IMINT – a very basic introduction

Introduction

“Imagery intelligence (IMINT) is the technical, geographic, and intelligence information derived through the interpretation or analysis of imagery and collateral materials.” Typically, this means analysis and interpretation of reconnaissance images acquired from air or space.
Aerial reconnaissance began prior to the first world war and was then further developed throughout the following wars – with the cold war it also arrived in the space domain.

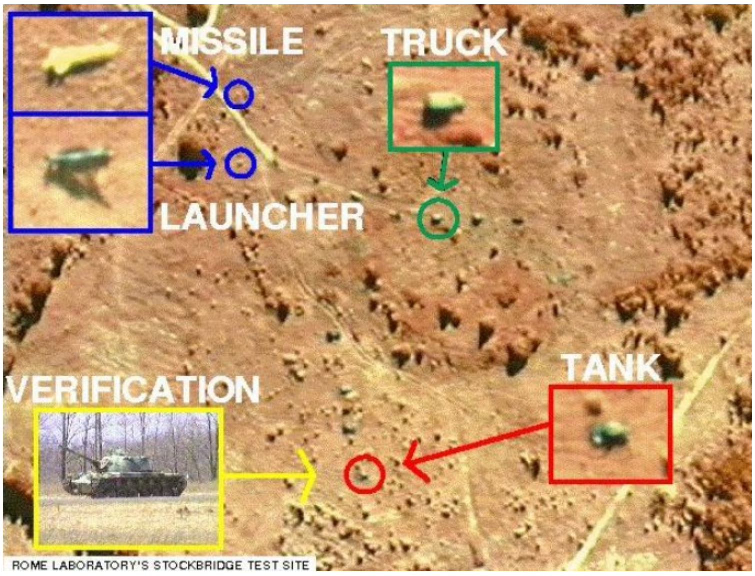


Figure 1 Example of a very basic IMINT analysis/ target detection

Here we will give you a short overview of how IMINT works and on which factors a good IMINT analysis depends. Further, we will give you an overview of sensors (optical, infrared and SAR) and platforms (aerial, satellite and drones) used for IMINT with many real examples.

Remote Sensing

The basis for aerial or space reconnaissance is the image acquisition. The scientific field for this is remote sensing, meaning the monitoring of the Earth’s surface from the view from above. Remote sensing describes how an image can be acquired with respect to different sensors. In general, a remote sensing sensor detects some sort of electromagnetic radiation. In case of optical sensors (just like every basic camera) the radiation measured is reflected sunlight from the Earth’s surface.
So, what we are doing with our sensor is to measure how much light a surface reflects or emits to the sensor. Let’s see what different types of sensors there are.

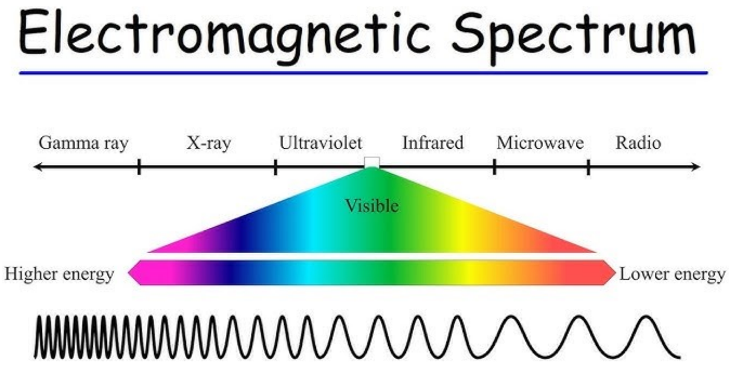


Figure 2 Electromagnetic spectrum. IMINT works with different sensors working in the visible, infrared or microwave spectrum.

Sensor Types

Electro-Optical

Optical sensors basically work like normal digital cameras. They detect light in the visible spectrum, the same light that also our eyes can detect/see. Most of these sensors capture the light in a panchromatic (PAN) mode, this means in a wider range of the visible light. Usually, this range is a combination of the visible light colors with the center in the green light spectrum. The resulting image will then be black/white, because we only acquire the light in one spectrum/ band and do not differentiate different colors. Most reconnaissance sensors therefore also have a multispectral (MS) mode, where 3 images are acquired in the red, the green and the blue spectrum of light (RGB), when we then combine these 3 images, we get a “normal” true color image.
So then why do most platforms even have a PAN mode? Because the spatial resolution (see next chapter) is typically 4x better in the PAN mode, because the sensor receives much more energy when it does not have to split the light into different bands.

