Preliminary Design report

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The Project:

Our goal is to design a video readout system for an alignment telescope to increase the ease of use with the telescope. Essentially, the readout system will consist of a CCD camera, a focusing lens, and a mounting system to attach the optical unit to the eyepiece so that the eye will not have to be used.

Background:

An alignment telescope is a device used to determine the proper alignment of lenses or mirrors. A set of reticles is placed in the alignment telescope so that a lens or mirror can be adjusted in tip and tilt to have the retro-reflected spot line up with the center of the reticles. This can become bothersome since the user must travel back and forth between the optical system and the telescope in order to properly align the system. Also, the position of the eye can be crucial since it is very easy to change the field being viewed by rotating the eye. If a camera system reads out the image from the telescope onto a computer, the user can remain at the lenses and adjust the lenses while looking at the image on a computer. This also has its advantages since the user does not always have to get behind the telescope which can also be bothersome based on its orientation.

The Optical System:

Figure 1 shows an image of the actual alignment telescope being used. Unfortunately, we cannot dissemble the alignment telescope to measure the optical characteristics of the lens system; however, we can measure, and have measured, the optical parameters of the eyepiece that is used with the system. Using an Eidolon Lens Bench, we were able to approximately determine the FFD and the BFD to be about 12.34 mm and 17.285 mm respectively. The full field captured by the eyepiece was also measured to be about 10 mm, and with the system fully assembled, the XP was found to be about 16 mm away from the lens of the eyepiece with a diameter of about 3 mm.

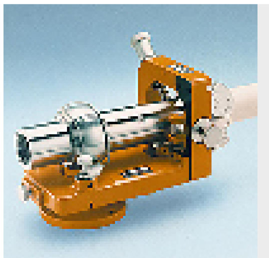


Figure 1) The Alignment Telescope

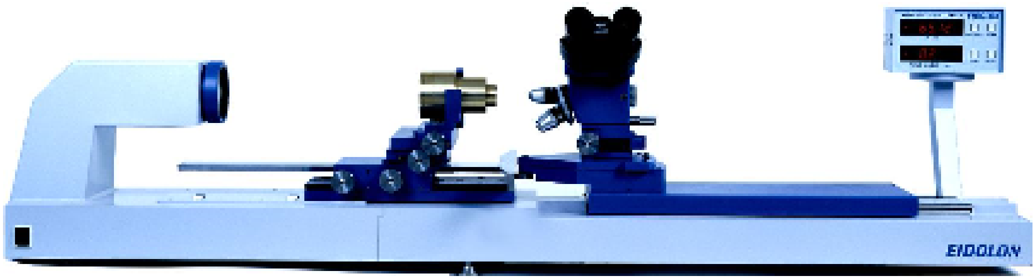


Figure 2) Eidolon Lens Bench

Using these numbers, a first order optical drawing was done to determine the appropriate parameters needed to capture the entire image. Figure 3 shows a sketch of these parameters. Since the image produced by the telescope is placed at the front focal length of the eyepiece, the rays exiting the eyepiece will be collimated; therefore, the CCD camera must be placed at the focal length of our "to be made" optical system. It should be noted that Professor Parks has a 3.6 by 4.8 mm CCD camera which defines our imagining plane or image size. Using this knowledge, the appropriate focal length of the "to be made" system was found using the equation shown below. Since we know that the image height is constrained to be 3.6 mm, and the virtual object height (the field of the eyepiece) is 10 mm, the magnification was found to be 3.6 over 10 which is .36. Also, since we know that Z is 16 mm, the focal length of the optical system should be about 5.76 mm.

