

Preliminary Design of Near-Infrared Imaging Spectrometer onboard NEXTSat-1

*Woong-Seob Joeng¹⁾²⁾, Sung-Joon Park¹⁾, Bongkon Moon¹⁾, Dae-Hee Lee¹⁾, Jeonghyun Pyo¹⁾, Youngsik Park¹⁾, Il-Joong Kim¹⁾, Won-Kee Park¹⁾, Duk-Hang Lee¹⁾, Kyeongyeon Ko¹⁾, Ukwon Nam¹⁾, Goo-Hwan Shin³⁾, Jangsoo Chae³⁾, Toshio Matsumoto¹⁾⁴⁾⁵⁾

¹⁾ Korea Astronomy and Space Science Institute, Daejeon 305-304, Korea

²⁾ Korea University of Science and Technology, Daejeon 305-350, Korea

³⁾ Satellite Technology and Research Center, KAIST, Daejeon 305-701, Korea

⁴⁾ Institute of Space Astronautical Science, JAXA, Kanagawa 252-5210, Japan

⁵⁾ Institute of Astronomy and Astrophysics, Academia Sinica, Taipei 10617, Taiwan

¹⁾ jeongws@kasi.re.kr

ABSTRACT

The NISS (Near-infrared Imaging Spectrometer for Star formation history) onboard NEXTSat-1 is the near-infrared instrument optimized to the small satellite. The capability of both imaging and low spectral resolution spectroscopy in the near-infrared range is a unique function of the NISS. The major scientific mission is to study the cosmic star formation history in local and distant universe. For those purposes, the main targets are nearby galaxies, galaxy clusters, star-forming regions and low background regions.

The off-axis optical design of the NISS is optimized to have a wide field of view (2 deg. x 2 deg.) as well as the wide wavelength range from 0.95 to 3.8μm. The mechanical structure is considered to endure the launching condition as well as the space environment. The stray light analysis is being made to evade a light outside a field of view. The dewar inside the telescope is designed to operate the infrared detector at 80K stage. From the thermal analysis, we confirmed that the telescope and the dewar can be cooled down to around 200K and 80K, respectively in order to reduce the large amount of thermal noise. The NISS will be expected to demonstrate core technologies related to the development of the future large infrared telescope in Korea.

1. INTRODUCTION

The research and development for space science in Korea have been achieved from compact space telescope onboard small satellite. Although there were

international collaborations in ultraviolet and infrared missions (GALEX and AKARI), it was limited only in the scientific research. The FIMS/SPEAR (Edelstein et al. 2006) and MIRIS (Han et al. 2014) have been developed through the STSAT (Science and Technology Satellite) series managed by Korea Aerospace Research Institute. After the termination of STSAT series, the NEXTSat (NEXT generation of small Satellite) program operated by SaTReC (Satellite Technology and Research Center) was started in 2012. As one of the scientific payloads onboard NEXTSat-1, the NISS (Near-Infrared Imaging Spectrometer for Star formation history) have being developed by Korea Astronomy and Space Science Institute. The previous space experiences and heritages on ultraviolet and infrared imaging system enable us to develop the sophisticated observational technique with a capability of both imaging and spectroscopy using linear variable filters (LVF).

The NISS is a 15cm telescope cooled down to 200K by a passive cooling and covers wide wavelength range from $0.95\mu\text{m}$ to $3.8\mu\text{m}$ (Jeong et al. 2014). The NISS with a wide field of view of 2×2 deg. will perform the large area imaging spectroscopic survey of near-infrared sky up to 100 deg 2 . The spatial resolution of 15 arcsec will be better than that of MIRIS and the sensitivity for a point source will be around 17 AB magnitude in all wavelength range. These unique features of the NISS are expected to bridge the gap between optical ground surveys and infrared space surveys.

2. Instrument Design

The scientific targets of the NISS range from star-forming regions in the Galaxy to distant galaxies including unveiled near-infrared background. The spectral catalog from surveyed area will provide as valuable inputs for ground follow-up observations. Interesting spectral lines for scientific objectives in the wavelength range will be Paschen α , PAH and H₂O ice which are related to the star formation and are difficult to observe in ground due to strong atmospheric absorption. Fig.1 shows the design and expected output data of the NISS and the Table 1 shows the specification of the NISS.

