Remote Sensing License Tiering Q3 2021

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:

- 61 Tier 1 licenses
- 6 Tier 2 licenses
- 24 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 data was found to be available.

- Panchromatic (PAN) imagery with;
    - 0.40 meters spatial resolution
    - 65 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
- Short Wave Infrared (SWIR) Data
    - 20 meter spatial resolution,
    - limited spectral coverage
    - 5 day revisit
- Long Wave Infrared (LWIR) Data
    - 90 meter spatial resolution
    - Approx. weekly revisit
- Night-Time Image (NTI) Data
    - 0.70 meter spatial resolution
    - > 24 hour revisit time
- Synthetic aperture radar (SAR) imagery (X-band) with;
    - 51 (bits/m^2) (Information density)
    - 24 hours average revisit rate.

Satellite or Constellation	Country	Resolution (type)[1] Spectral or Other Information	Number of Satellites (advertised revisit rate)[2]
PANCHROMATIC (PAN)[3,4]			
KOMPSAT-3A	S. Korea	0.40 meter (m) (spatial)[5] (0.54 m raw)	1 (2.7 days <20º off nadir)
KOMPSAT-3	S. Korea	0.50 m (spatial)[6] (0.7 m raw)	1 (2.7 days <20º off nadir)
SuperView	China	0.50 m (spatial)	4 (24 hours)
Pléiades	France	0.50 m (spatial)	2 (24 hours)
EROS-B	Israel	0.70 m (spatial)[7]	1 (5–6 days)
Jilin-1 Optical	China	0.72–1.06 m (spatial)	23 (4 hours)[8]
Best US	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] Kompsat-3A equipped with 80 cm aperture AEISS camera, 8.6 m focal length telescope. 528km altitude. Kompsat-3A native resolution is 54 cm and the oversampled data is processed to produce 40 cm resolution at nadir. Source: ESA EO Portal. Retrieved Sept 22, 2021
[6] Kompsat-3 equipped with 80 cm aperture AEISS camera, 8.6 m focal length telescope. 625km orbit. Native resolution is 70 cm, the oversampled data is processed to 50 cm resolution at nadir. Source: ESA EO Portal Retrieved Sept 22, 2021
[7] Apollo Mapping reports EROS-B data as 70 cm for both PAN and Night-Time imaging.
[8] The Jilin constellation operated by Charming Globe contains a variety of satellite types, including, as of March 4, 2021, 11 high-resolution optical, 12 video, and 2 hyperspectral. The values here are as reported by Charming Globe and Apollo Mapping. The revisit rate for Jilin-1 varies by product.

MULTISPECTRAL (MSI)			
Aleph-1	Argentina	0.7-1.0 m (spatial) 5 bands between 400–900 nm	varies
KOMPSAT-3A	S. Korea	1.6 m (spatial)[9] (2.0 m raw) 4 bands between 450–900 nm	2 (33.6 hours)
KOMPSAT-3	S. Korea	2.0 m (spatial)[10] (2.8 meter raw) 4 bands between 450–900 nm	2 (33.6 hours)
SuperView	China	2.0 m (spatial) 4 bands between 450–890 nm	4 (24 hours)
Jilin-1 GXA, GF02A/3A/2B/ 3B01-06, KF01, SP04-8	China	2.88–4.24 m (spatial) 4 bands between 450–900 nm SPO4-08 include a 5th band	16 (-)
Jilin-1 GP01/02	China	5.0 m (spatial) 16 bands between 400–900 nm 7.5+ nm (spectral)	2 (2–3 days)
Best US	US	0.81 m (spatial) 4 bands between 450-900 nm	24 (3-8 hours)
COLOR and VIDEO			
Zhuhai-1 OVS-2, 3	China	0.9 m (spatial, video)	4 (-)
Jilin-1 Video 1LQ, SP01-8, F03C01-3	China	0.92–1.1 m (spatial, RGB color and video)	13 (-)
CE-SAT-I	Japan	1.0 m (spatial, color)	1 (>1 day)
Best US	US	0.5 m (spatial, PAN video)	24 (3-8 hours)

[9] Revised figures reflect reprocessed oversampled imagery.
[10] Revised figures reflect reprocessed oversampled imagery.

HYPERSPECTRAL (HSI)			
Zhuhai-1 Orbita OHS-2, 3	China	10 m (spatial) 32 bands between 400–1,000 nm 2.5–15 nm[11,12,13] (spectral bandwidth)	8 (~24 hours)
Aleph-1	Argentina	25–30 m (spatial) Up to 600 bands between 400–900 nm[14] 5 nm FWHM (spectral bandwidth)	varies
GaoFen-5 AHSI[15]	China	30 m (spatial) 320 bands between 400-2500 nm 5 nm VNIR (spectral bandwidth)	1 (-)
Best US	US	TBD	TBD
SHORT WAVE INFRARED (SWIR) 1200-3000 nm[16]			
Sentinel-2A, 2B	European Space Agency	20 m (spatial)[17] 2 bands centered at 1610, 2185 nm 91 and 175 nm (spectral bandwidth)	2 (5 days)
GaoFen-5 AHSI	China	30 m (spatial) 320 bands between 400-2500 nm 10 nm FWHM (spectral bandwidth)	1 (-)
PRISMA[18]	Italy	30 m (spatial) 171 bands between 920-2505 nm 12 nm FWHM (spectral bandwidth)	1 (7 days)
Best US	US	3 m (spatial) 380-1200 (spectral coverage)	3 (-)

[11] Full Width Half Maximum

[12] HSI spectral resolution range varies across spectral coverage and from satellite to satellite. (Sources: Apollo mapping, Zhuhai)

[13] Minimum operator specified spectral resolution: https://www.obtdata.com/en/zhuhai1.html

[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 Feb 26, 2021.