$$m = \frac{h'}{h} = \frac{f}{Z} \rightarrow f = Z * \frac{h'}{h}$$

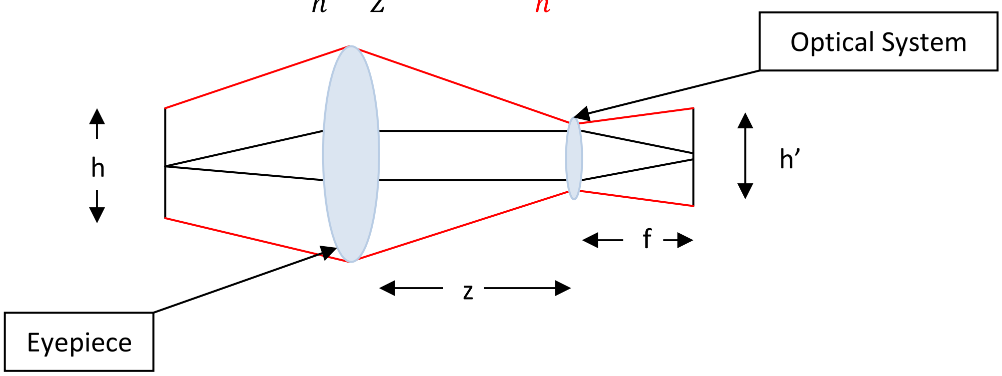


Figure 3) First Order optical Drawing (Note that this is not to scale)

Professor Parks has available to us a set of micro imaging lenses that are all F/2.5 which are pre-mounted and can be placed into a C-mount adapter. Table 1 shows the Edmund Catalog specifications to these lenses. Using these specifications, a quick analysis was done to see how the lenses would perform in terms of the maximum field they could capture as well as how well their resolution (both spatial and angular) is. Table 2 shows the values to these results, and figures 4 and 5 show plots of these results. As it can be seen, with the higher focal length lenses available, there is less field captured, but there is a better angular resolution; however, the angular resolution is only slightly less than that achieved with the smaller focal length lenses. It should also be noted that the plots show the 5 mm focal length lens; however, professor Parks only has the 6 mm lens through the 17.5 mm lens. Therefore, we have concluded that the 6 mm lens would be the idea lens to use for this system. Though it does not capture the entire field, it is able to capture about 96% of the field and has the best spatial resolution.

Table 1) the lens specifications

Focal Length	Max. Sensor Format	f/#	Primary Mag	Field of View*	Working Distance	Resolution** (megapixel)	A (mm)	B (mm)	C‡ (mm)	D (mm)
5.0mm	1/3"	2.5	0.033-0.020X	224-372mm	150-250mm	1.35	14.0	14.6	4.0-3.9	3.7
6.0mm	1/3"	2.5	0.040-0.024X	177-294mm	150-250mm	1.35	14.0	14.1	6.9-6.8	4.5
8.0mm	1/3"	2.5	0.053-0.032X	118-196mm	150-250mm	1.35	14.0	12.3	8.8-8.6	3.7
10.0mm	1/3"	2.5	0.068-0.040X	90-150mm	150-250mm	1.35	14.0	17.0	6.6-6.3	3.7
12.5mm	1/2"	2.5	0.084-0.050X	95-159mm	150-250mm	2.41	15.0	22.9	10.1-9.7	4.8
17.5mm	1/2"	2.5	0.130-0.076X	60-104mm	150-250mm	2.41	14.0	20.7	5.8-4.9	7.6
25.0mm	1/2"	2.5	0.190-0.110X	42-74mm	150-250mm	2.41	18.0	30.0	8.5-6.5	11.5

Table 2) Analysis of lenses

Focal length	Aperture	EP	F/#	spatial resolution (microns)	Angular resolution (arc-minutes)	m	Field captured (mm)
5	2	2	2.5	3.355	1.153364063	0.3125	11.52
6	2.4	2.4	2.5	3.355	0.961136714	0.375	9.6
8	3.2	3	2.666667	3.578666667	0.768909367	0.5	7.2
10	4	3	3.333333	4.473333333	0.768909367	0.625	5.76
12.5	5	3	4.166667	5.591666667	0.768909367	0.78125	4.608
17.5	7	3	5.833333	7.828333333	0.768909367	1.09375	3.291429

