Design, Development and Characterization of Optically butted focal plane of Cartosat-2 Series Payloads

Arti Sarkar*, Manish Saxena, B N Sharma, Parul Singh, Nitesh Thapa, Ravi Atreya, Anand Kumar, K J Shah, H K Dave, S S Sarkar
Space Applications Centre, Ahmedabad
* arti@sac.isro.gov.in

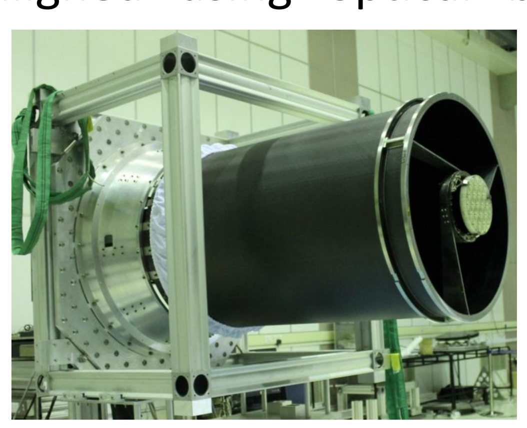
Abstract

Complexity in focal planes of very high resolution space borne optical imaging systems for cartographic applications are ever increasing, with the demand of sub-meter ground sampling distance (GSD) having reasonably long swath coverage on the ground. Meeting these contradicting requirements with small format detectors and restricted real estate availability makes the realization of focal plane assemblies (FPA) very challenging task. In Cartosat-2 Series Payloads, these challenges have been met with innovative design of focal plane assembly using **Optical butting technique.** Optical butting technique links required number of CCDs together to form a continuous image line without occurrence of any gaps. An optical device like a flat mirror or a prism can be used to divide the image line into segments, which are then imaged on the individual CCD sensitive areas. All the sub images are composited to form a high resolution large format image. In Cartosat 2S, two detectors in PAN chain and five detectors in Mx chain meets user requirement of 10 kms swath with 0.65-meter GSD in Panchromatic and better than 1.6m GSD in multispectral chains from 505 km orbit. This poster presents the overall configuration of the focal plane, sensitivity studies on misalignment factors, performance optimization and characterization methodologies and test setups. The paper also discusses the results obtained and accuracies achieved in the detector alignment process.

Introduction

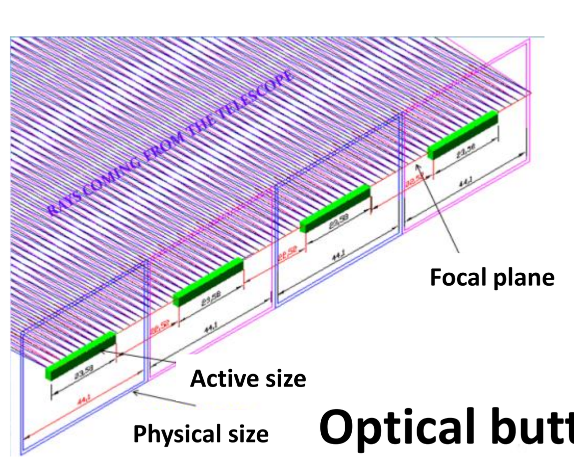
Remote sensing imaging systems generally require large field of view (FOV), which is determined by two factors: the FOV of the optical system and the resolution (format size) of the image sensor used. There is a constant need of improving resolution and increasing the swath area in remote sensing applications. Swath can be increased by increasing the number of detector elements in the linear array. Cartosat 2S series of satellite provides large swath using multiple detectors aligned using optical butting technique

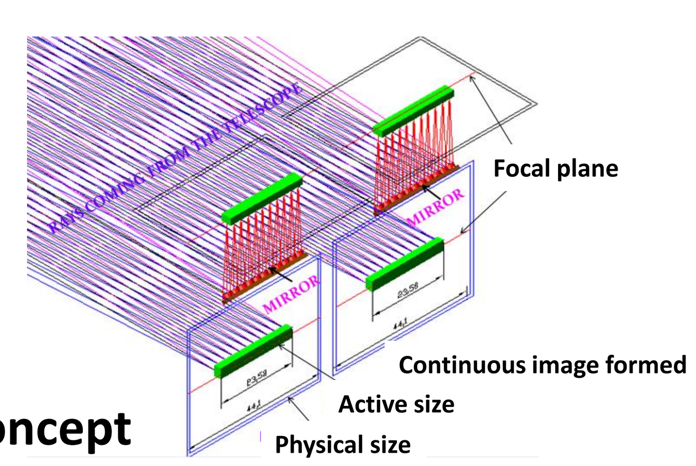
Main Telescope



Optical Butting concept

The constraint due to the physical dimensions of the available small format detectors results in discontinuous images and also in under-utilization of available field of view from the optical system. Optical butting technique links required number of CCDs together to form a continuous image line without occurrence of any gaps. An optical device like a flat mirror or a prism can be used to divide the image line into segments, which are then imaged on the individual CCD sensitive areas. All the sub images are composited to form a high resolution large format image. The continuity of line image is obtained by partially overlapping the elementary CCDs.