Figure 3 Pleiades Neo satellite PAN image with 0.3 m spatial resolution

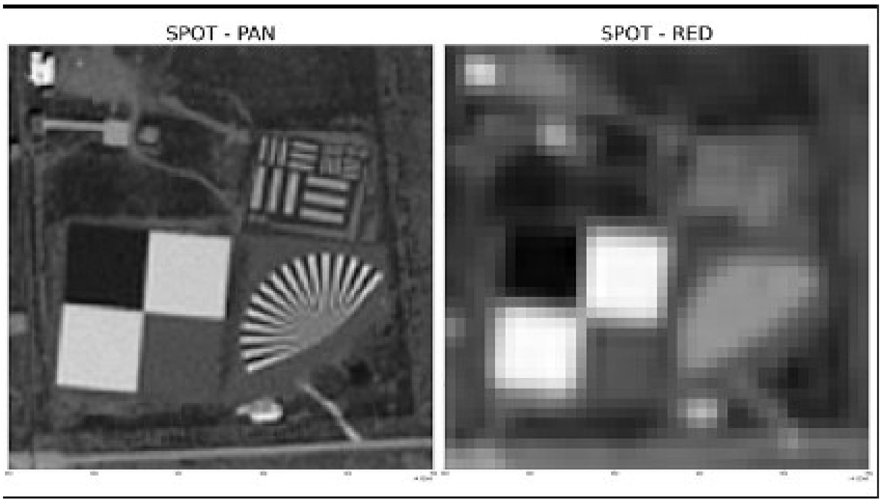


Figure 4 SPOT satellite images in its PAN and red band, where we can clearly see a much lower spatial resolution in the red channel.

Infrared

An infrared sensor is actually an optical sensor as well, just working in a different spectrum of the light. It works in the thermal infrared of the light spectrum instead of the visible spectrum. The small difference here is that this light is usually not reflected sunlight, but emitted light – or heat - from the Earth's surface. Emitted means, that the object itself is radiating this light – it sends away its heat. However, the emitted radiation cannot be directly compared to the temperature of an object, because it also depends on the material itself. Some materials, like water, typically emit a lot more infrared light than other materials, like polished metals. One of the big advantages here is that it also works at night, because we need no sunlight for reflection. Infrared sensors typically have a lower spatial resolution than PAN or true color images, because the longer the wavelength we detect with our sensor, the worse the spatial resolution – because longer wavelengths have less energy and there is less radiation in that spectrum on the Earth.