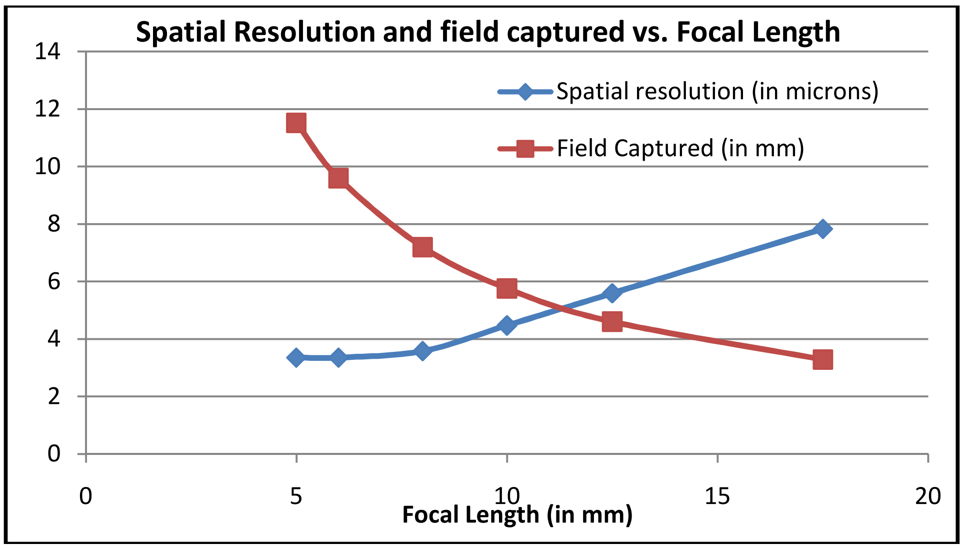


Figure 4) a plot of the spatial resolution and field captured vs. Focal Length

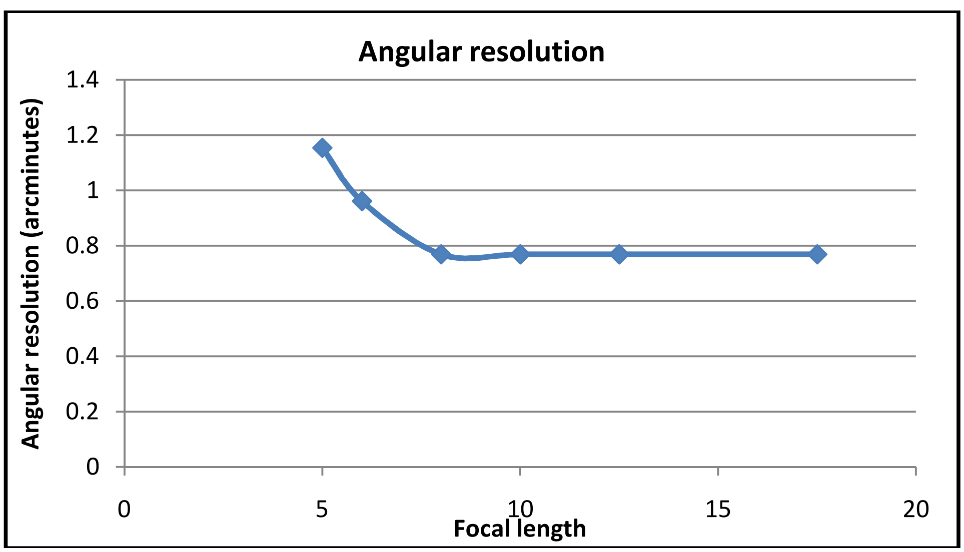


Figure 5) a plot of the angular resolution vs. Focal length

A quick test was done to test the results of our calculations as well as to see if the system would actually work. Using the CCD camera from the PSM and the imaging software of the PSM, we assembled the camera system and placed it at the XP of the telescope while looking at a ruler. With our eye, we were able to see about 20 mm on the ruler or 20 tick marks. Figure 6 and Figure 7 show our results using the 6 and 8 mm focal length lenses respectively. As it can be seen, with the 6 mm lens, we could see about 18 mm and with the 8 mm lens, we could only see about 14 mm which came close to the theoretical amount of field that should be captured.