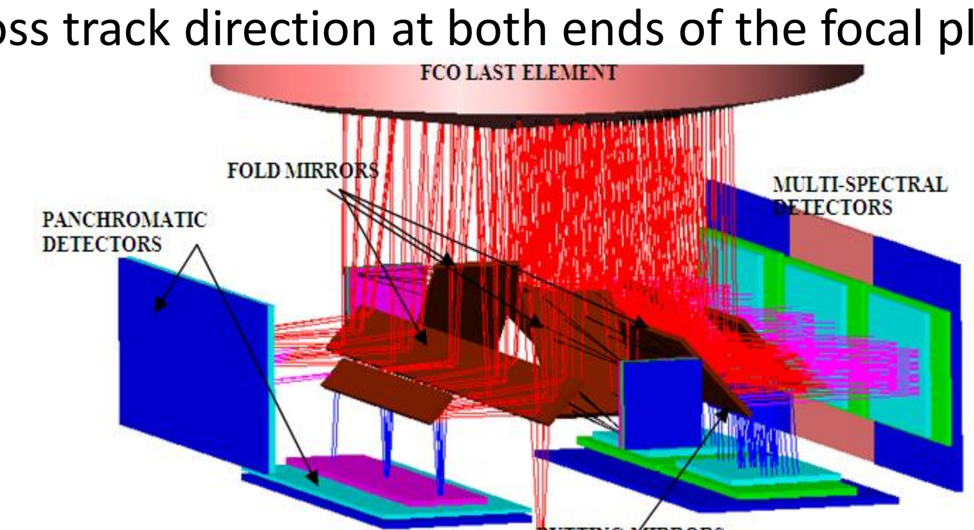




Optical butting concept

Focal plane assembly development

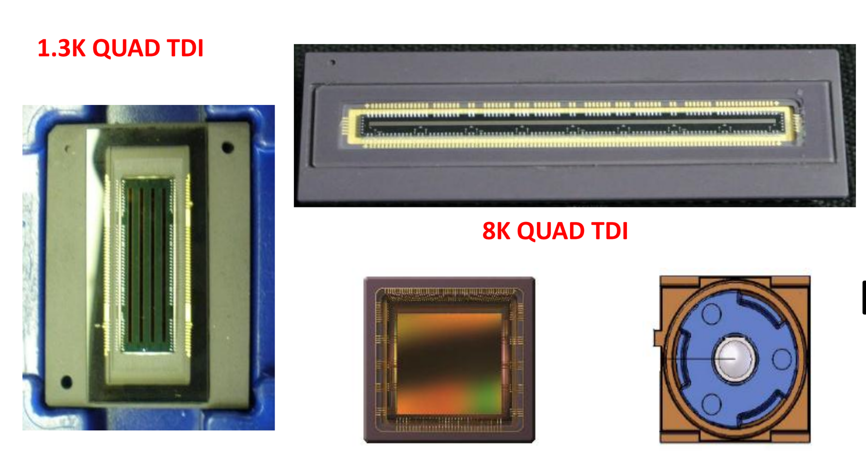
In the innovative optical butting configuration, main telescope rays reaching the focal plane was spilt in along-track direction using two fold mirrors to form PAN and MX focal planes. And by using one butting mirror in the path of converging rays just before the focal plane, two 8K TDI detectors were accommodated in two orthogonal planes. Similarly, 3 and 2 detectors of MX chain were accommodated in two orthogonal planes by using two butting mirrors. In order to accommodate two Event monitoring camera chains, two individual fold mirrors were used in the across track direction at both ends of the focal plane.



Focal plane module

Detectors in the focal plane

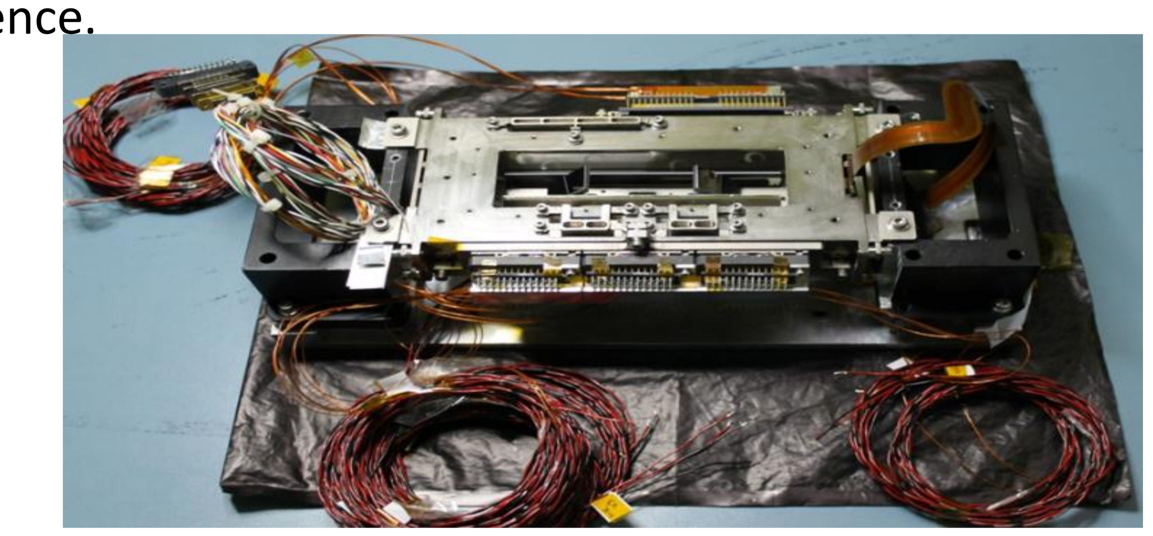
There are four types of detectors present in the focal plane. Five 1.3k quad TDI detectors for MX bands each consisting of four arrays with 45 TDI stages, two 8k TDI detectors for PAN each consisting of 80 TDI stages and two detectors for EvM1 and EvM2.



