## Remote Sensing License Tiering Q1 2023

Per 15 CFR 960.6, the NOAA Commercial Remote Sensing Regulatory Affairs (CRSRA) office categorizes each private space-based remote sensing system it licenses based on an analysis of whether the system produces or is capable of producing unenhanced data already available from other entities.

- A system with the capability to collect unenhanced data substantially the same as unenhanced data already available from entities or individuals not licensed under this part, such as foreign entities, is categorized as Tier 1;
- A system with the capability to collect unenhanced data substantially the same as unenhanced data already available, but only from entities or individuals licensed by CRSRA, is categorized as Tier 2; and
- A system with the capability to collect unenhanced data not substantially the same as unenhanced data already available from any domestic or foreign entity or individual is categorized as Tier 3.

Currently, CRSRA has:

- 71 Tier 1 licenses
- 0 Tier 2 licenses
- 23 Tier 3 licenses

When determining whether unenhanced data are substantially the same as other unenhanced data, factors include but are not limited to: spatial resolution, spectral bandwidth, number of imaging bands, temporal resolution, persistence of imaging, local time of imaging, geographic or other restrictions imposed by foreign governments, and all applicable technical system factors listed in Appendix A of 15 C.F.R. Part 960 and Part D of a NOAA license. The list and table below outline certain foreign systems and their known capabilities that make available the finest unenhanced data across various types of imagery. Therefore, CRSRA currently uses the below systems as a starting point to differentiate Tier 1 licenses from Tier 2 licenses for several common sensor types.

These parameters are derived exclusively from open-source research, and reflect data that are *available*, as the term is defined at 15 CFR 960.4.

This information is provided as a reference for the public and CRSRA intends to provide regular updates. However, CRSRA continually evaluates the availability from foreign and other CRSRA-licensed systems and uses that analysis and considers all applicable factors (not only those listed here) when categorizing any system.

Metric values for the best/novel US systems currently operating are also provided in the table as a guide, but not an exclusive one, to Tier 2-Tier 3 categorization for applicants.

The following foreign data was found to be available.

- Panchromatic (PAN) Imagery with;
  - 0.30 meters spatial resolution
  - 24 hours (approximately) average revisit rate
- Multispectral Imagery (MSI) with;
  - 0.7 meters spatial resolution and
  - TBD (approximately) average revisit rate
- Video Imagery with;
  - 0.9 meters spatial resolution
  - TBD average revisit rate
- Hyperspectral Imagery (HSI) with;
  - 10 meters spatial resolution
  - 2.5-15 nm spectral bandwidth
  - 24 hours (approximately) average revisit rate
- Ultraviolet (UV) Imagery with
  - 7km spatial resolution
  - spectral coverage 9.4-30.4 nm
  - 0 day revisit (persistent)
- Short Wave Infrared (SWIR) Data with;
  - 30 meter spatial resolution
  - spectral coverage 400-2450 nm with 10 nm bandwidth
  - 4 day revisit
- Long Wave Infrared (LWIR) Data with;
  - 80 meter spatial resolution
  - Approx. weekly revisit
- Night-Time Image (NTI) Data with;
  - 0.70 meter spatial resolution
  - 500-900 nm spectral range
  - > 24 hour revisit time
- Non-Earth-Imaging (NEI) VIS, VNIR Data with;
  - 0.075 meter spatial resolution
  - 400-1000 nm (spectral range)
- Synthetic Aperture Radar (SAR) imagery (X-band) with;
  - 59 (bits/$m^2$) (Information density)
  - 24 hours average revisit rate
- Synthetic Aperture Radar (SAR) Data (C-band) with;
  - 6.1 (bits/$m^2$) (Information density)
  - 24 hours average revisit rate.
- Synthetic Aperture Radar (SAR) Data (L-band) with;
  - 2.7 (bits/$m^2$) (Information density)
  - 14 days average revisit rate.

- Light Detection and Ranging (LIDAR) (532-nm) Data with;
    - 0.25 m vertical precision averaged over the 17m beam footprint
    - Profile pairs spaced at 3000m provide ~17-m in-track horizontal resolution
    - 91 days average repeating ground-track revisit rate.

| Satellite or Constellation | Country | Resolution (type)[1] Spectral or Other Information | Number of Satellites (advertised revisit rate)[2] |
|---|---|---|---|
| **PANCHROMATIC (PAN)[3,4]** | | | |
| Pléiades Neo-3, -4[5] | France | 0.30 meters (m) (spatial) | 2 (~24 hours) |
| KOMPSAT-3A[6] | S. Korea | 0.40 m (spatial)[7] (0.54 m raw) | 1 (7 days <20º off nadir) |
| SuperView | China | 0.50 m (spatial) | 4 (24 hours) |
| Jilin-1 Optical VHR | China | 0.50–1.2 m (spatial) | 64 (15 min., 9am-1230pm)[8] |
| Best US[9] | US | 0.25 m (spatial) | 4 (<1 day) |