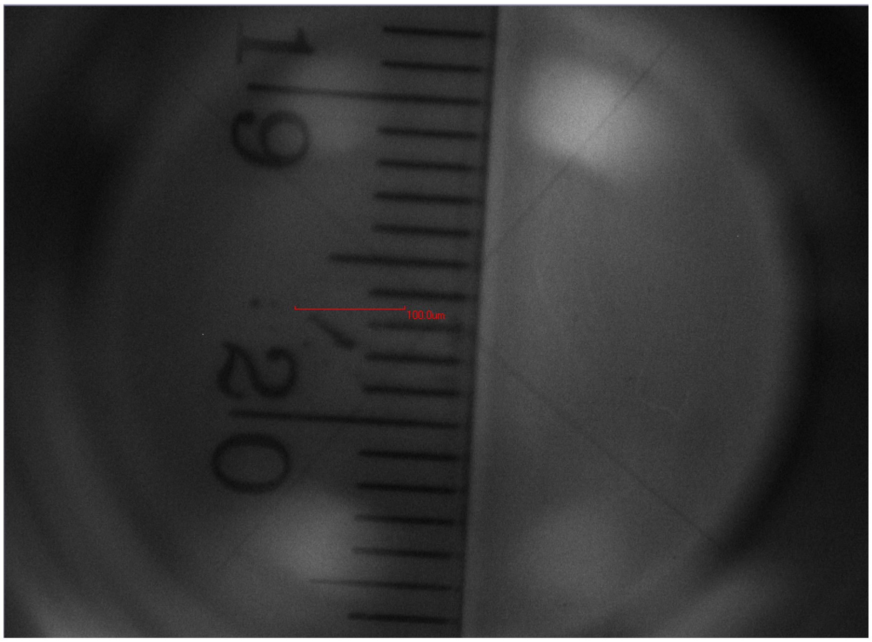


Figure 6) The image with the 6 mm lens

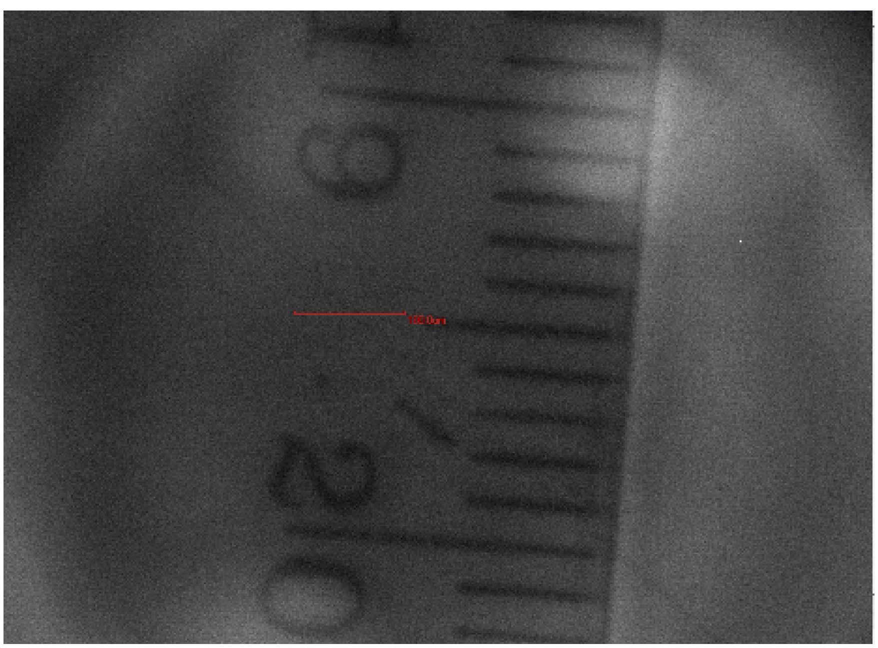


Figure 7) the 8 mm lens

Mechanical Mount for Lens

Assuming we go with one of the micro-imaging lenses from Edmund Optics, the mechanical design will be fairly straightforward. Figure 8 and 9 below show the mechanical housing for the lens and its C-mount adaptor which will be able to screw into our CCD camera.