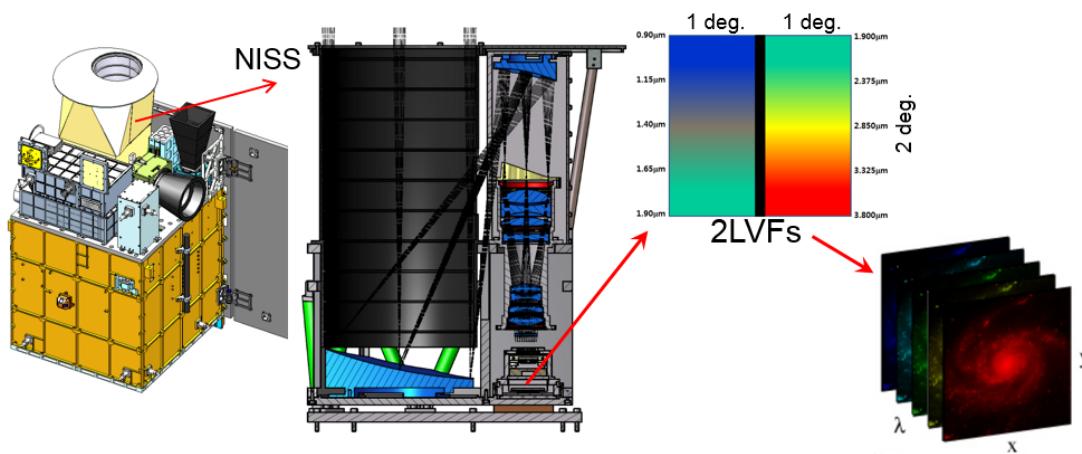


Fig. 1 Design and output data of the NISS

Table 1. Specification of the NISS

Parameter	Specification	Remark
Telescope aperture	15 cm	
Spectral coverage	0.95 ~ 3.8 μ m	wide wavelength coverage
Spectral resolution	20	$\lambda/\Delta\lambda$
Field of view (FoV)	2 deg \times 2 deg	wide FoV
Pixel FoV	7 arcsec	
Resolution	15 arcsec	limited by pointing stability
Number of filter	1	combined one with 2 LVFs
Detector array	HgCdTe 1024 \times 1024	18 μ m pixel pitch
Readout noise	10 ~ 15e ⁻	
Dark current	1 e ⁻ /s	IR sensor at 80K
Temperature of telescope	200 K	passive cooling

2.1 Optical Design

To get the better throughput and reduce the stray light from outside of FoV, we employed an off-axis optical design without any obscuration from secondary mirror. The material for mirrors is Aluminum 6061-T6 and lens materials such as calcium fluoride (CaF₂), zinc sulfide (ZnS), zinc selenide (ZnSe) and K-GIR79 are used for relay optics. The coating materials are chosen to have good transmission in the target wavelength range. Fig.2 shows the optical design of the NISS.

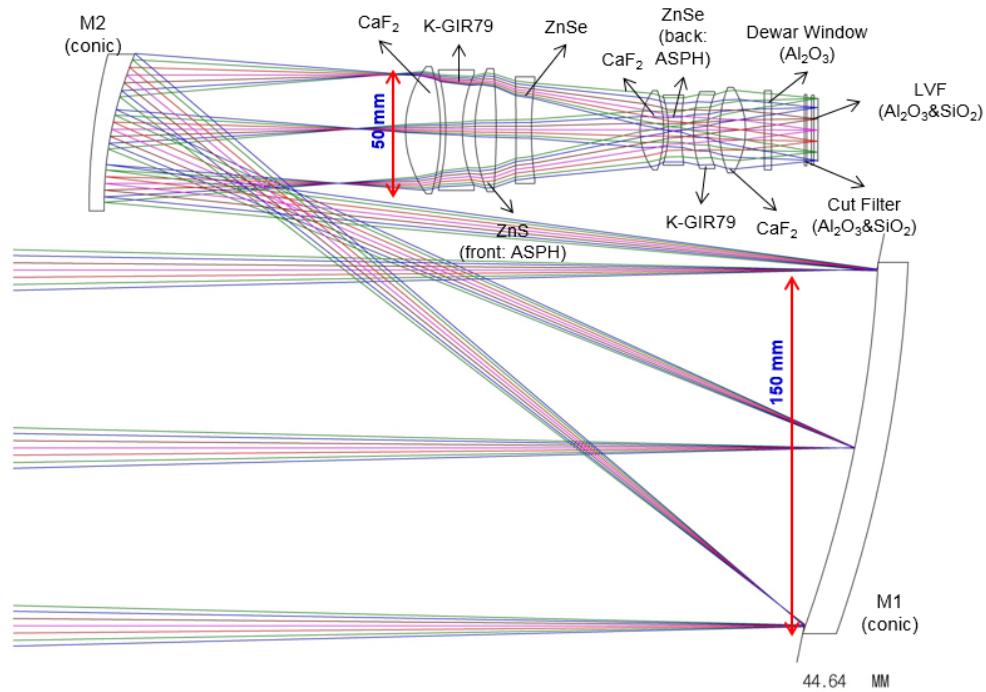


Fig. 2 Optical design of the NISS

2.2 Mechanical Design

The space environments such as radiation of high energy particles, launching vibration and shock, and thermal loads are considered in the mechanical design. In addition, the requirement of allocated mass and volume is satisfied. The designed overall size is 290(L) x 270(W) x 400(H) mm and total mass is estimated to be 16.57kg. The support structure and radiator is designed to minimize the heat loads from outside and to dissipate the heat loads inside. Fig. 3 shows the mechanical design of the NISS. From the mechanical analysis, a natural frequency of the NISS is estimated to be higher than the requirement of 100Hz. As seen in Fig. 4, the thermal analysis shows that the telescope can be cooled down to 200K. We also confirmed that small stirling cooler can cool the infrared detector down to the target temperature of 80K at ambient temperature range.