[1] Resolution types listed in this column refer to spatial resolution, measured in meters (m), spectral resolution, measured in nanometers (nm), thermal accuracy or resolution, and measured in Kelvin (K). As other types of resolution become relevant to the listed capabilities, they will be added to this column.
[2] CRSRA currently reports revisit rates as advertised by the constellation operators or, in absence of operator information, as advertised by resellers.
[3] India's Cartosat-3 satellite collects PAN imagery with up to 0.25 m resolution and MSI at 1.1 m but does not meet the criterion for availability (data access is "very constrained") therefore it cannot be used as a commercial benchmark. Source: http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=917
[4] TripleSat (DMC3, SSTL S1-4) was removed. Although SSTL S1-4, the fourth satellite in the constellation, was initially launched in 2018 into a lower (580 km) orbit versus DMC3A/B/C (645 x 670 km orbit) the overall performance of the constellation is advertised as 0.80 – 1.0 meter. At 80 cm, it is no longer benchmark level.
[5] Airbus Pleaides Neo-3 and -4 entered operations in Nov and Dec 2021.
[6] Source: Apollo Mapping: Link: Buy 40-cm KOMPSAT-3A Satellite Imagery - Apollo Mapping
[7] Kompsat-3A is equipped with a 80 cm aperture AEISS camera and 8.6 m focal length telescope. 528km altitude. Native resolution is 54 cm and the oversampled data is processed to produce 40 cm resolution at nadir. Source: ESA EO Portal. Retrieved 22 Sept 2021
[8] The Jilin-1 constellation operated by Charming Globe (CGSTL) contains a variety of satellite types, including high-resolution optical, video, and hyperspectral. As of 11 August 2022, Jilin-1 includes 64 imaging satellites. The revisit rate for Jilin-1 varies by product but for 0.5 to 1.2 meter can achieve 15 minutes revisit from 9am to 1230pm, with less frequent coverage from 1230 pm to 5 pm (daylight hours). (Source: HEAD Aerospace; https://www.head-aerospace.eu/post/ten-more-75cm-satellites-added-to-the-jilin-1-constellation)
[9] For *Best U.S.* systems, the licensed resolution parameters are shown, not actual performance, which may be less.

| MULTISPECTRAL (MSI) | | | |
|---|---|---|---|
| Aleph-1 | BVI/ Argentina | 0.7-1.0 meters (m) (spatial)<br>5 bands between 400–900 nm | 307 (varies) |
| Pleaides Neo-3, -4 | France | 1.2 m (spatial)<br>6 Bands between 400-880 nm | 2 (~24 hours) |
| Superview-1 | China | 2.0 m (spatial)<br>4 bands between 450–890 nm | 4 (daily) |
| Jilin-1 GP01/02 | China | 5.0 m (spatial)<br>16 bands between 400–900 nm<br>7.5+ nm (spectral) | 2 (2–3 days) |
| Best US | US | 0.62 m (spatial)<br>4 bands between 380-1200 nm | 19 (3-7 hours) |
| **COLOR and VIDEO** | | | |
| Zhuhai-1 OVS-2, 3 | China | 0.9 meters (m) (spatial, video) | 4 (-) |
| Jilin-1 Video | China | 0.92 m (spatial, RGB color video) | 9 (3x per day) |
| CE-SAT-I | Japan | 1.0 m (spatial, color) | 1 (>1 day) |
| Best US | US | 0.5 m (spatial, PAN video) | 19 (3-7 hours) |

