Question: *The manuscript describes the non-coaxial operating characteristics of the visible channel and the mid-wave and long wave channels. However, it should further clarify the impact of such characteristics on existing image registration methods, as well as the rationale for introducing the ground-based laser.*

Our Reply: Thanks for your suggestion. We agree that the implications of the non-coaxial optical configuration for existing image registration methods, as well as the motivation for introducing the ground-based laser positioning system (GLPS), should be further clarified.

For FY-4A GIIRS, image navigation relies primarily on the visible channel. The image navigation of GIIRS is achieved through the combined application of attitude compensation, orbit compensation, and thermal deformation compensation derived from star observations. These compensation parameters, together with the pre-calibrated relative geometric relationship between the visible and infrared channels, are incorporated into the infrared image navigation model to determine the geographical locations of infrared observations.

However, since the visible and infrared channels follow separate optical paths, uncertainties in their relative geometric relationship may introduce additional navigation errors in the infrared channels. Therefore, accurate navigation of the visible channel does not necessarily guarantee equivalent navigation accuracy for the infrared channels. Independent validation of the infrared navigation results is thus necessary.

Moreover, conventional image registration and validation methods have limitations when applied directly to the GIIRS infrared channels. Their relatively low spatial resolution and staggered detector arrangement make accurate landmark matching challenging, while direct star-based validation is not available for these channels.

To address these limitations, the GLPS provides an independent geographical reference by transmitting laser signals from ground stations with precisely known coordinates. These signals can be directly detected by the LW detectors, enabling quantitative evaluation of the actual infrared navigation accuracy without relying on visible-to-infrared image registration. This approach allows us to independently assess the navigation results obtained from the infrared navigation model.

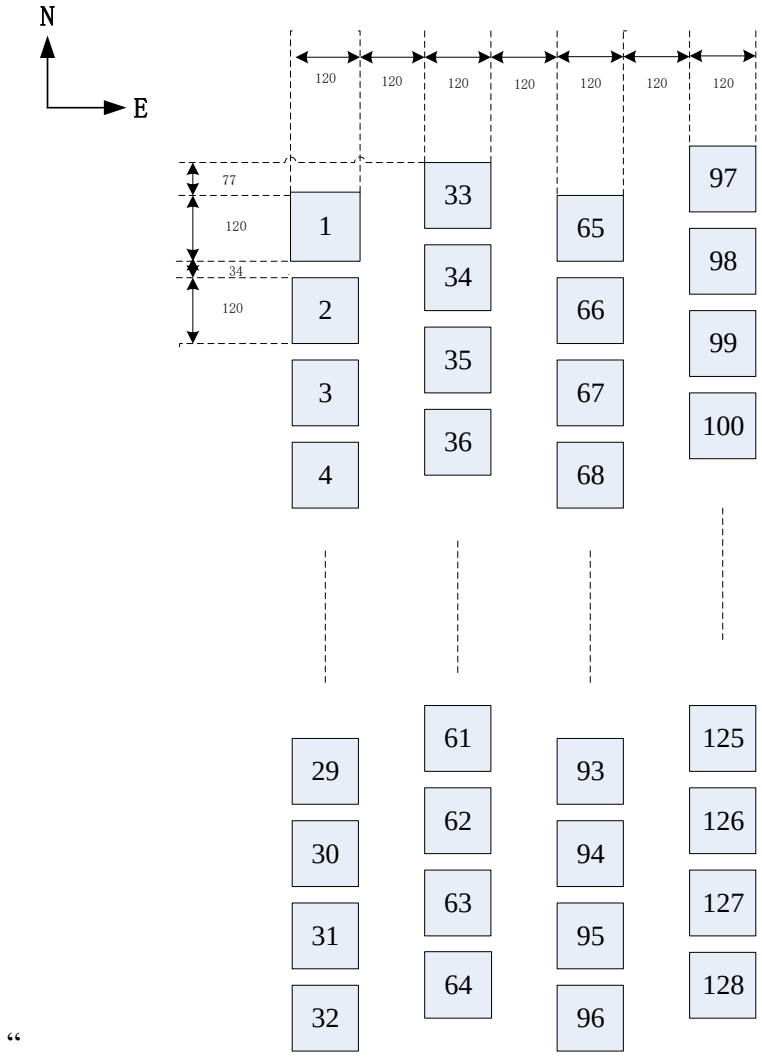
Accordingly, we have revised the Introduction and Section 2 to provide a clearer explanation of the GIIRS navigation mechanism, the influence of the non-coaxial optical configuration, and the rationale for introducing the GLPS.

