Bull. Astr. Soc. India (2002) 30, 407–409

# Mechanical Design Improvements in the "TACTIC" Gamma Ray Telescope

**R.L. Suthar, S.Guha, P.K.Biswas, R. Koul*, N.K.Aggarwal***
**Bhabha Atomic Research Centre, Nuclear Research Laboratory, Mumbai- 400 085, India*
*Bhabha Atomic Research Centre, Central Workshop, Mumbai - 400 085, India*

**Abstract** : The basic mechanical design of the TACTIC ( TeV Atmospheric Cerenkov Telescope with Imaging Camera) telescope was received from the Lebedev Institute of the Academy of Physical Sciences, Moscow, in November 1990. A large number of mechanical design improvements and additions were incorporated in the basic design of the telescope and the first ( Imaging ) unit of an array of four telescopes was made operational in 1997. Three Vertex units were erected thereafter and are operational at present . This paper details the improvements / additions incorporated in the TACTIC array of four telescopes.

*Key words*: TACTIC telescope – mechanical structure – design improvements

## 1. Introduction

The Bhabha Atomic Research Centre (BARC) Mumbai, India, has set up a Gamma Ray Observatory for AstronomicaL Studies (GOALS) at Mt. Abu in Rajasthan. This facility will finally have four experiments / facilities for gamma ray astronomical studies. The first facility, "TACTIC", consists of an array of four telescopes, one central telescope called the Imaging Unit (having the Imaging Camera at its focal plane) and the other three Vertex Units (situated at the vertices of an equilateral triangle of 20 meter side with duplex detector cameras at their focal planes.

The basic mechanical design of the telescope was received from Lebedev Institute of the Academy of Physical Sciences, Moscow, under an ILTP (Integrated Long Term Program) of scientific co-operation between India and Russia. A number of mechanical design additions / improvements were incorporated by Central Workshops, BARC, Mumbai, for ease of manufacture and for ease of assembly / erection of parts and sub-assemblies of the telescope. Various types of cameras e.g. Mini-cameras, Imaging Camera and Vertex Element Cameras were designed, developed and installed by BARC, Mumbai. Details of such improvements / additions are explained in this contribution.

## 2. Description of important additions / improvements

**2.1 Improved tubular camera support booms and tie rod:** In the basic design, each of the 4 meter long booms and tie-rod were designed like square box sections made up from four angles screwed around a number of equi-spaced square rings. For ease of manufacture and for good aesthetic appearance, a strong circular standard pipe section with equivalent rigidity was selected by CWS, BARC.

**2.2 Design and development of mini-cameras:** Basic design of camera was not received with the mechanical design drawings of the telescope. First, a mini-camera using 9 photomultiplier tubes of 1 inch photo cathode diameter was designed and manufactured . Later on a mini-camera using 25 photomultiplier tubes of ¾ inch photocathode diameter was designed and tested. Based on the experience of these mini-cameras, a much larger imaging camera using 349 photomultiplier tubes of ¾ inch diameter was designed, manufactured and installed.

**2.3 Design and development of Imaging camera:** Imaging camera was designed and manufactured at CWS, BARC. It contains 349 PMTs of ¾ inch size, placed at a square pitch of 23mm. In front of each PMT one light guide of Compound Paraboloidal Cone (CPC) shape, with entry diameter 21mm and exit diameter of 15mm, is provided to increase the light collection area. Two 5mm diameter cables leading from each PMT ( and therefore a total of 700 cables) are carried from the Imaging Camera to the Control Room. Weight of the Imaging camera itself is about 150 Kg. Imaging camera is used to record the image formed by the photons received at the focal plane and thus to separate gamma ray induced events from cosmic ray hadron -- induced events on the basis of image shape and orientation characteristics.