2.3 Electronics Design

As seen in Fig. 5, the electronics consists of two parts; one is inside the dewar for the operation of infrared sensor and the other is to process the data package from the sensor in the electronics box. The electronics box is composed of three parts; AMP for bias voltage setting, signal amplification and analog / digital conversion, DSP/IF for array clock generation, command/data processing and bus interface, and Power/CTR for DC to DC power conversion, regulation and control. The CAN (Controller Area Network) is used for the command and the status interfaces between the satellite and the NISS, and the SERDES (Serializer/Deserializer) is for data transfer. The interface and power lines have its backup lines for the redundant function.

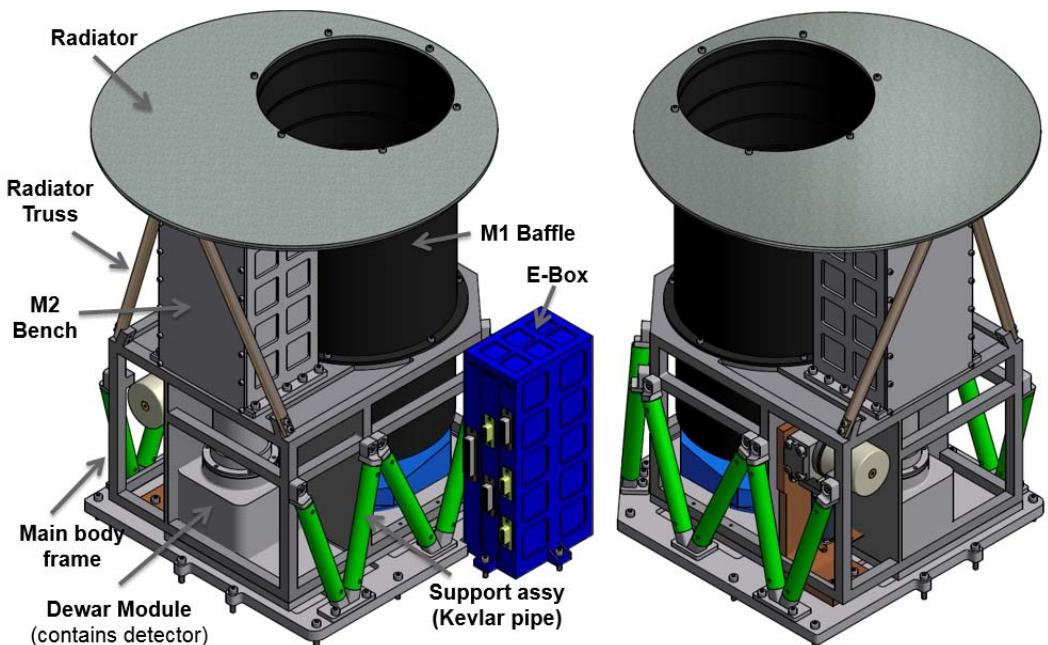


Fig. 3 Mechanical design of the NISS

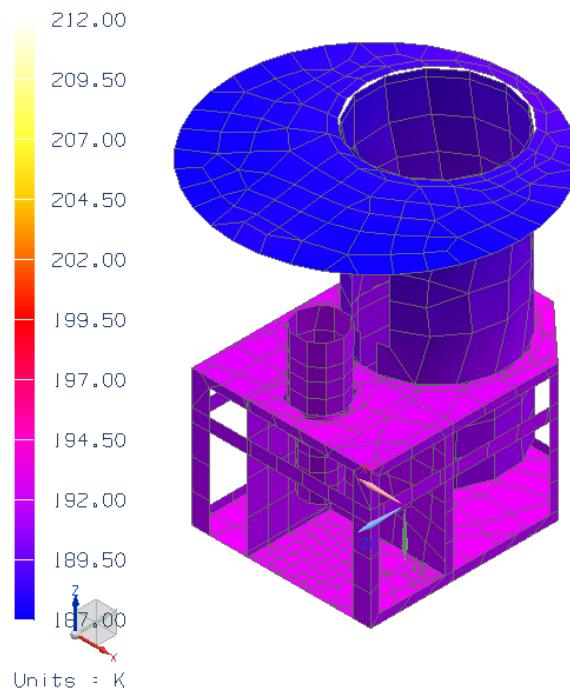


Fig. 4 Thermal analysis of the NISS

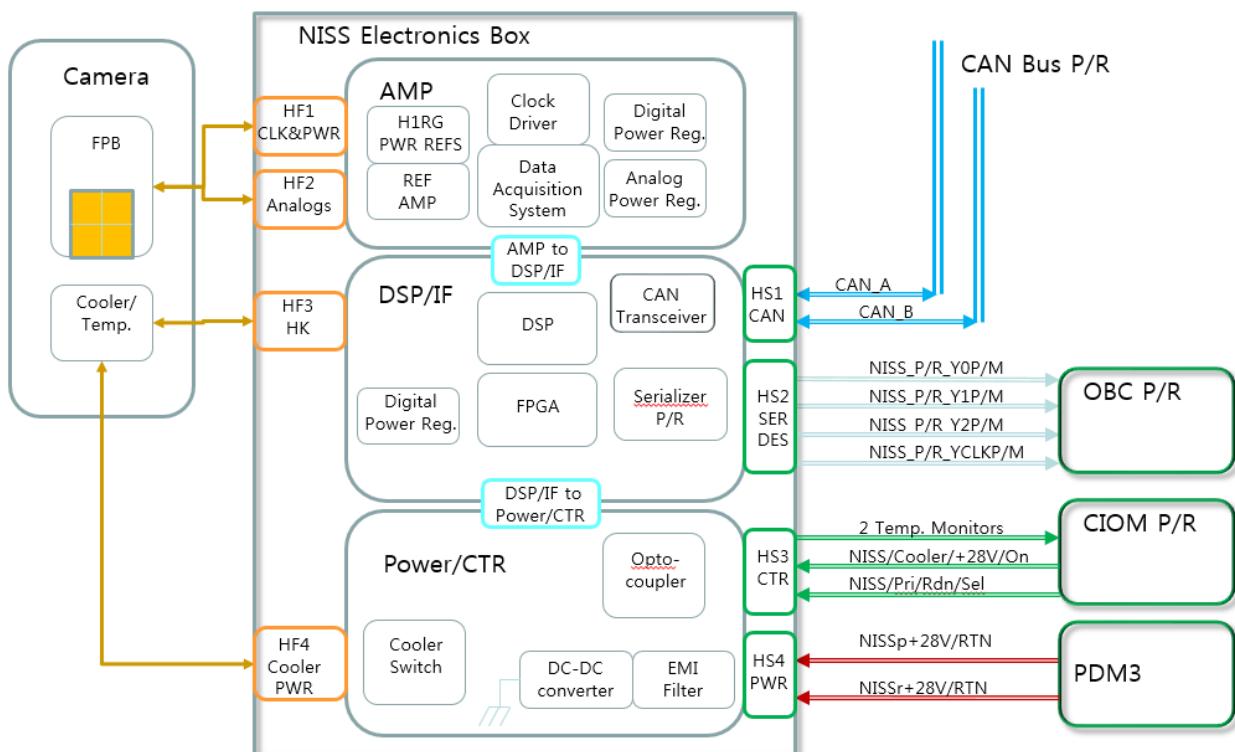


Fig. 5 Configuration of electronics

3. SUMMARY AND CONCLUSIONS

