# ASTER PROJECT OVERVIEW

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## ABSTRACT

*Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is a high spatial resolution multi-spectral imaging radiometer on NASA's Terra satellite launched in December 1999. ASTER spectrally covers the visible and near-infrared (VNIR), short-wave-infrared (SWIR), and thermal infrared (TIR) regions with 14 spectral bands, 15 to 90 m spatial resolution, and 60 km imaging swath. Observational performance of the ASTER instrument was examined by using the actual ASTER images, and it was confirmed that the ASTER has excellent radiometric and geometric performance. Currently ASTER is acquiring approximately 600 scenes per day as an average. The ASTER data are being used for a variety of applications in earth sciences.*

## 1. INTRODUCTION

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is a high spatial resolution multi-spectral imaging radiometer (Yamaguchi *et al*., 1993, 1998; Fujisada, 1994; Fujisada *et al*., 1998). ASTER is onboard the NASA's Terra spacecraft, which was successfully launched on December 18, 1999. The ASTER data release to public was started in November 2000 from both the ASTER Ground Data System (GDS) of Earth Remote Sensing Data Analysis Center (ERSDAC) in Japan and EROS Data Center (EDC) of U.S. Geological Survey in U.S.A. For more details and updates, please visit the following web site; http://www.ersdac.or.jp/ASTERProject /ASTERPro.html

ASTER covers the visible and near-infrared, short-wave-infrared, and thermal infrared regions with 14 spectral bands, and creates high-spatial-resolution (15-90 m) multi-spectral images of the Earth's surface. The primary science objective of the ASTER mission is to improve understanding of the local- and regional-scale processes occurring on or near the Earth's surface and lower atmosphere. ASTER data can be used to help establish a baseline for long-term monitoring of local and regional changes on the Earth's surface, which either lead to, or are in response to, global climate change. Specific areas of the science investigation include; (a) land surface climatology, (b) vegetation and ecosystem dynamics, (c) volcano monitoring, (d) hazard monitoring, (e) aerosols and clouds, (f) carbon cycling in the marine ecosystem, (g) hydrology, (h) geology and soil, and (i) land surface and land cover change.

The ASTER instrument has three separate optical subsystems; the visible and near-infrared radiometer (VNIR), short-wave-infrared radiometer (SWIR), and thermal infrared radiometer (TIR), as shown in Table 1. The VNIR is especially useful for topographic interpretation because of its along-track stereo coverage with 15 m spatial resolution and 0.6 base-to-height ratio. The VNIR bands are also useful in assessing vegetation and iron-oxide minerals in surface soils and rocks. The spectral bandpasses of the SWIR bands were selected mainly for the purpose of surface soil and mineral mapping. Having multispectral TIR data allows for a more accurate determination of the variable spectral emissivity of the land surface, and hence a more accurate determination of the land surface temperature. Because the ASTER data have wide spectral coverage and high spatial resolution, we can discriminate a variety of surface materials and reduce problems resulting from mixed pixels.

**Table 1. ASTER baseline performance requirements.**

| Subsystem (Spatial Resolution) | Band No. | Spectral Range (μm) | Radiometric Resolution | Absolute Accuracy (σ) | Signal Quantization Levels |
|---|---|---|---|---|---|
| VNIR (15 m) | 1<br>2<br>3N<br>3B | 0.52 - 0.60<br>0.63 - 0.69<br>0.78 - 0.86<br>0.78 -0.86 | ≤ 0.5 % | ≤ ± 4 % | 8 bits |
| SWIR (30 m) | 4<br>5<br>6<br>7<br>8<br>9 | 1.600 - 1.700<br>2.145 - 2.185<br>2.185 - 2.225<br>2.235 - 2.285<br>2.295 - 2.365<br>2.360 - 2.430 | NEΔρ ≤ 0.5 %<br>NEΔρ ≤ 1.3 %<br>NEΔρ ≤ 1.3 %<br>NEΔρ ≤ 1.3 %<br>NEΔρ ≤ 1.0 %<br>NEΔρ ≤ 1.3 % | ≤ ± 4 % | 8 bits |
| TIR (90 m) | 10<br>11<br>12<br>13<br>14 | 8.125 - 8.475<br>8.475 - 8.825<br>8.925 - 9.275<br>10.25 - 10.95<br>10.95 - 11.65 | ≤ 0.3 K | ≤ 3K (200-240K)<br>≤ 2K (240-270K)<br>≤ 1K (270-340K)<br>≤ 2K (340-370K) | 12 bits |