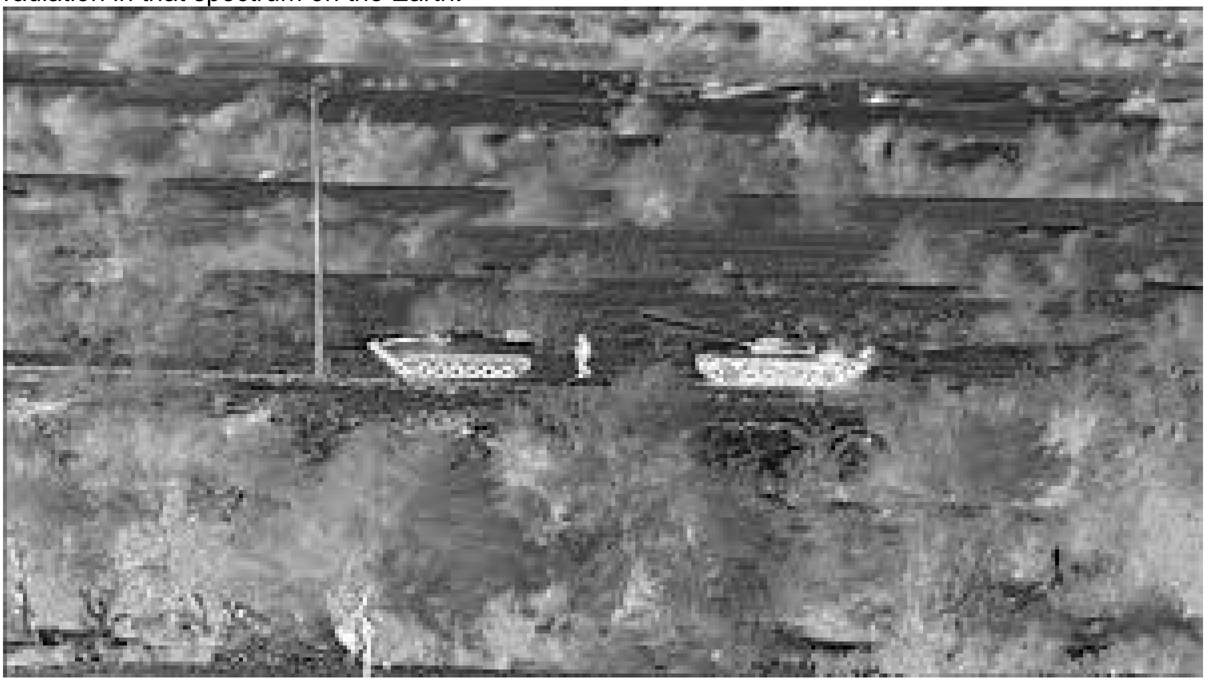


Figure 5 Thermal infrared image from two tanks and a soldier.

Hyperspectral

Hyperspectral sensors are a special case of optical sensors, because they not only acquire images in PAN or RGB, but in many more spectral bands. They typically acquire images in several dozen, up to several hundred spectral bands ranging from ultraviolet up to longwave infrared (LWIR). With these differentiations it is possible to distinguish a lot of different materials from each other, because every material has its own unique reflectance pattern, it is like a unique fingerprint. But these sensors typically have a very low spatial resolution (several meters), that is why these sensors are not very much used in IMINT – or at least not yet.

