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# DESIGN AND DEVELOPMENT OF A LONG RANGE TELESCOPE COUPLED WITH CCD CAMERA FOR REMOTE DETECTION APPLICATIONS

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*With the availability of variety formatted Charge Coupled Device (CCD) sensors as detecting elements, the real time imaging applications are expanding rapidly. The combination of conventional optical telescope technology and CCD sensors is enabling engineers to design and develop real time, better dynamic range, long-range imaging devices for detection, recognition, identification and image capturing applications.*

*Our group has undertaken one such application relevant to the military instrumentation activity. The aim is to design and develop a remotely operational, real time, large dynamic range, and long-range detection device for motion capturing application. This device is intended to be useful in real time flight capture of a live weapon. Other applications foreseen are remote identification of flora and fauna, remote detection of leakage of toxic gases in nuclear power plants, remote detection and identification of glowing materials etc.*

*The paper deals with application specific design, development activities of a long-range telescope-CCD camera. The advantages are explained. Salient features of this system are capturing of the flight event/image and retrieval of the image for analysis and feedback.*

## 1. INTRODUCTION

Seeing the object when in motion, at least a slice of it, live through own eyes amazes any observer! Image capture for motion studies of fast occurring events places some very demanding requirements on film and video cameras. Real-time

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video cameras have notable advantages over their film counterparts and are used even with lower spatial resolution and slower frame rates. This preference arises from the analog and/or digital output format, which can provide real-time video with transmission to remote locations, and permits rapid experimental analysis by eliminating time delays associated with film processing. Aside from convenience and cost implications, these capabilities have expanded the field to applications previously inaccessible with film cameras. Further benefit arises from the concomitant storage technology available to the analog as well as digitized image, which allows a density advantage over film and is amenable to a variety of media.

Spurred by requirements in commercial, scientific and military imaging applications, CCD image sensors [1] have undergone significant advancements to the extent that their performance characteristics are beginning to approaching those of the film. The traditional vestiges of film, i.e., resolution, sensitivity and speed, are now being lost to the CCD due to technical improvements, which include : (1) fabrication processes capable of producing small to large format arrays, and (2) design and process developments for low noise and high speed CCD operation.

These features, when incorporated into sensors design tailored to the specific requirements of high-speed photography and videography, will result in major performance enhancements.

With a view of these developments, requirements for high-speed camera system are : a large dynamic range, spatial resolution. Additionally, the sensor array must have sufficient light sensitivity for daylight imaging conditions, and must suppress blooming when over-exposed.

## 2. NECESSITY FOR A NEW TELESCOPE - CCD CAMERA

Developed weapons with a range of 2 to 5 km are normally undergoes proof firing and validation in firing ranges. This activity shall be carried out in the presence of an evaluation team. Typically this team shall have to experience some problems for diagnosing the quality aspects basing on the actual performance of the weapons as the flight times involved are 12 to 25 sec. Evidence of evaluation of a weapon firing shall be carried out basing on the visual observation as well recording devices such as photographic cameras and camcorders.

If all goes well there shall not be any post-mortem. Otherwise, the post-mortem is carried out basing on the individual observer opinion or takes the help of photographs or video camera recording.

However, the observer's opinion is subjective in nature and leads to multitude of ambiguities on the course of failure. When the help, of the other two types of recording evidence, is to be taken, it is normally not possible to get accurate results due to the camcorder or photographic recordings as such they are carried out quite away from the weapon proof firing area and are not at all harmonized with respect to the weapon launcher guidance optics. Therefore, the recordings are not reliable for the analysis. If a dedicated camera system is available that could be mounted alongside of the weapon launcher and harmonized with respect to guidance optics. During live firing of the weapon, it is possible to record the firing event in real time. The storage and retrieval of the image for post recording analysis can be made possible with the available instrumentation. Our group has the experience of designing and developing such instrumentation [2].

Taking such practical problem as a project, our team has carried out a study to search out a solution. The authors have designed and developed a daylight, realtime telescope - CCD imager that satisfied many of the requirements for remote operation for detecting the moving objects in slower time intervals. The outcome of the design and development effort is the main theme of this paper.