| | |
|---|---|
| Stereo Base-to-Height Ratio | 0.6 (along-track) |
| Swath Width | 60 km |
| Total Coverage in Cross-Track Direction by Pointing | 232 km |
| MTF at Nyquist Frequency | 0.25 (cross-track)<br>0.20 (along-track) |
| Band-to-Band Registration | 0.2 pixels (intra-telescope)<br>0.3 pixels (inter-telescope) |
| Peak Data Rate | 89.2 Mbps |
| Mass | 406 kg |
| Peak Power | 726 W |

## 2. INSTRUMENT PERFORMANCE

The ASTER images were evaluated in order to check observation performance and functionality of the ASTER instrument. The measured signal-to-noise ratios (SNRs) for the VNIR bands 1 and 2 exceed the specification as shown in Table 2. The SNR for the band 3 looks slightly lower than the specification. However, these measurements were performed by using the onboard calibration lamps, and the signal level was lower than the defined high level input radiance, which was used to specify the SNRs of the ASTER instrument. Therefore, we think that the radiometric performance of the VNIR subsystem can meet the specifications. For the SWIR subsystem, the SNRs were evaluated by using the onboard calibration lamps as well. The result exhibits very high SNRs for all the SWIR bands, although the radiance used was slightly higher than the defined input radiance.

**Table 2. Signal-to-noise ratios (SNRs) of the ASTER VNIR and SWIR bands.**

| Subsystem | VNIR | | | SWIR | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Band | 1 | 2 | 3N | 4 | 5 | 6 | 7 | 8 | 9 |
| Measured | 224.3 | 200.1 | 135.8 | 218 | 177 | 181 | 177 | 213 | 212 |
| Specified | ≥140 | ≥140 | ≥140 | ≥140 | ≥54 | ≥54 | ≥54 | ≥70 | ≥54 |
| Remarks | On-board lamp data, slightly lower than the defined input radiance. | | | On-board lamp data (the minimum values for lamp A), slightly higher than the defined input radiance. | | | | | |

As the ASTER instrument consists of three subsystems in order to optimize the optical design in different wavelength regions, it is a big challenge to perform band–to-band registration of the 14 spectral bands. Accuracy of the ASTER band-to-band registration is specified as 0.2 pixels for bands within each telescope, and 0.3 pixels for bands among different telescopes. The band-to-band registration is a part of the Level-1 data processing, whose algorithm is provided by the ASTER Science Team (Fujisada, 1998). Table 3 shows comparison of the Level-1 band-to-band registration. Reference bands were selected for each telescope; band 2 for VNIR, band 6 for SWIR, and band 11 for TIR. As shown in Table 3, we could conclude that the specification was successfully fulfilled by the version 2.0.

**Table 3. Band-to-band registration accuracy for ASTER Level 1B data.**

| | Band-to-Band Registration Errors | | | Pixel Geolocation Knowledge | |
|---|---|---|---|---|---|
| | Within Each Telescope | Among Telescopes | | Relative | Absolute |
| | | SWIR/VNIR | TIR/VNIR | | |
| ver.1.02 | < 0.2 pixels | < 0.2 pixels | < 0.5 pixels | 15 m | 50 m |
| ver.2.0 | < 0.1 pixels | < 0.2 pixels | < 0.2 pixels | 15 m | 50 m |

## 3. OPERATION SCENARIO AND STATUS

There are several constraints on ASTER data acquisition. The primary limitation on ASTER data collection is the data volume allocated to the instrument in Terra's memory (solid state recorder) and in the communications link with TDRSS and ground stations. The maximum average data rate allocated to ASTER, based on a two-orbit average, is 8.3 Mbps, which roughly corresponds to 8 minutes of full-mode daytime operation plus 8 minutes of nighttime TIR operation per orbit. The single orbit maximum data acquisition time is 16 minutes, if no data is acquired in both previous and following orbits.