| HYPERSPECTRAL (HSI) | | | |
|---|---|---|---|
| Zhuhai-1 Orbita OHS-2, 3 | China | 10 meters (m) (spatial)<br>32 bands between 400–1,000 nm<br>2.5–15 nm[10,11,12] (spectral bandwidth) | 8 (~24 hours) |
| CHRIS (Compact High-Resolution Imaging Spectrometer) PROBA-1 | ESA | Configurable 17 m or 34 m (spatial)<br>200 bands 415-1050 nm[13]<br>1.25 nm @400 incr. to 11 nm @1050 nm | 1 (7 days) |
| Aleph-1 | BVI/ Argentina | 25–30 m (spatial)<br>Up to 600 bands between 400–900 nm[14]<br>5 nm FWHM (spectral bandwidth) | 30 (varies) |
| ENMAP | Germany | 30 m (spatial)<br>VNIR: 96 bands between 400-1030 nm<br>6.5 nm FWHM (spectral bandwidth)<br>SWIR: 136 bands between 950-2450 nm<br>10nm FWHM (spectral bandwidth) | 1 (4 days) |
| HISUI (Hyperspectral Imager Suite) | Japan | 20 m x 30 m (spatial)<br>185 bands between 400-2500 nm<br>VNIR: 10 nm, SWIR: 12.5 nm (spectral bandwidth) | 1 (~12-hour revisit)<br>(ISS orbit: 55º N to 52º S latitude) |
| Best US (spectral coverage, global coverage) | US | 34.7 m (spatial)<br>472 bands between 400-2500 nm<br>4.0 nm FWHM (spectral bandwidth) | 1 (7 days) |
| Best US (Spatial resolution, spectral resolution) | US/ Germany (DLR)[15] | 24 m (spatial)<br>235 bands between 400-1000 nm<br>2.55 nm FWHM (spectral bandwidth) | 1 (~12-hour revisit)<br>(ISS orbit: 55º N to 52º S latitude) |

[10] Full Width Half Maximum (FWHM)
[11] HSI spectral resolution range varies across spectral coverage and from satellite to satellite. (Sources: Apollo mapping, Zhuhai Orbita)
[12] Minimum operator specified spectral resolution: https://www.obtdata.com/en/zhuhai1.html
[13] CHRIS is capable of producing (filtering) up to 200 spectral bands but is constrained to acquiring just 19 bands at a time. The CCD offers the ability to: increase spectral bandwidth by summing sets of row-signals in the shift register before read-out, to bin pairs at the output port to increase across-track spatial resolution by a factor 2, and to restrict images to half swath widths to increase the number of spectral bands that can be read out. Source: https://earth.esa.int/eogateway/instruments/chris/description
[14] Aleph-1 is capable of producing (filtering) up to 600 spectral bands but is constrained to acquiring just 29 bands at a time. Source: Satellogic: https://www.euspaceimaging.com/wp-content/uploads/2020/10/Satellogic-Aleph-1-Data-sheet-final.pdf. Accessed 26 Feb 2021.
[15] DLR Earth Sensing Imaging Spectrometer (DESIS) on the International Space Station (ISS): Sensors | Free Full-Text | Data Products, Quality and Validation of the DLR Earth Sensing Imaging Spectrometer (DESIS) (mdpi.com)

| | | | |
|---|---|---|---|
| **ULTRAVIOLET (UV)<br>280-400 nm[16]** | | | |
| Sentinel-5P Tropomi | European Space Agency | 7 kilometers (km) (spatial)<br>270-320 nm (spectral bandwidth) | 1 (1 days) |
| Best US | US | TBD | |
| **SHORT WAVE INFRARED (SWIR)<br>1200-3000 nm[17]** | | | |
| Sentinel-2A, 2B | European Space Agency | 20 meters (m) (spatial)[18]<br>2 bands centered at 1610, 2185 nm<br>91 and 175 nm (spectral bandwidth) | 2 (5 days) |
| ENMAP | Germany | 30 m (spatial)<br>136 bands between 950-2450 nm<br>10 nm FWHM (spectral bandwidth) | 1 (4 days) |
| Best US | US | 3.7 m (spatial)<br>8 bands between 1150-2400 nm<br>50-60 nm (typ.) (spectral bandwidth) | 1 (-) |
| Best US<br>(spectral coverage, spectral resolution) | US | 34.7 m (spatial)<br>472 bands between 400-2500 nm<br>4.0 nm FWHM (spectral bandwidth) | 1 (7 days) |
| **MID-WAVE INFRARED (MWIR)<br>3000-8000 nm[19,20]** | | | |
| Best US[21,22] | US | 80 m (spatial)<br>1 band between 3300-5400 nm | 1 (~12-hour revisit)<br>(coverage ±53.6º lat.) |