"*GIIRS is equipped with a visible focal plane with a spatial resolution of 2 km and two infrared channels, namely the medium-wave (MW) and longwave (LW) channels, with a spatial resolution of 16 km. The infrared image navigation relies on corrections derived from visible-channel star observations and pre-calibrated inter-channel registration parameters. However, because the visible and infrared channels follow separate optical paths, uncertainties in inter-channel registration may introduce additional navigation errors. Consequently, visible-channel navigation accuracy cannot directly represent the actual navigation accuracy of the infrared channels. Furthermore, the relatively low spatial resolution and staggered detector arrangement of the infrared channels make direct landmark-based validation challenging, while direct star-based validation is unavailable. Therefore, an independent approach is required to assess the actual navigation accuracy of the infrared channels.*

"*The image navigation of FY-4A GIIRS is achieved through coordinated satellite–ground operations, involving attitude motion compensation (AMC), orbit motion compensation (OMC), and thermal deformation compensation (TMC; Xu et al., 2024). The ground system predicts observable stars and generates observation schedules and commands based on satellite orbit information and instrument operating conditions. GIIRS then performs scheduled star observations using its visible channel, and the acquired data are transmitted to the ground system for processing. The observed star centroids are extracted and compared with their predicted positions to determine pointing deviations. Based on these deviations, thermal deformation correction parameters are derived and uploaded to the satellite. Together with attitude and orbit motion compensation, these parameters are applied to correct the scanning mirror pointing angles and maintain the accuracy of the instrument's line of sight. For the LW and MW channels, the navigation corrections derived from visible-channel observations are transferred through pre-calibrated inter-channel registration parameters to determine the geographical locations of infrared observations. However, because the visible and infrared channels follow separate optical paths, uncertainties in inter-channel registration may introduce additional navigation errors. Therefore, independent validation is necessary to assess the actual navigation accuracy of the infrared channels.*"

Question: *The first and second columns are offset by 77 um, but this is not intuitively illustrated in Fig. 1. It is recommended to replace it with a complete 128-pixel layout diagram.*

Our Reply: Thank you for this helpful suggestion. We agree that the original Fig. 1 did not clearly illustrate the 77 μm offset between the first and second detector columns. Accordingly, we have replaced Fig. 1 with a complete layout diagram of all 128 detectors to provide a clearer and more intuitive representation of their spatial arrangement.



“

Figure 1: Layout of GIIRS detector array. The unit of the numbers in the figure is μm.”

Question: *When the ground-based laser is in operation, the laser signal received by the payload differs from the atmospheric radiation background under normal detection conditions. Here, the signal-to-noise ratio (SNR) should specify the noise sources under the ground-based laser positioning operating condition.*

Our Reply: Thank you for this valuable comment. We agree that the noise sources considered in the signal-to-noise ratio (SNR) estimation under ground-based laser observation conditions should be clearly specified.

GIIRS is designed to measure atmospheric infrared radiation. Under normal observation conditions, the instrument receives atmospheric infrared radiance, and the measured signal is also affected by instrumental noise, including thermal noise and 1/f noise. During ground-based laser observations, the received laser signal is superimposed on the atmospheric infrared background. Therefore, in our analysis, the radiance measured by GIIRS at the laser center wavelength under normal observation conditions is used as an effective background reference for evaluating laser signal detectability. This background reference reflects the atmospheric infrared radiance and the residual contributions of instrumental noise, including thermal noise and 1/f noise, after routine data processing.

We have revised Section 3.3 to clarify the background reference and the noise sources considered in the SNR estimation under laser observation conditions. We appreciate the reviewer's suggestion, which has helped improve the clarity of the laser signal detectability analysis.

"Under normal observation conditions, GIIRS measures atmospheric infrared radiance, and the resulting radiance data have undergone processing to account for background noise and instrumental noise, including thermal noise and 1/f noise. During ground-based laser observations, the received laser signal is superimposed on the atmospheric infrared background. Therefore, the radiance measured at the laser center wavelength during normal observations is adopted as an effective background reference for evaluating laser signal detectability. Considering this background reference, the laser transmission characteristics, and the spectral response of the LW detectors, the estimated signal-to-noise ratio exceeds 20 under clear-sky conditions, indicating that the ground-based laser signal can be detected by the GIIRS LW detectors."