag bolts and washers to attach the two together. Our experience is that it makes for a very sturdy and stable attachment system.

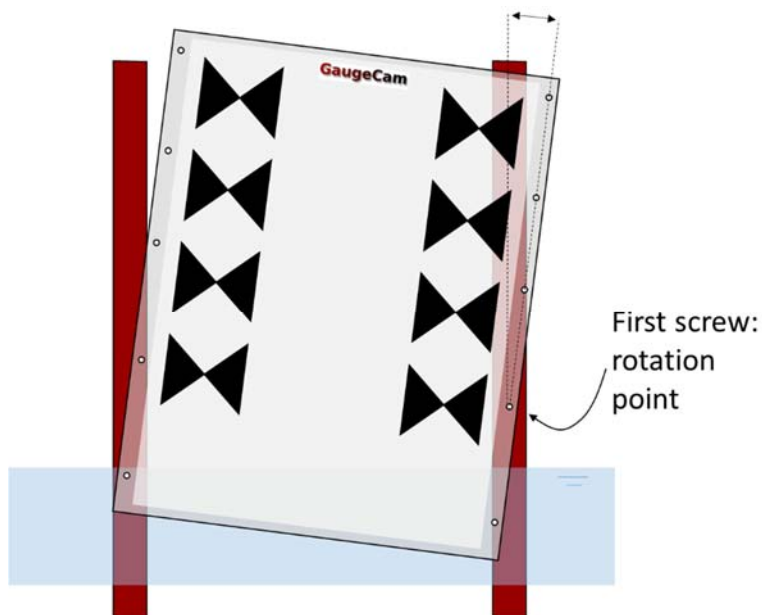


*Figure 9: Schematic for bracing and maintaining vertical support posts*



Best time for installation of the background is during low flow conditions. It is not an obligation but it makes things a lot easier. If installation cannot be done during low flow, it is necessary to be able to know that at low flow, all the fiducials will appear on the images, i.e., the water level is lower than the bottom of the bottom fiducials. This is very important because the software needs all 8 fiducials to appear in the picture at one point for initial calibration. During low flow installation, one can easily adjust the height of the background so that all fiducials are above water (we recommend 2-3 cm difference between the low stage and above is enough).

Once the height where the background must be installed is known, the background is placed against the two posts. Using a level, one can see in which direction it is leaning (towards or away from the camera). Again, it is important to realize that despite all the previous efforts, the probability for the background to be vertical is still not very high, but this is not too problematic since additional corrections can still be done. Upon the previous observation, one can decide which corner needs to be attached to the post first. This corner will be the one which tends to put the background the most out of verticality. The background can then be adjusted to verticality using shim or thin pieces of wood or even better, pieces of PVC of varying thicknesses.



*Figure 10: Attach background around a first rotation point corresponding to the point tending to put the background out of verticality*

Once this is done, the background rotates around the first screw at about the right height so that all fiducials are visible during low flow conditions. The next step is to put the background as horizontal as possible. In still water, the best benchmark might be the water level. Laser levels can also be used nicely although the uncertainty on horizontality over 50 cm is probably above 0.5 mm. Ideally, the uncertainty on horizontality should not exceed 1 mm over 50 cm in the stream direction. It is very difficult to

adjust better than that. Use a C-clamp while adjusting for horizontality and clamp the background against its support when this is achieved. Be sure to check for verticality. If not vertical, add PVC or wood shim between the background and the support until the background is nicely vertical. This may require to readjust for horizontality in an iterative process. Attach the second corner of the background using a screw. Make a pilot hole for better result. Check after attachment that the background has remained horizontal as during the screwing process, it might have shifted a little bit. If the second screw has been added nicely perpendicular to the background the background should not have moved enough to be noticed. The background is now horizontal! Five screws per post are a minimum. Ten screws attaching a 1.5 cm thick Plexiglas against the wooden support recommended makes for a remarkably sturdy ensemble which would take large debris to dislodge.

Once all this is done, and despite all efforts to place the background properly, chances are that it is not really perfectly horizontal or vertical. This is actually still all right, as long as the exact X and Z of each fiducial can be measured and consigned. For all water level measurements, a meaningful benchmark or datum is required so that measurements can be reliably verified over time. At this time, it is important to know what the stage at the middle point of the background is compared to this benchmark. Water level can then usually be a good reference for a horizontal line.

Measure, using a precise meter stick, the height of at least the four bottom fiducial centers. If the meter available stick is longer, measure more. These measurements will provide information on by how much the background is rotated. A laser level which can measure both vertical and horizontal lines, can provide very valuable information on the actual rotation of the background. Consign this information on a notebook. Back in the lab, calculate the X and Z of each fiducial center in real world coordinates. As much as the Z is obviously very important, and is measured to a known benchmark, the X does not have a true benchmark, but it just as important. We have used the distance to the upstream border of the background at stage = 0 as a reference. If the background is perfectly horizontal, all the X values for the four vertical fiducials of each column will end up being the same. But a 1 mm difference in Z between the two columns of fiducials, can make a difference of 2-3 mm in X between the bottom and the top fiducial, and this matters in the end.











## Template for fiducial centers

Use the template below and fill the boxes corresponding to coordinates of each of the fiducial centers, which have been calculated from the measurements performed in the field. Please scan and send this sheet back to [team@gaugecam.com](mailto:team@gaugecam.com).

Customer name or company: \_\_\_\_\_

Name the station: \_\_\_\_\_ ( + name to be used on the picture file names)

Latitude of the station : \_\_\_\_\_ Longitude of the station : \_\_\_\_\_

GaugeCam	
 <div>X=     mm Z=     mm</div>	 <div>X=     mm Z=     mm</div>
 <div>X=     mm Z=     mm</div>	 <div>X=     mm Z=     mm</div>
 <div>X=     mm Z=     mm</div>	 <div>X=     mm Z=     mm</div>
 <div>X=     mm Z=     mm</div>	 <div>X=     mm Z=     mm</div>









## Template for fiducial centers

Use the template below and fill the boxes corresponding to coordinates of each of the fiducial centers, which have been calculated from the measurements performed in the field. Please scan and send this sheet back to [team@gaugecam.com](mailto:team@gaugecam.com).

Customer name or company: \_\_\_\_\_

Name the station: \_\_\_\_\_ ( + name to be used on the picture file names)

Latitude of the station : \_\_\_\_\_ Longitude of the station : \_\_\_\_\_

GaugeCam	
 <div>X=    mm Z=    mm</div>	 <div>X=    mm Z=    mm</div>
 <div>X=    mm Z=    mm</div>	 <div>X=    mm Z=    mm</div>
 <div>X=    mm Z=    mm</div>	 <div>X=    mm Z=    mm</div>
 <div>X=    mm Z=    mm</div>	 <div>X=    mm Z=    mm</div>