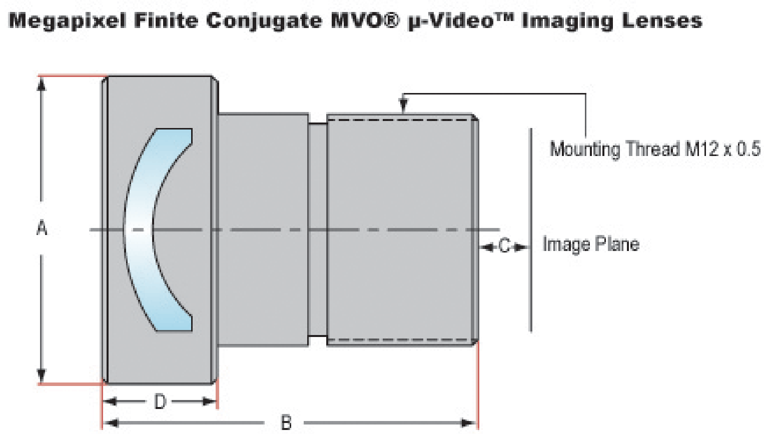


Figure 8) Mechanical housing of the lens

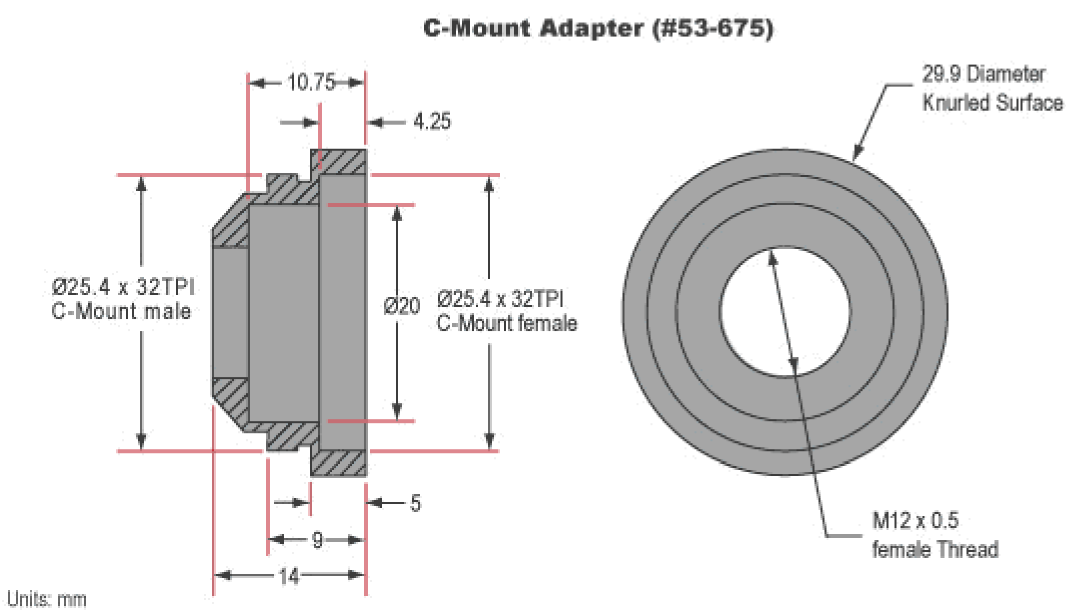


Figure 9) C-Mount Adapter for the lens

The positioning of the lens will need to be such that it is focused at infinity. This can be accomplished in two ways: moving the entire C-mount adaptor or moving the lens within it.

- To adjust the positioning of the C-mount adaptor we can use a C-mount spacer along with brass spacer rings, which can yield translations of as lows as 0.25 mm.
- Adjusting the lens within the C-mount adaptor can be done using a M12 x 0.5 threaded spacer (to be machined).

The housing to adapt the CCD camera to the eyepiece can be seen in figure 10. The housing has the ability to slide over the eyepiece and can then be tightened down using an M4 screw and nut. The screw would be placed through the hole above the largest ring and the nut would be used to try and close the gap cut into the largest ring of the tube. On the back ring of the tube (the smallest ring) threads would be placed along the outside edge of the ring so that the C-mount adapter could be screwed onto to mounting tube. Figure 11 shows a picture of what the system should look like when completed.