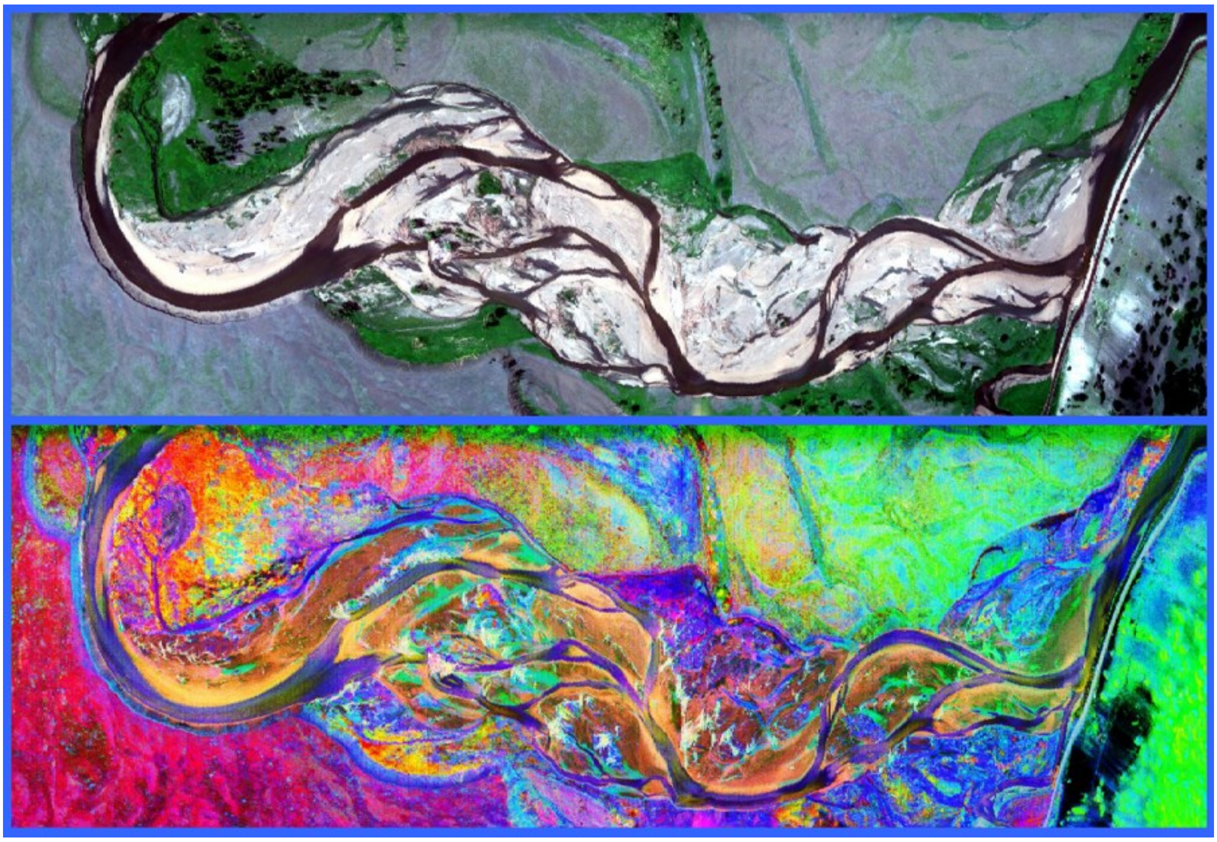


Figure 6 Top: a true color image of a river. Bottom: false color image of the same river, where additional spectral bands were used and now we can distinguish different minerals from each other.

SAR

Synthetic Aperture Radar (SAR) is a very special case of IMINT sensors, but very much used. SAR is an active sensor, whereas all the optical sensors are passive. Active means, that the sensor emits its own light source and measures how much of the light will return to the sensor through reflectance. The light spectrum used for this is in the microwave/radio spectrum – or simply RADAR. So, these sensors send out radar pulses, which are then reflected to some degree by the target and are then again measured by the sensor.

The big advantage of such an active sensor is that it also works at night, because we have our own “light” source. A second advantage is that these radio wavelengths are weather independent (because the wavelength is very long compared to visible light) – they just go through clouds. Therefore, a SAR sensor works almost ever no matter of the weather or daytime.

A disadvantage of a SAR sensor is that it can be very hard to interpret the images. They are black and white and the geometries can be distorted caused by the special image acquisition method of a SAR sensor. With a SAR we always look to the side with respect to the flying direction and not nadir (perpendicular), but always with an angle typically between 20° and 60°.

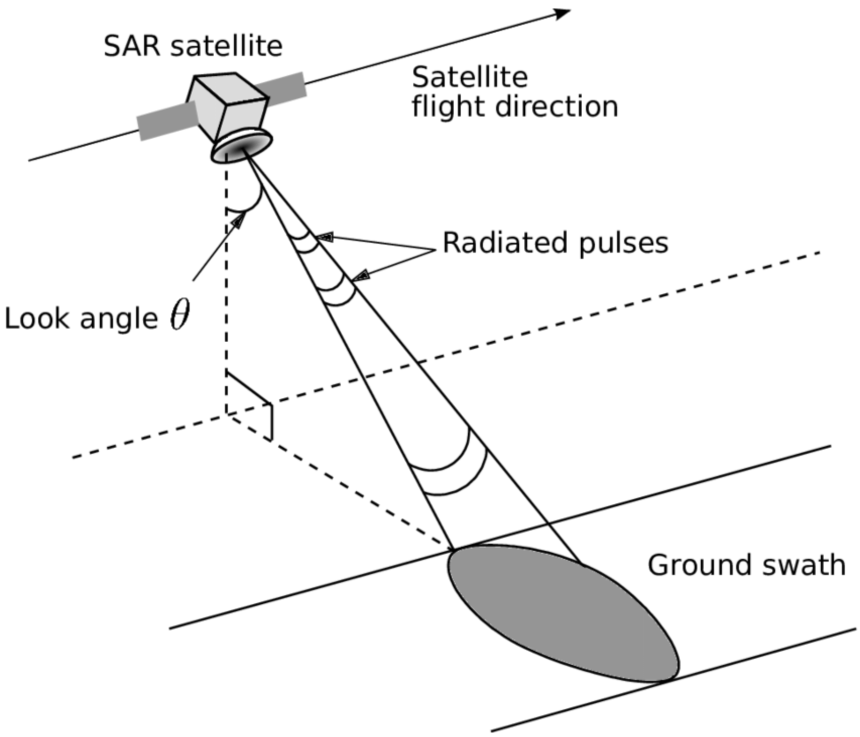


Figure 7 SAR acquisition mode, where the sensor looks sidewards

Furthermore, the color or brightness in a SAR scene is not connected to the true color or human perception, but it typically tells us how good an object scatters the radar signal or scatters it directly back to our sensor. Depending on the radar frequency use, for example forests will appear very bright, because they scatter the signal very well. And there can be other effects in the image, e.g. so called layover, where a mountain base and its peak are switched or moving objects that are shifted in the image because of their velocity with respect to the sensor. Nevertheless, most of these effects can be overcome to some degree with software and elevation data, but it takes some time and processing to do so.