The nominal daytime mode is simultaneous data acquisition using the three subsystems looking at the same 60 km imaging swath. The nominal nighttime mode is TIR-only operation. Four additional operation modes have been recognized as shown in Table 4. If a pointing angle of greater than 8.55 degrees is needed, the daytime VNIR or stereo mode can be used, pointing out to plus/minus 24 degrees. The TIR mode is also available in daytime. These three modes are complementary to the daytime full mode, and are used only when allocated resources cannot permit the full mode. The earth's night hemisphere is usually observed in TIR mode. However, it is possible to use the SWIR bands at night, the volcano mode. Such an occasion might arise if a target temperature is higher than the maximum input radiance for the TIR bands that could occur with high temperature targets like wildfires, lava lakes or active volcano flows. The SWIR bands can measure surface temperatures up to about 650 K with 30 m ground resolution in nighttime.

**Table 4. ASTER operation modes.**

| | Operation Modes | Subsystem | | | Data Rates |
|---|---|---|---|---|---|
| | | VNIR | SWIR | TIR | |
| Daytime | Full Mode | O | O | O | 89.2 Mbps |
| | VNIR Mode | O | | | 62.038 Mbps |
| | Stereo Mode | O | | | 31.019 Mbps |
| | TIR Mode | | | O | 4.109 Mbps |
| Nighttime | TIR Mode | | | O | 4.109 Mbps |
| | Volcano Mode | | O | O | 27.162 Mbps |

There are several types of instrument activity requests, collective termed xARs. Approved ASTER investigators can request activities relating to data acquisitions via Data Acquisition Requests (DARs). Local observations are made in response to DARs from individual investigators or individual teams. In cases where the request results in a major load on the instrument resources or where the request can be used to satisfy a large number of users, the request is from the ASTER Science Team in the form of Science Team Acquisition Requests (STARs).

Currently ASTER is acquiring approximately 600 scenes per day as an average. As of May 15, 2002, the total number of the obtained ASTER scenes has reached more than 413,000 scenes, including more than 150,000 scenes with less than 20% cloud coverage.

## 4. END-TO-END ARCHITECTURE

The overall end-to-end architecture of the ASTER mission, and the fundamental relationship between Japan and U.S. is illustrated in Figure 1. The EOSDIS in U.S. negotiates the Tracking and Data Relay Satellite System (TDRSS) schedule, captures data from Terra via TDRSS, and creates Level 0 data products. All Level 0 data are sent to Japan by either electronic means or by air freight. The ASTER GDS ingests the Level 0 data, processes all data to Level 1A (radiometric and geometric calibration coefficients computed but not applied), performs quality assessment on the data, and converts a subset to Level 1B (coefficients applied). The ASTER GDS also produces higher level data products at the requests of users. All Level 1A data are archived in Japan, and sent to the U.S. as well. Level 1B processing is carried out on-demand for as many as 310 scenes per day. The ASTER GDS and EOSDIS provide user access to all the ASTER standard data products, and distribute requested subsets of them to users either electronically or on appropriate media.