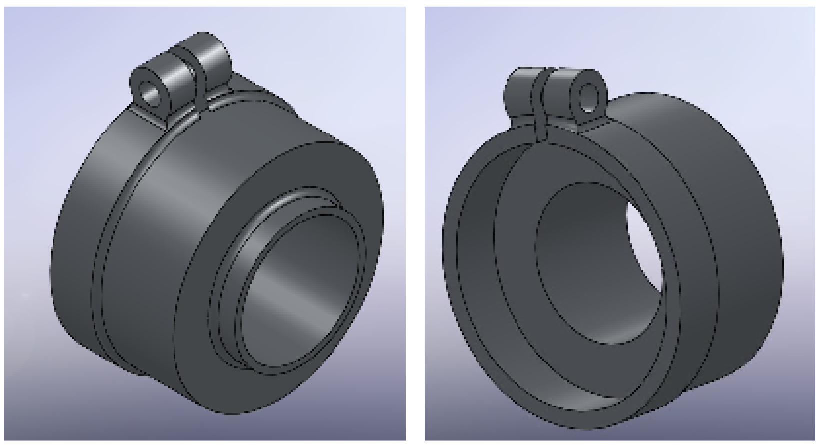


Figure 10) The mounting tube design

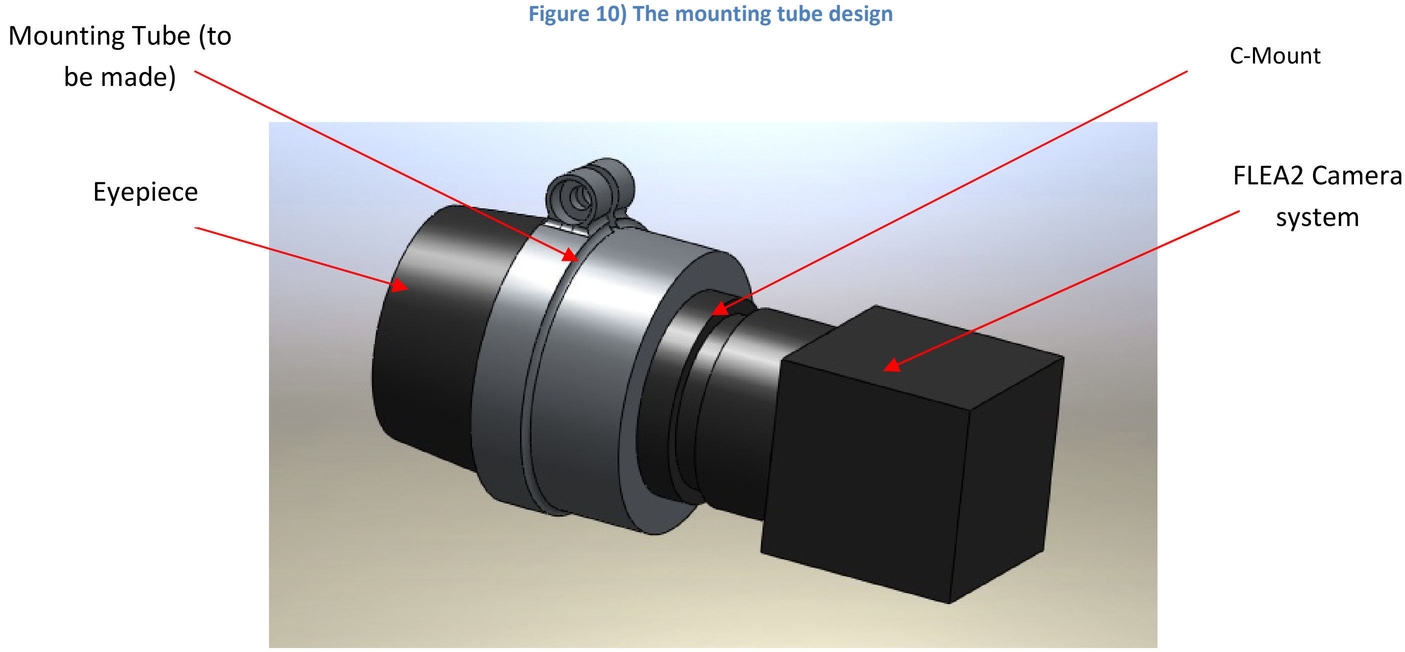


Figure 11) The idea final design

Also note, attached to the end of this document are drawings with idea specification to the mechanical mount. Before fabricating the final mechanical mounting design, a prototype will be made to prove that the system will work. The prototype design will essentially consist of the same structure; however, the screw hole on top of the mount will not be fabricated and the larger diameter portion of tube will be made longer than the final design to ensure that the proper distance is created between the lens system and the eyepiece. Figure 12 shows a picture of this prototype mount.