[16] UV-A and UV-B only as shorter UV wavelengths are fully attenuated by the atmosphere
[17] Jilin-1 GPO1/02 removed. 4 MSI bands with 100 m spatial and 30-80 nm spectral resolution is below benchmark.
[18] Sentinel 2A, 2B have a 60 m spatial resolution SWIR band centered at ~1375 nm with 30 nm spectral bandwidth.
[19] India's Cartosat-3 collects 5.7 m MWIR data which is not commercially distributed. Source: http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=917
[20] S. Korea's KOMPSAT-3A satellite collects 5.5 m MWIR data which is not commercially distributed.
[21] Compact Thermal Imager (CTI), NASA. ISS mission 2019-2020. This is a USG system not licensed by NOAA. Sources: https://earthobservatory.nasa.gov/images/146547/taking-temperatures-from-iss, https://altirs.gsfc.nasa.gov/cti.html (Site viewed on 2 September 2021)
[22] CTI has collected over 10 million images of the earth with 80-meter spatial resolution, in continuous snapshot mode (1 image/sec), alternating bands (MWIR/LWIR). "QWIPs, SLS, Landsat and the International Space Station", M. Jhabvala NASA Goddard Space Flight Center et al. Retrieved 3 September 2021: https://ntrs.nasa.gov/api/citations/20190033892/downloads/20190033892.pdf

| | | | |
|---|---|---|---|
| **LONG WAVE INFRARED (LWIR)<br>8000-14000 nm** | | | |
| Aleph-1 | BVI/ Argentina | 90 meters (m) (spatial)<br>1 band between 8000-14000 nm | 30 (weekly) |
| CBERS-4 IRMSS[23,24] | China / Brazil | 80 meters (spatial)<br>1 band between 10400-12500 nm | 1 (16 days) |
| Best US[25] | US | 60 m (spatial)<br>1 band between 10400-12500 nm | 1 (16 days) |
| Best US[26] | US | 69 x 38 m (Azimuth vs Range) (spatial)<br>3 bands between 8500-12500 nm<br>CF: (1) 8800, (2) 10500, (3) 12100 nm.<br>31-61 nm FWHM (spectral bandwidth) | 1 (~12-hour revisit)<br>(ISS orbit: coverage between ±53.6º latitude) |
| **NIGHT-TIME-IMAGING (NTI)** | | | |
| EROS B | Israel | 0.70 meters (m) (spatial)<br>PAN: 500- 900 nm (spectral range) | 1 (3 days <30° off-nadir) |
| Jilin-1 SP03-8 | China | 0.92 m (spatial)<br>Blue: 437-512 nm, Green: 489- 585 nm,<br>Red: 580-723 nm (spectral range) | 9 (3x/day)[27] |
| Best US | US | TBD | TBD |
| **NON-EARTH-IMAGING (NEI)** | | | |
| HEO Robotics | Australia | 7.5 centimeters (cm)/pixel (spatial)<br>400-1000 nm (spectral range) | >20 (N/A) |
| Best US | US | 1 cm (spatial)<br>350-1050, 7900-12000 nm (spectral range) | 2 (N/A) |

[23] 2020 Joint Agency Commercial Imagery Evaluation—Remote Sensing Satellite Compendium (usgs.gov)
[24] The HuanJing-2B (HJ-2B) IRMSS-2 CRESDA sensor program acquires MWIR/LWIR data at 48/40 meters spatial resolution but has not made this data available. See distributor SpaceWill (en.spacewillinfo.com)
[25] Landsat 7: The Enhanced Thematic Mapper Plus (ETM+) - Landsat Science (nasa.gov)
[26] NASA ECOSTRESS Mission with Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR). This is a USG system not licensed by NOAA. Source: https://ecostress.jpl.nasa.gov/instrument
[27] Jilin-1 night-time imagery is available from nine satellites as of 28 Feb 2022. Values reported by HEAD Aerospace.

| Satellite or Constellation | Country | Resolution (type)[28] Spectral or Other Information | Slant Range /Azimuth Resolution[29] (meters) | Number of Satellites (current advertised revisit rate)[30] |
|---|---|---|---|---|
| **SYNTHETIC APERTURE RADAR (SAR)[31]** | | | | |
| **X-Band (9.2-10.4 GHz)** | | | | |
| ICEYE | Finland | 23 (bits/m$^2$) (Information Density: ID) | 0.5/0.25 | >10 (3-6 hours)[32] |
| TerraSAR/ TanDEM/PAZ | Germany/ Spain | 39 (bits/m$^2$) (ID) | 0.5/0.25 | 3 (24 hours)[33] |
| COSMO SkyMED 2nd Generation (CSG)[34] | Italy | 59 (bits/m$^2$) (ID) | 0.17/0.3 | 2 (~24 hours)[35] |
| Best US | US | 1619 (bits/m$^2$) (ID) | 0.25/0.01 | 44 (3-6 hours) |
| **C-Band (5.25-5.57 GHz)** | | | | |
| Tianxian[36,37] (Chaohu-1) | China | 8.39 (bits/m$^2$) (ID) | 1.0/0.5 | 1 (6-10 days) |
| Gaofen-3[38] | China | 6.1 (bits/m$^2$) (ID) | 0.9/1.0 | 2 (3 days) |
| Best US | US | TBD | TBD | TBD |
| **L-Band (1.215-1.30 GHz)** | | | | |
| ALOS-2[39] | Japan | 2.7 (bits/m$^2$) (ID) | 1.8/1.0 | 14 days |
| Best US | US | TBD | TBD | TBD |