KASI is now developing the NISS for the imaging spectroscopic survey of the near-infrared sky. The design of the NISS is optimized to the small satellite for the purpose of obtaining the high throughput and survey speed in all target wavelength range. The NISS can cover wide FoV as well as wide wavelength range by employing two LVFs in the focal plane. The mechanical structure is also designed to endure the space environments and operate in the cryogenic temperature.

The detailed design of the NISS will be finished soon. After the test and calibration of the engineering qualification model of the NISS, the fabrication of flight model will be started. It will be launched on the middle of 2017. The NISS is expected to make a big impact on the development of future large infrared telescope.

REFERENCES

- Edelstein J., Korpela E.J., Adolfo J., Bowen M., Feuerstein M., et al. (2006), "The SPEAR Instrument and On-Orbit Performance", *Astro. Phys. J. Lett.*, **644**(2), 159-162.
- Han, W., Lee, D.-H., Jeong, W.-S., Park, Y., Moon, B., et al. (2014), "MIRIS: A Compact Wide-field Infrared Space Telescope", *Pub. of Astron. Soc. Pac.*, **126**, 853-862.
- Jeong, W.-S., Park, S.-J., Park, K., Lee, D.-H., Pyo, J., et al. (2014), "Conceptual Design of the NISS onboard NEXTSat-1", *J. Astron. Space Sci.*, **31**(1), 83-90.