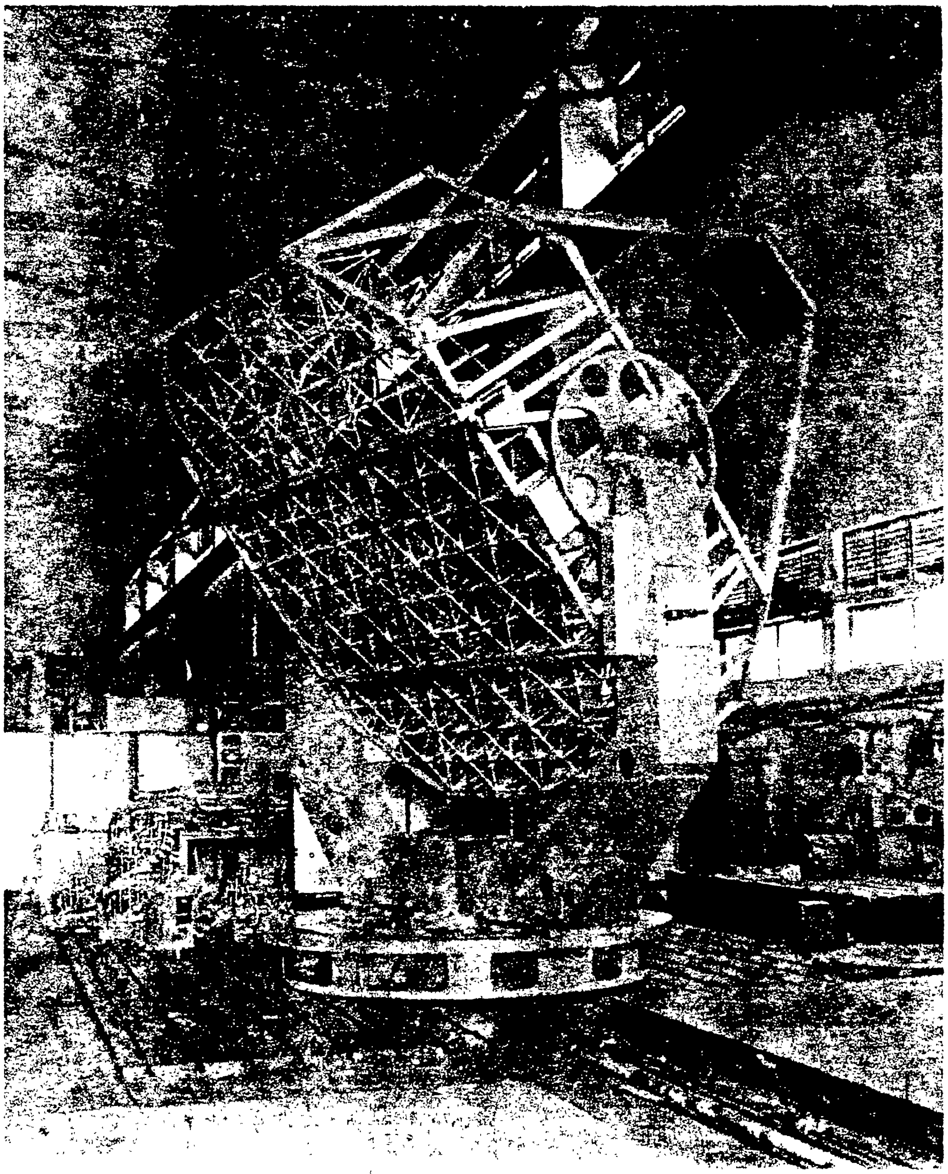

Fig. 1 Mechanical structure of the TACTIC Imaging Element

**2.4 Mirror support frames with facility for mirror alignment:** Basic design received by CWS, BARC, had provision only for fixing of 6mm thick , 600 mm diameter glass mirrors. New mirror support frames had to be designed to accommodate and support glass mirrors of various thicknesses e.g. 25mm, 30mm and 38mm. These frames had to be provided also with clamping brackets to accommodate (a) up to 30 mm thick mirrors and (b) up to 40mm thick mirrors. Aluminium shim rings were placed behind mirrors to make the combined thickness equal to either 30mm or 40mm. Frames had provision for 3 leveling / alignment screws at the clamp locations, to precisely tilt the mirrors in the desired direction at the time of alignment of mirrors.

**2.5 Ball joints for mirror support frames:** When mirrors were installed in mirror support frames, it was found that mirrors could not be tilted to the desired angle without shifting the position of the mirror. This shifting of position of mirrors resulted in interference between adjacent mirrors. To overcome this problem special ball joints were designed and fixed under the mirror support frames, to get additional degree of freedom. These ball joints permitted tilting of the mirror, without shifting its position in the mirror basket.

**2.6 Development of laser based plumb line:** For alignment of 34 x 600 mm diameter heavy mirrors (weighing up to 32 kg. each) a laser based plumb line was designed and developed. It was successfully used in the work of alignment of mirrors of all four telescopes. The 34 mirrors in each telescope form a reflector covering an area equal to a 3.6 meter diameter circle.