Figure 8 SAR example image – in this case the sensor was on the upper side of the image and was looking towards the bottom, we can clearly see the shadows to the bottom of the image. This shadow is not caused by the sun, but by the sensor itself.

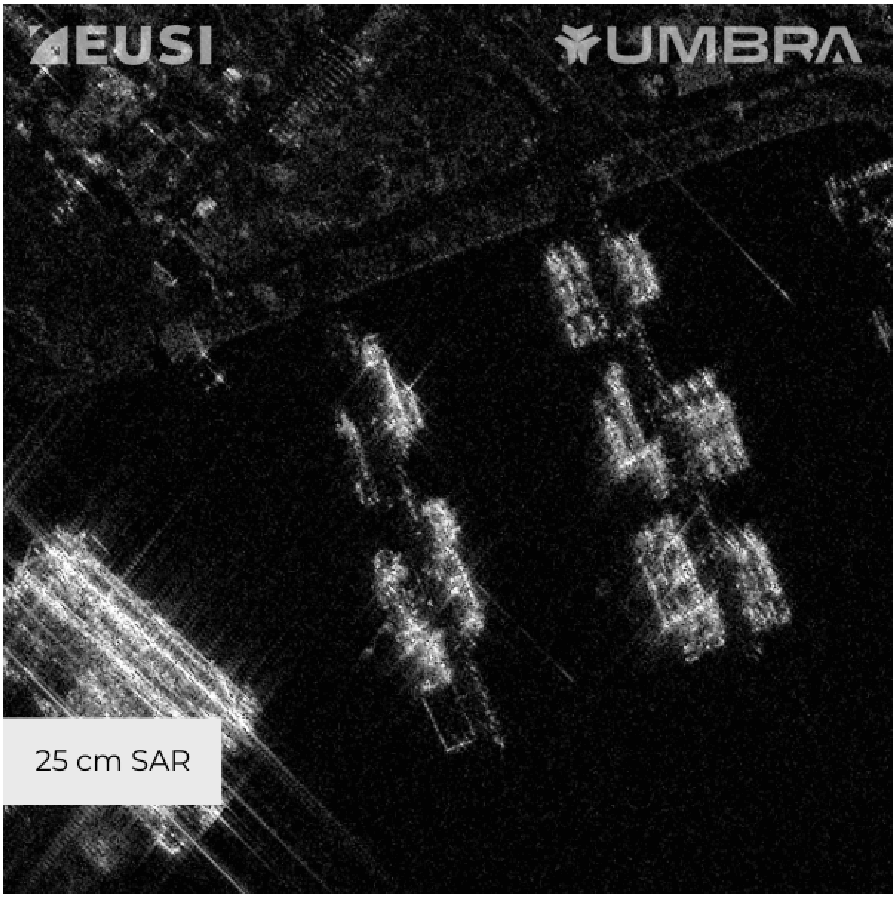


Figure 9 SAR example image of some ships in a harbor in 0.25 m spatial resolution.