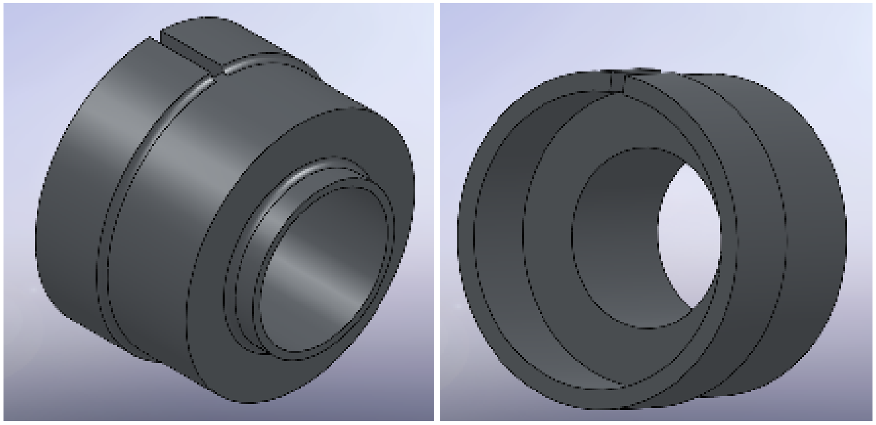


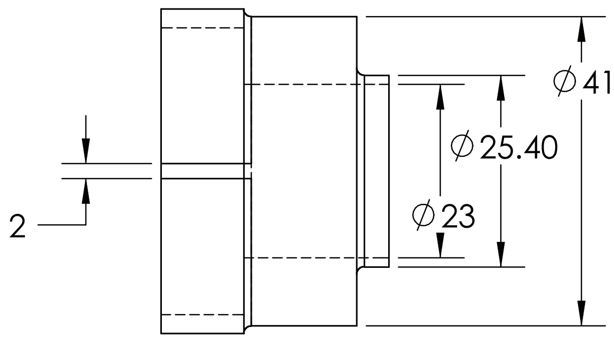
Figure 12) Prototype Mounting Tube

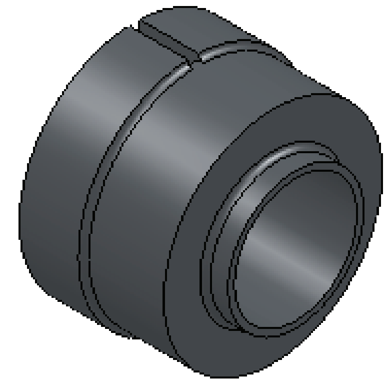
Integration with LabVIEW

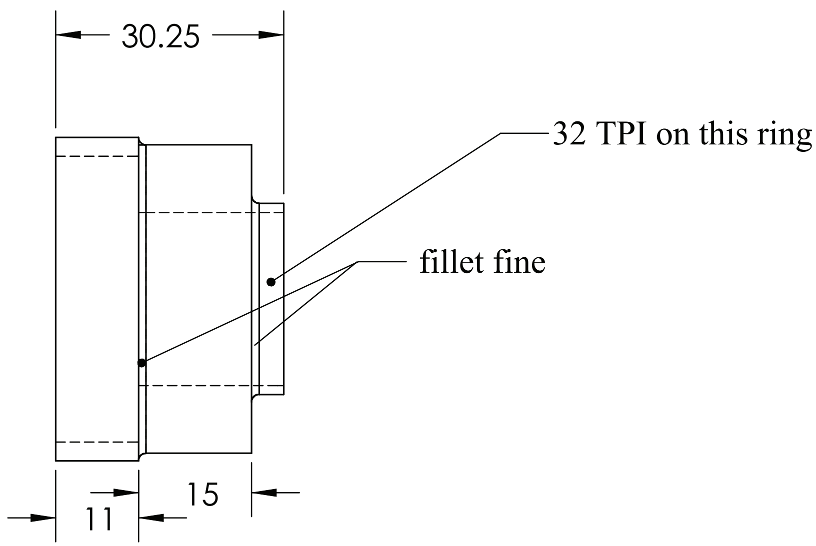
The National Instruments Developer Zone has a number of tutorials and example programs for various LabVIEW applications.

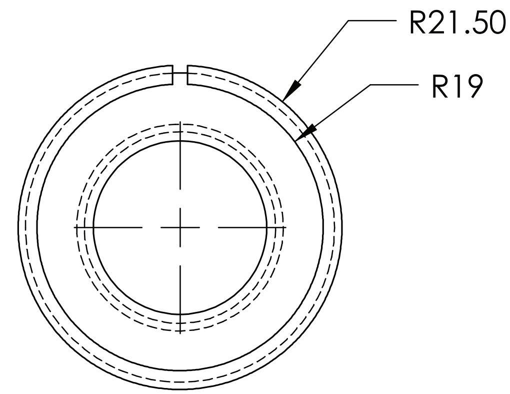
- Image Processing and Machine Vision Development Section
  - Display Examples (example program)
  - http://zone.ni.com/devzone/fn/p/sn/n24:SignalProcessingAnalysis.Vision

With these tutorials, a base for the software program can be established and later modified. Ideally, the program should allow the user to modify the shutter speed of the camera as well as the gain of the camera. Of course, the program will have to show an image of what is being viewed, and the user should have the ability to zoom in on one part of the image or zoom out.