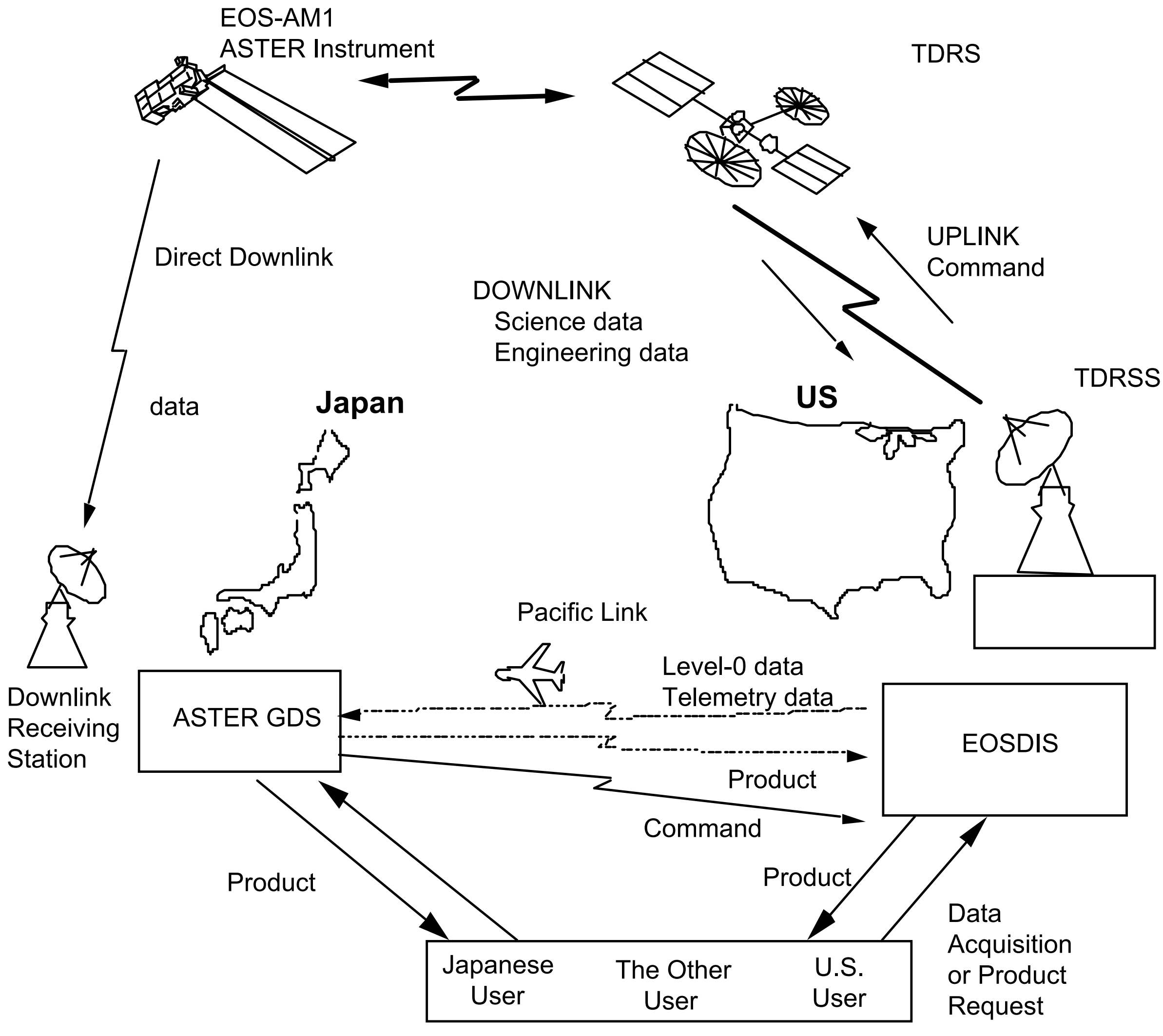


**Figure 1. ASTER end-to-end data system.**

## 5. DATA PRODUCTS

Table 5 shows a list of the ASTER standard and semi-standard data products available from GDS. Algorithm development for the standard data products has been carried out collaboratively by Japan and the U.S. A user can submit a Data Product Request (DPR) in order to obtain a standard data product either from U.S. EOSDIS or Japanese ASTER GDS. The category of semi-standard data products is defined only for GDS. A user can submit a DPR, however production of a semi-standard data product is not guaranteed, as the production schedule is controlled not only by DPRs but also by the long-term production.

**Table 5. ASTER standard and semi-standard data products available from GDS.**

| Product Code | Product Name | Standard | Semi-standard |
|---|---|---|---|
| 1A | Reconstructed, unprocessed instrument data | O | |
| 1B | Radiance at sensor | O | |
| 2A02 | Relative spectral emissivity (D-stretch) | O | |
| 2A03 | Relative spectral reflectance (D-stretch) | O | |
| 2B01 | Surface radiance | O | |
| 2B03 | Surface temperature | O | |
| 2B04 | Surface emissivity | O | |
| 2B05 | Surface reflectance | O | |
| 3A01 | Radiance at sensor with ortho-photo correction | | O |
| 4A01 | Digital elevation model (Relative) | | O |

## 6. CONLUDING REMARKS

The ASTER instrument is functioning well, and its observation performance is exceeding not only the specification but also our expectation. The investigation results of the ASTER early images exhibit excellent image qualities. The ASTER data are being used for a variety of applications in earth sciences, e.g., systematic monitoring of active volcanoes, coral reefs and glaciers, surface geologic mapping, and analysis of urban heat budget.

## 7. REFERENCES

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