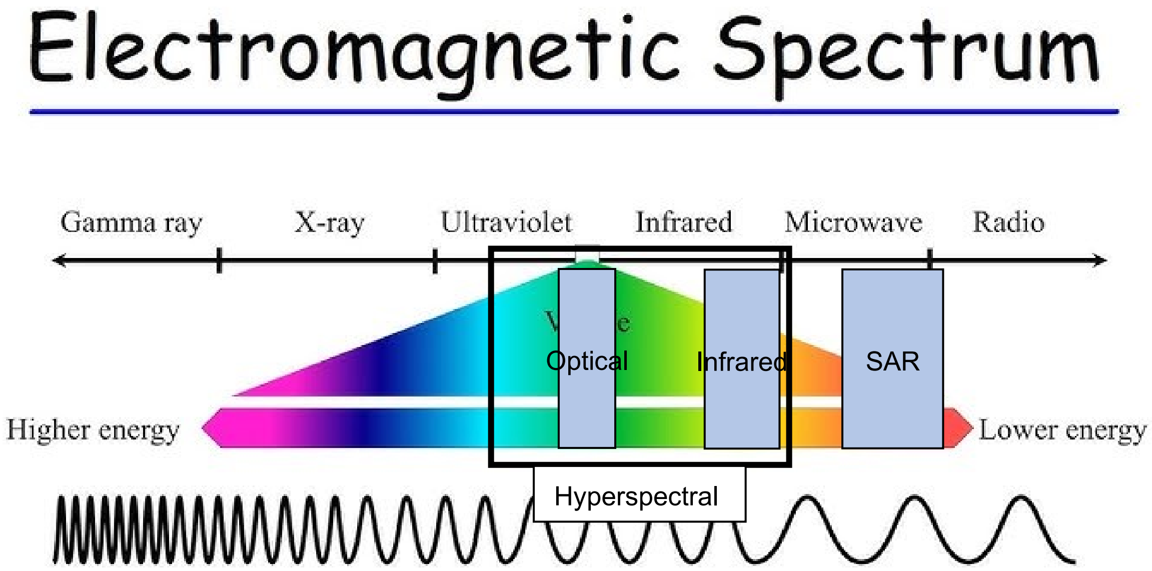


Figure 10 Different sensors work in different spectral bands

Resolutions

Spatial

The spatial resolution describes the smallest possible geometry distinguishable in the image. It is scientifically not really correct, but basically it is the native pixel size of an image or its GSD (ground sampling distance). For example, a GSD of 1 meter means, that one pixel in the image corresponds to 1 x 1 m in reality. Therefore, a high spatial resolution is favorable in IMINT, where, for example a tank can only be detected, or even identified with a certain spatial resolution or better – in the case of a tank it has to be around 0.5 m or better to be identified.

Figure 11 Example of the spatial resolution and its impact

Temporal

The temporal resolution describes how often the same target can be detected/ identified. For example, if a satellite has such an orbit that it can acquire an image of a certain object every day at 11:00, then its temporal resolution is 1 day.

Spectral

The spectral resolution is the sensor's ability to distinguish between different spectral bands – or simply how many colors/ spectral bands/ wavelength spectra it can distinguish and acquire. We have seen before the hyperspectral sensors, they have a very high spectral resolution, up to several hundred spectral bands.

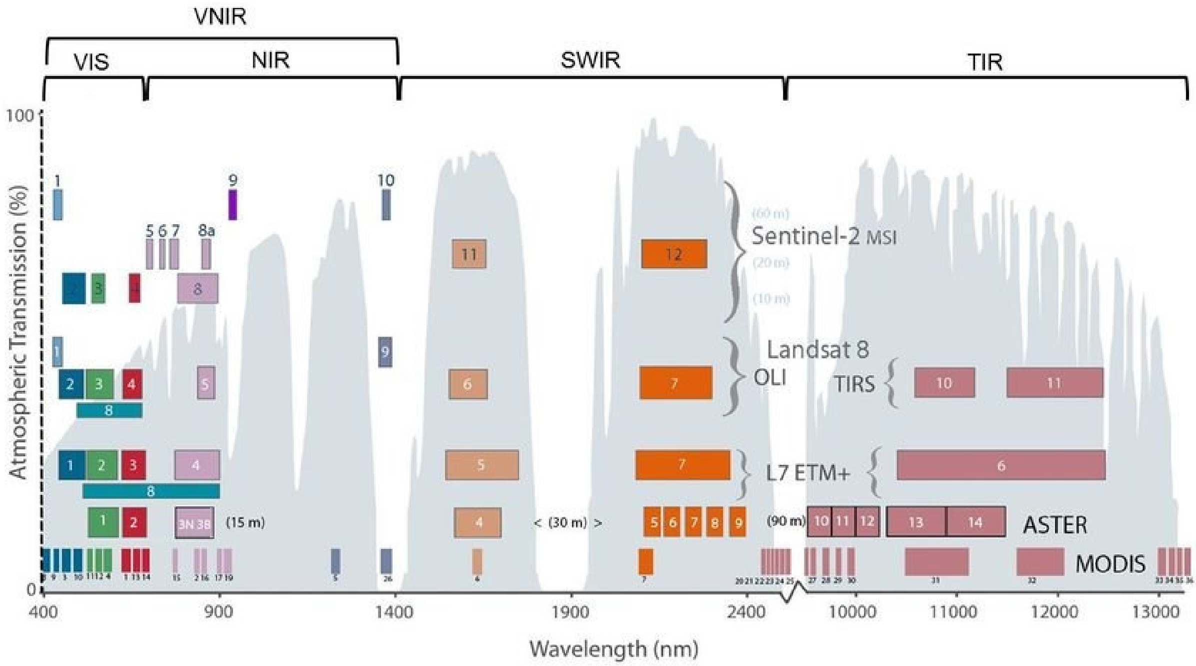


Figure 12 5 different satellites and the spectral bands they are capable to detect. For example the satellite Sentinel-2 can image 12 different bands and the satellite MODIS more than 30.