[15] Source: https://www.researchgate.net/publication/338053662_The_Advanced_Hyperspectral_Imager_Aboard_China's_Gao Fen-5_Satellite

[16] Jilin-1 GPO1/02 (China) removed. At 100 m spatial resolution, 4 sub-bands, and 30-80 nm spectral resolution, data is not benchmark level.

[17] Sentinel 2A and 2B also have a 60 m spatial resolution SWIR cirrus band centered at ~1375 nm with a spectral bandwidth of 30 nm.

[18] ESA EO portal. https://directory.eoportal.org/web/eoportal/satellite-missions/p/prisma-hyperspectral

MID-WAVE INFRARED (MWIR) 3000-8000 nm[19,20]			
TBD	TBD	TBD	TBD
Best US[21,22]	US	80 meters (spatial) 1 band between 3300-5400 nm	1 (~12-hour revisit) (coverage ±53.6º latitude)
LONG WAVE INFRARED (LWIR) 8000-14000 nm			
Aleph-1	Argentina	90 meters (spatial) 1 band between 8000-14000 nm 0.01K (thermal sensitivity)	13 (weekly)
Best US[23]	US	69 x 38 meters (azimuth vs Range) (spatial) 3 bands between 8500-12500 nm CF: (1) 8800, (2) 10500, (3) 12100 nm. 31-61 nm FWHM (spectral bandwidth) 0.1K (thermal sensitivity)	1 (~12-hour revisit) (ISS orbit: coverage between ±53.6º latitude)
NIGHT-TIME-IMAGING (NTI)			
EROS B	Israel	0.70 meters (spatial)	1 (3 days <30° off-nadir)
Jilin-1 Video 04-08	China	0.92 meters	5 (-)[24]
Best US	US	TBD	TBD

[19] India's Cartosat-3 satellite collects MWIR at 5.7 m but does not meet the criterion for availability therefore it cannot be used as a commercial benchmark. Source: http://database.eohandbook.com/database/instrumentsummary.aspx?instrumentID=917

[20] S. Korea's KOMPSAT-3A satellite collects MWIR at 5.5 m but does not meet the criterion for availability–not sold commercially (Apollo mapping) or observably provided to academic community.

[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 reviewed on September 2, 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

[23] 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

[24] The Jilin-1 constellation operated by Charming Globe contains a variety of satellite types; as of 4 March 2021, 11 high-resolution optical, 12 video, and 2 hyperspectral. Night-time imagery available from at least five video satellites. Values reported by Charming Globe, Apollo Mapping. The revisit rate for Jilin-1 varies by product.

Satellite or Constellation	Country	Resolution (type)[25] Spectral or Other Information	Slant Range Resolution[26] (meters)	Number of Satellites (current advertised revisit rate)[27]
	SYNTHETIC APERTURE RADAR (SAR)[28] X-Band			
ICEYE	Finland	23 (bits/m^2) (Information Density: ID)	0.5	>10 (3-6 hours)[29]
COSMO Sky MED 1st Generation (CSK)[30]	Italy	33 (bits/m^2) (ID)	0.4	4 (12 hours)[31]
TerraSAR/TanDEM/ PAZ	Germany/ Spain	39 (bits/m^2) (ID)	0.5	3 (24 hours)[32]
COSMO Sky MED 2nd Generation (CSG)[33]	Italy	51 (bits/m^2) (ID)	0.29	1 (~24 hours)[34]
Best US	US	1619 (bits/m^2) (ID)	0.25	44 (3-6 hours)
	C-Band			
RADARSAT-2[35]	Canada	5.17 (bits/m^2) (ID)	1.6	1 (24 hours)
TY-MiniSAR[36] (Hisea-1)	China	4.2 (bits/m^2) (ID)	1.0	1 (6-10 days)
Best US	US	TBD	TBD	TBD

[25] 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.
[26] Slant range resolution figures provided for reference only.
[27] CRSRA currently reports revisit rates as advertised by the constellation operators or, in absence of operator information, as advertised by resellers.
[28] 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 (β_{Range} * $\beta_{Azimuth}$)), SNR=the signal-to-noise ratio = 1 / (Noise Equivalent Sigma Zero (NESZ)) with MNR=0 (1 dB). In this equation, Azimuth resolution has been standardized (best available foreign) to 0.25 meters (X-band) and 1.0 meter (C-band). Results are considered comparable if they are within 25%. Slant range resolution provided for reference only.
[29] Revisit time is per ICEYE direct contact (September 24, 2021).
[30] Published CSK/CSG commercially available resolution statistics: e-geos Price List February 22, 2021 (Pg. 6)
[31] e-geos advertises 4 acquisitions a day with two in the early morning and two in the late afternoon.
[32] 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.
[33] Published CSK/CSG commercially available resolution statistics: e-geos Price List February 22, 2021 (Page 6).
[34] CSG-1, the first Next Generation satellite, is in the same orbit as the four CSK satellites.
[35] The newer RCM constellation is for Government of Canada use and is not commercially available.
[36] Sihan Xue, et al, HISEA-1: The First C-Band SAR Miniaturized Satellite for Ocean and Coastal Observation, MDPI, Remote Sens. 2021, 13, 2076. https://doi.org/ 10.3390/rs13112076