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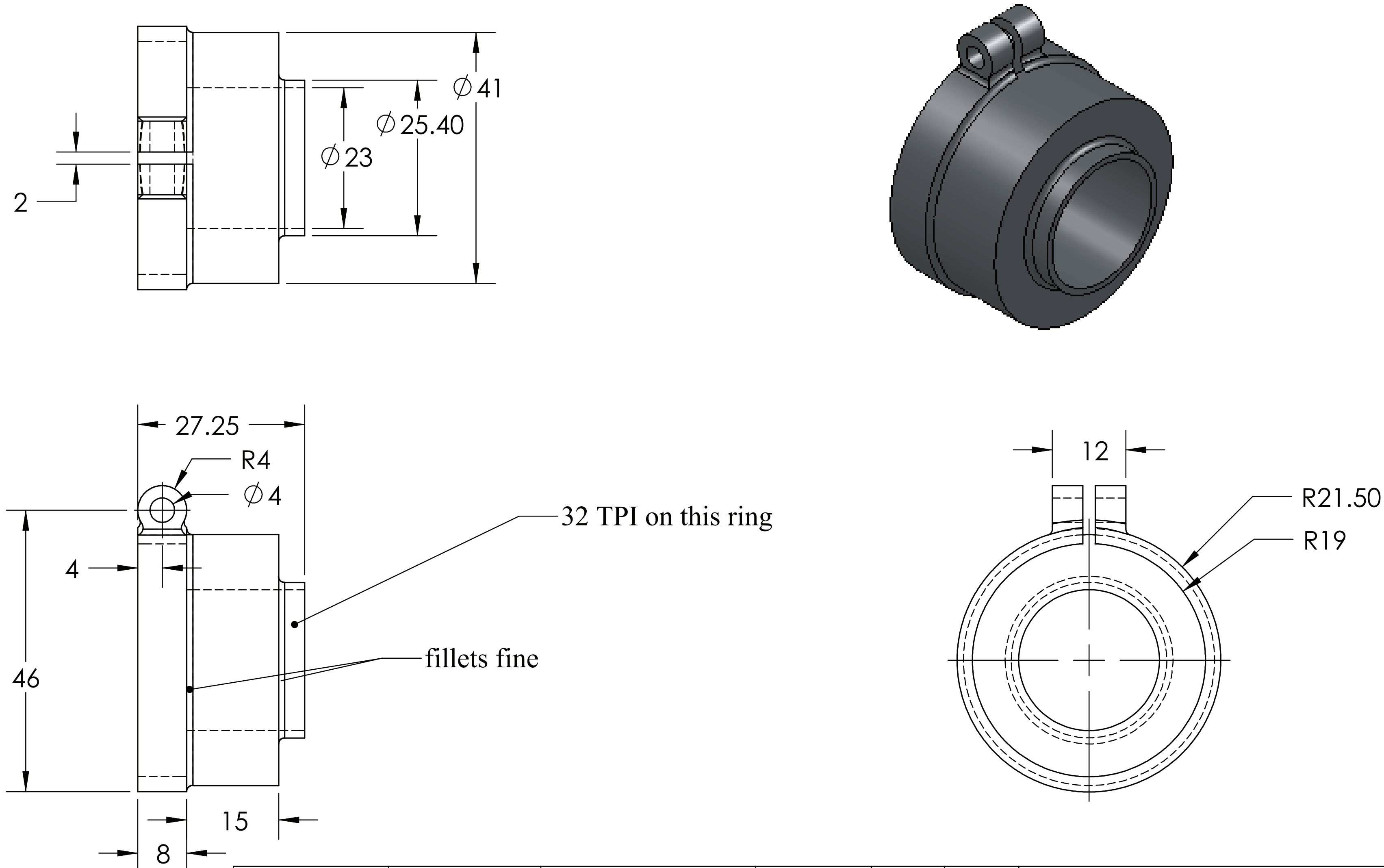

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