Detectors

Challenges

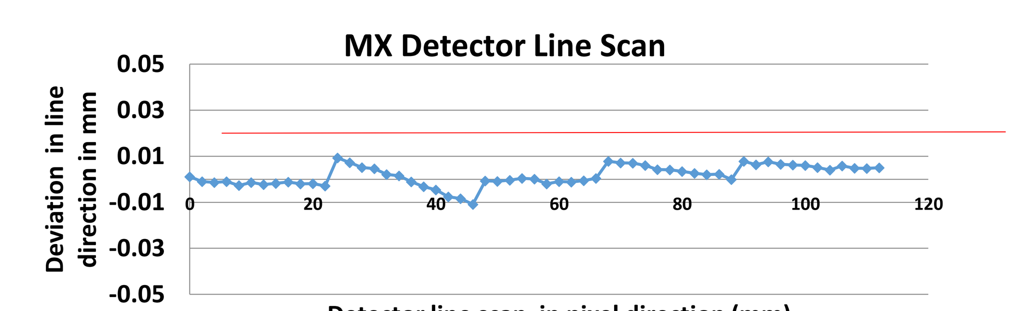
The main challenges to be met in this technique are the high relative geometric orientation stability of the sensitive areas and the necessary high accuracy of assembling devices in the focal plane, spatial recti-linearity (co-registration and co-alignment) and adjustment in focus, during FPA integration and test operation sequence.



Electro-optical module for Focal plane

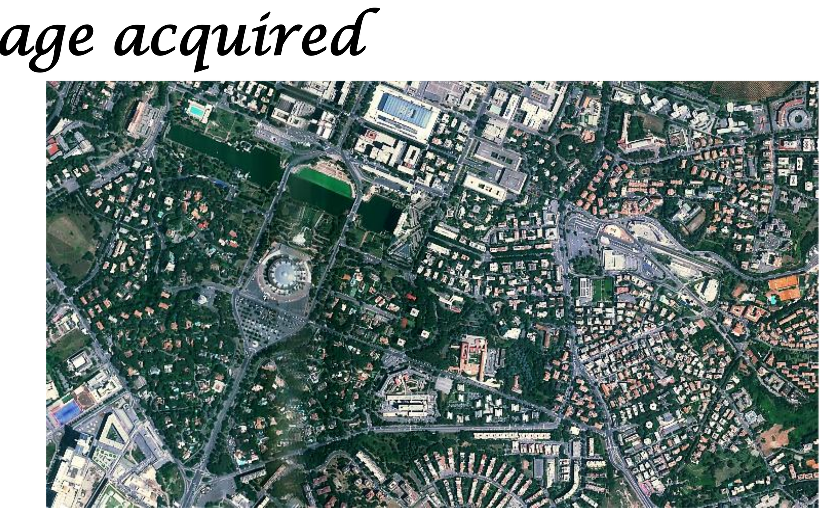
Results

Active and passive alignment methodology was developed and used extensively for aligning MX and PAN detectors. The alignment of detectors in all the X,Y and Z planes has been achieved within ±5microns.



Alignment data for five detectors of MX

First image acquired



The optical butting technique developed was successfully implemented in realizing the complex focal plane of Cartosat-2S that involves precise placement of fold mirrors and detectors within a few micron accuracy inclusive of meeting the highly stringent stability requirements over the specified operational loads. These kind of complex FPAs pose great challenges in alignment and characterization of their components. Passive and active mode of alignment methodologies, requiring the development of high precision test benches, were used in ensuring the alignment of all focal plane components. A novel methodology was developed for final characterization of FPA for which the TDI detectors were required to be operated in area array mode facilitating the active alignment of multiple detectors. The optical butting technique implemented successfully in Cartosat-2S paves way for the realization of many upcoming and future high resolution payloads for various missions of ISRO.