## 3. DESIGN AND DEVELOPMENT DETAILS

Total system design fundamentally depends on the constituent parts it contains. Main components of the system are :

a) Lens System,
b) Image Sensor module,
c) Control System,
d) Display Device and
e) Recording Device.

Lens system, image sensor module and display device selection is carried out concurrently. Selection is a two-phase process. Phase one considers the application constraints, requirements and desired results. Phase two is the selection of the lens system, image sensor module and display device that will provide the system performance necessary to achieve the desired results.

**Phase one :**

Application evaluation process looks at the application in terms of specific parameters that define the constraints, requirements and desired results. Key parameters to consider are field of view, acceptable working distance, object accuracy and resolution.

**Phase two :**

This is the determination phase where the application, lens system, image sensor module and display device parameters are considered and evaluated.

Design work starts by following the guidelines proposed. Phase one - process deals with the application aspect of the telescope-CCD camera. The constraints and requirements are already explained in the section 2. The main requirements of the optical system are given here :

a) Field of view,

b) Acceptable working distance and

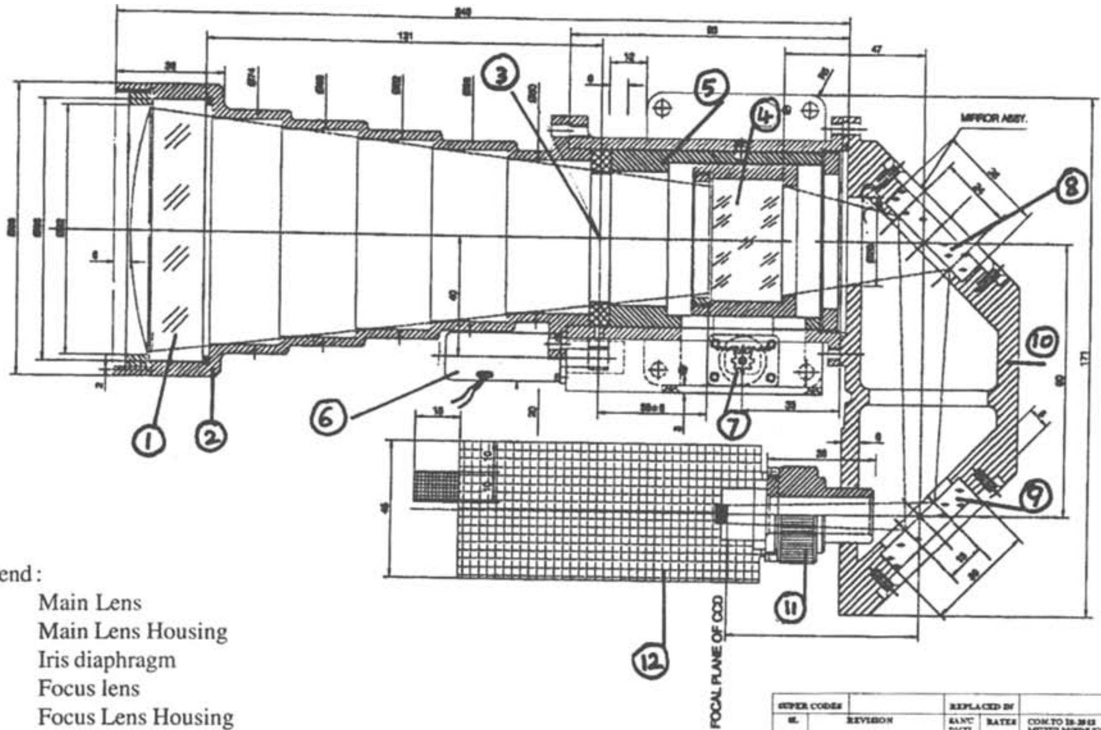
c) Resolution.