**2.7 Improved zenithal drive gear train:** In the basic design, there were two gear trains, one at each end of the basket, resulting in backlash about zenithal axis, when direction of rotation changed. In the improved design both the gear trains were shifted to one end of the mirror basket. Also a provision for manual rotation and locking of zenithal rotation of the mirror basket was made.

**2.8 Modified azimuthal encoder mounting arrangement and flexible couplings:** Azimuthal encoder in the basic design was connected through a set of spur gears and this arrangement resulted in non-repeatability of angular position of the optical axis of the telescope as read by azimuthal encoder. The arrangement was modified by removing this set of spear gears and by mounting encoder concentric to the azimuthal axis of rotation. Also improved flexible couplings were provided for backlash free encoder readings.

**2.9 Design of circular cable drag chains :** The Imaging telescope carries 700 signal, EHT and other cables from the camera to the control room. Provisions had to be made to permit ± $110^0$ rotation about the zenithal axis and ± $220^0$ rotation about the azimuthal axis, for easy and free movement of these cables. Large capacity circular cable drag chain was designed and installed for Imaging Telescope. Similarly small capacity (130 cables) circular cable drag chains were provided for the Vertex elements.

**2.10 New main roller thrust bearing:** Rotary table of the telescope needed a large, 900 mm diameter, ball thrust bearing. It was difficult to import or manufacture locally such a large size ball thrust bearing. A new roller thrust bearing based on easily available rollers (rolling elements) was designed and used as the main thrust bearing carrying the weight of about 5 tonnes of the telescope.

**2.11 Design and development of Vertex cameras:** Vertex units are to function as detector units to detect gamma ray induced photons. Vertex camera is a duplex camera having main camera at the focal plane and which receives light directly through a beam splitter. An identical camera fixed opposite to the main camera receives light after reflection from the beam splitter. The beam splitter is fixed at the mid-plane of the two cameras. As the ratio of UV / Visible light content is expected to be high in the gamma ray induced showers, the increased content of UV in the reflector camera denotes existence of gamma ray induced events. Detector units will signal the presence of Cerenkov photons and Imaging unit will accordingly record the event / signal.

**2.12 Study of formation of images by mirrors and efforts to reduce focal spot size:** Imaging unit was installed in 1995 and its reflector produced a very large focal spot size of about 55mm diameter. The mirrors used are of equal focal length of 4000mm and their centers are positioned on an imaginary paraboloidal surface. Focal distance initially was kept at 4000 mm. It was then felt that a decrease in the focal distance would reduce the focal spot size. Accordingly focal distance was reduced in two stages to 3850 mm leading to a reduced focal spot size of 35 mm diameter in Jan 1998. In such a situation mirrors closer to optical axis produced pre-focussed type of images and mirrors farthest to the optical axis produced long, feather like, post-focussed type of images. It was felt that the farthest mirrors should be brought closer to the focal plane. Suitable studs, longer by 50mm and 100mm, to suit specific mirrors, were then designed for 10 such mirrors and these changes have produced the smallest practically achievable focal spot size of 22mm diameter in Jan. 2001.

**2.13 Strengthening of camera support boom joints:** The weight of the Imaging camera being 150 Kg, the friction (ball) joints at the ends of the booms could not hold and support the weight of the camera. It was felt that the camera support frame and the booms be welded permanently through stiffening / rigid members. This modification work was done and the problem of slippage of ball joints and consequent mis-alignment of the camera was solved.

**2.14 Developing procedure for alignment of heavy mirrors:** Although a laser-based plumb line was developed, the alignment of the mirrors, based on single point reflection method, did not produce the desired small size of the focal spot. Subsequently after a thorough study of the images formed by individual mirrors it was found that different mirrors produced different shape and size of images. Therefore fivc-point reflection method of alignment was developed. It involved obtaining reflection from five points on each mirror e.g. Center, Outer, Inner, Left and Right points of each mirror. These five reflection points obtained in the focal plane defined the shape and size of image of each of the mirror. This method of alignment then resulted in satisfactory focal spot size.

## 3.Conclusions

Incorporation of several improvements and additions in the TACTIC Telescope has given confidence in satisfactory operation and maintenance of the Telescope and in taking up design and development work on the much larger proposed 17 meter size MACE Telescope.