[28] Resolution types listed in this column refer to spatial resolution, measured in meters (m), spectral resolution, measured in nanometers (nm), thermal accuracy or resolution, and measured in Kelvin (K). As other types of resolution become relevant to the listed capabilities, they will be added to this column.
[29] Slant range and azimuth resolution figures provided for reference only.
[30] CRSRA currently reports revisit rates as advertised by the constellation operators or as advertised by resellers.
[31] The SAR primary performance characterization metric has been changed from ground range detected (GRD) square pixel resolution to Information density **C** (bits/m$^2$) as defined by the Radar General Image Quality Equation (RGIQE) =β*LOG (1+SNR) where β=bandwidth per unit area on the ground at lowest acceptable grazing angle (β =SQ RT ($\beta_{Range}$ * $\beta_{Azimuth}$)), SNR=the signal-to-noise ratio = 1/(Noise Equivalent Sigma Zero (NESZ)) with MNR=0 (1 dB). Results are considered comparable if they are within 25%. Slant range resolution provided for reference only and may not represent best resolution as in some cases azimuth resolution may be superior.
[32] Revisit time is per ICEYE direct contact (24 September 2021).
[33] Revisit time is given for the Airbus SAR constellation consisting of: TerraSAR-X, Tandem-X, and PAZ. Source: https://www.intelligence-airbusds.com/en/8694-terrasar-x-tandem-x.
[34] Published CSK/CSG commercially available resolution statistics: e-geos Price List February 22, 2021 (Page 6).
[35] CSG-1 and -2 are in the same orbital plane as the four CSK satellites.
[36] "Chinese partnership to create Tianxian SAR satellite constellation", Andrew Jones, SpaceNews, 8 October, 2021. https://spacenews.com/chinese-partnership-to-create-tianxian-sar-satellite-constellation/
[37] Earth Observation Satellites Technical Specifications (Brochure), HEAD Aerospace, Viewed 22 December 2022. The Hisea-1 Tianxian concept demonstrator has 1 meter spatial resolution, while the newer Chaohu-1 has 0.5 meter resolution.
[38] Data disseminated through HEAD Aerospace: https://head-aerospace.eu/eo-satellites. Resolution is 0.9 x 1.0 m
[39] Advanced Land Observing Satellite-2: ALOS-2 - Satellite Missions - eoPortal Directory (esa.int)

| Satellite or Constellation | Country | Resolution (type)[40] Spectral or Other Information | Number of Satellites (advertised revisit rate)[41] |
|---|---|---|---|
| **LIDAR** | | | |
| TBD | TBD | | |
| Best US[42] | US | 17 m footprint, densely sampled range-profiler with 0.25 m vertical precision; in-track resolution of approx. 17 m; sparse cross-track sampling with 3,000 m beam-pair spacing operating at 532 nm supporting both topographic and bathymetric measurements. | 1 (91 days) |

[40] Resolution types listed in this column refer to spatial resolution, measured in meters (m), spectral resolution, measured in nanometers (nm), thermal accuracy or resolution, and measured in Kelvin (K). As other types of resolution become relevant to the listed capabilities, they will be added to this column.

[41] CRSRA currently reports revisit rates as advertised by the constellation operators or, in absence of operator information, as advertised by resellers.

[42] The high-level description of the NASA ICESAT-2 system, collection methods and resulting data products can be found at https://icesat-2.gsfc.nasa.gov/sites/default/files/page_files/ICESat2missionBrochureFINAL1.pdf. Viewed 7 Oct 2022. This profiling instrument provides six simultaneous 3-km-spaced pairs of densely-sampled measurements that provide in-track resolution that is approximately 2x the beam footprint of 17 m. The range precision of 0.25 m is the average elevation of the objects within that footprint and over very large distances can be averaged to provide mm-scale estimates of ice-sheet height change over time. This ranging instrument operates in the green portion of the optical spectrum at 532 nm and provides both topographic and bathymetric measurements and the range resolving capability enables both foliage penetration (with ~3 m resolution from examples on the website) and littoral water and seabed detection (depths being highly dependent on turbidity).