These parameters are determined based on the requirement of the system. As explained earlier, the system should be able to image the objects properly within the working distance between 200m to 4000m. The system is expected to capture the flight of a live weapon in real time, in a time scale of about 21 seconds. Since the target size is of the order of 2.5 m x 4.0 m located in the working range of the weapon, the system should be able to capture not only the weapon in flight but also the target located at its longest distance of 4 km and relayed it to the display device with clarity. The image acquisition system that this group had developed and adopted in different application is to be used in this application also. It means the display device accommodates of maximum 220 (H) x 144 (V) pixels for image display. The minimum condition, for identifying a long-range (4-km) standard target image in the display device, is that the image size should be more than 10 x 10 pixels. This constraint allows arriving at a field of view of $0.55^0$ (H) x $0.4125^0$(V). Basing on this, the three design parameters have been determined.

Going to the stage two involves the design and development of lens system, selection of CCD camera module, control system and display device.

The combination of the field of view required by the system and image sensor format available with us, such as 1/3-inch [a sensor size of 4.8 mm (H) x 3.6 mm(V)], defines the focal length of the lens system. The arrived value is 500 mm. The maximum working aperture kept for the lens system is Ø80 mm. This caters to the varying light conditions from low light conditions to the bright day light conditions. In order to control the lens system-working parameters functional for different day light conditions, an iris diaphragm having an opening aperture from 0 to 40mm is suitably placed in the optical layout of the system. Diaphragm minimum to maximum opening limit is remotely operated with a micro motor mechanism using a dedicated controller. The lay out diagram of the system is given in figure 1, and 1(a). The total length of the optical system is made to a shortest possible limit, using a combination of tele-photo design and folded optical path configuration. The important design criterion of the optical system is that by moving the focusing lens within specified limits, the full working distance (200 m to 4000 m) of the weapon is covered.

A fully configured computer is used with all the interfaces working. The computer works as a command and control work station. The display device is a computer monitor. A frame grabber resident in the computer digitizes the analog images delivered by the CCD camera. With the use of dedicated software to acquire images and format them, a facility exists such that the on-line, real-time images can be stored while carrying out the experiment. The images can be retrieved for further analysis. It is also possible to relay the analogue images from the telescope-CCD camera directly to an analogue CCTV for real-time viewing. If a recording and retrieval of the acquired image is required a PAL standard video record and play system (VCR/P)




Legend:
1. Main Lens
2. Main Lens Housing
3. Iris diaphragm
4. Focus lens
5. Focus Lens Housing
6. Iris Controlling micrometer
7. Focus Lens Controlling micrometer
8. Mirror 1
9. Mirror 2
10. Mirror Housing
11. Adaptor for CCD
12. CCD colour Camera

Design Layout of
Fig 1(a) Telescope-CCD Camera Asay

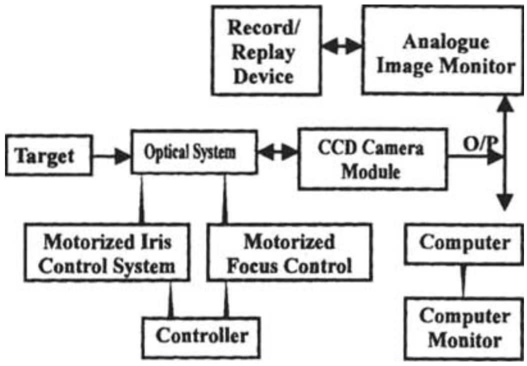



Fig.1. Layout of the telescope-CCD camera system

can be used into the system network.

## 4. APPLICATION OF TELESCOPE-CCD CAMERA

Application of the designed and developed telescope-CCD camera (see figure 1b), is to capture the live firing sequence of a weapon, simultaneously keeping the stationary target all the time in the field of view of the optical system. The mounting location for telescope - CCD camera on an ICV vehicle that also contains a weapon to be flight tested, is shown in figure 2. The acquired images are stored during the capturing time. Depending on the requirement the stored images can then be retrieved for analysis. It is possible to view the retrieved images on single frame basis. For example, the CCD camera module has a 30 frames/sec acquiring ability. That means

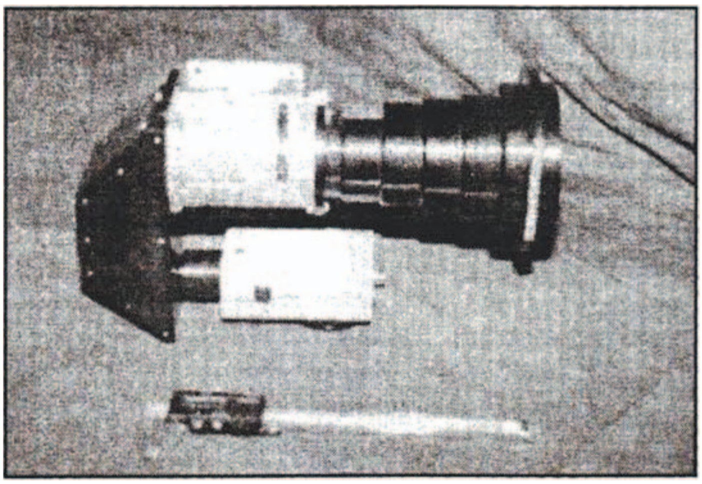


Figure 1(b). Telescope-CCD Camera Assembly during the flight time of the weapon say 20 seconds, a recording of 600 frames of motion is possible. It is also possible to view any of the individual frames. The dedicated software also supports to view any odd or even frames or skip some of the frames. Such versatile facility enables the total unit to be used for a variety of applications.

## 5. CONCLUSION

The design and development of the telescope - CCD camera has been completed. A factory trial for performance verification has been carried out successfully.

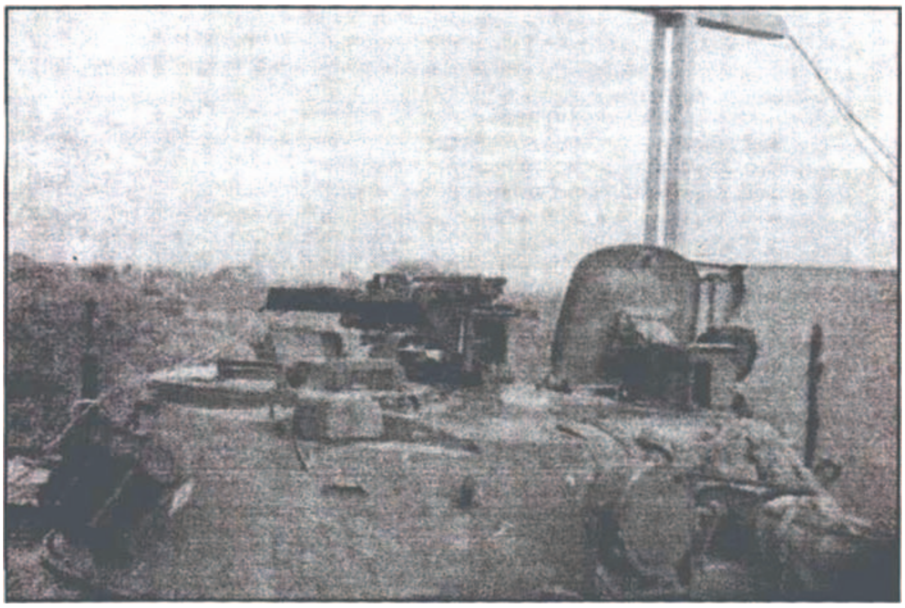


Figure 2. Mounting location of telescope-CCD Camera on a vehicle launcher for weapon flight capture

Furthermore integration trials are to be carried out before it can be fully used in designed application. The design and development of the unit has been taken into consideration the cost factor also. Now a days the high-speed camera systems [3] are costing about one hundred lakh rupees. Though such cameras are available in different configurations, they have to be ruggedized for the intended applications, that means, increase of their cost. Moreover, such cameras are not accompanied with any type of computer facility, so that they can be hooked in a network environment. These shortcomings have been taken into consideration while designing this equipment. The unit has been fabricated with a view to mount easily on the available weapon launchers whether it is a tripod type or vehicle mount. Since the optical system has a remote control facility to change lens focus and iris diaphragm, the unit can be operated even in inaccessible and hazardous places.

Other applications foreseen for this unit are remote detection, recognition, and surveillance also for military purposes. As far as it's scientific applications are concerned, its usage is expected in fluorescence detection application, and biological applications etc.

Further trials and study is required to know more about its multitude applications as well as its upgradation or value addition.

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