Radiometric

The radiometric resolution tells us in how many bits the image is acquired and stored – therefore the bit-depth of an image. Typically, this is in 8, 12, 16 or 32 bit, where we can distinguish more colors in the image with a higher bit-depth.

Bits	Range of values	Levels of grey
1Bit	$2^1 = 2$ (0-1)	0 … 1
4Bit	$2^4 = 16$ (0-15)	0 … 15
8Bit	$2^8 = 256$ (0-255)	0 … 255

Figure 13 bit depth – in 4 bit we can distinguish 15 different shades of grey, in 8 bit 255.

Trade-off

There is no sensor that has a high resolution in all these 4 different categories. We always have trade-offs, for example if we want to have a high spatial resolution, we typically have a lower temporal resolution, because we have to fly lower and can therefore only map a smaller area. Or if we want to have more spectral bands, we typically end up with a much worse spatial resolution just because our sensor receives less energy. In the practical IMINT case we often see high spatial resolutions (better than 1 m, favorable better or equal 0.5 m) and quite a high temporal resolution, but a low spectral resolution (PAN or at best 3 band true color and night-time infrared mode).

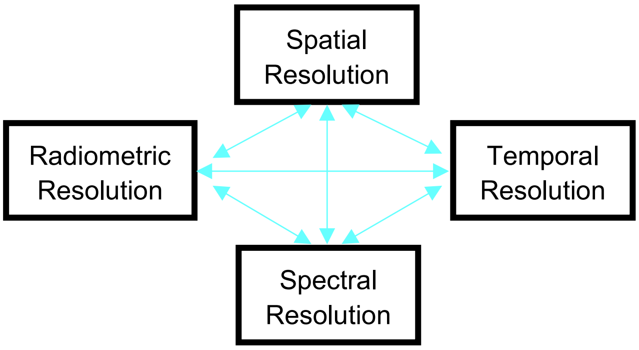


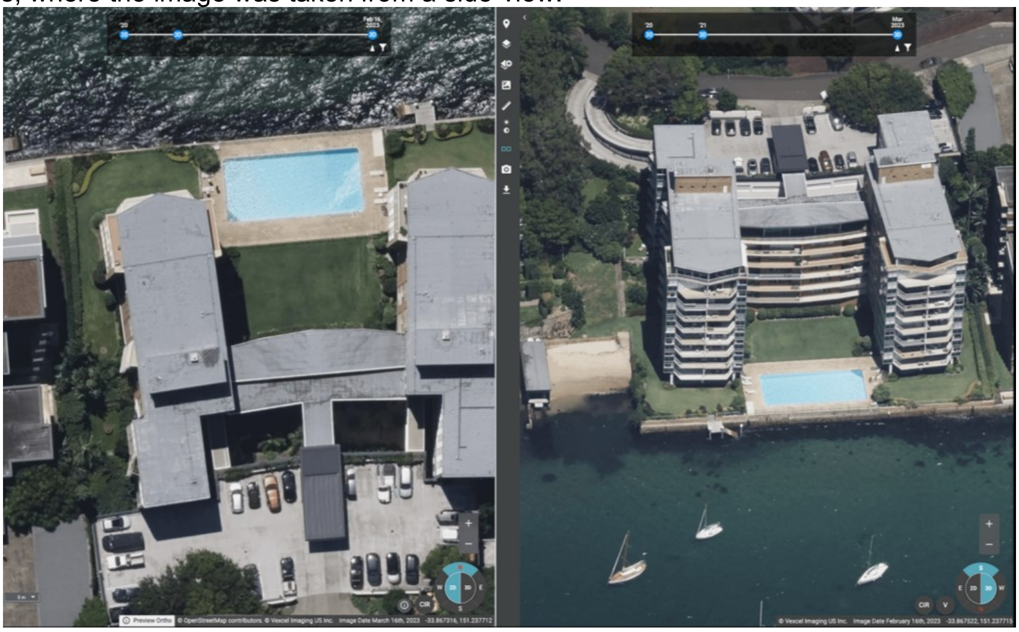
Image quality for IMINT

❖ Direction

Describes from which direction the image was taken, depending on the object this can of course have an impact.

❖ Angle

There are so called nadir images, where the image was taken right from above and oblique images, where the image was taken from a side-view.



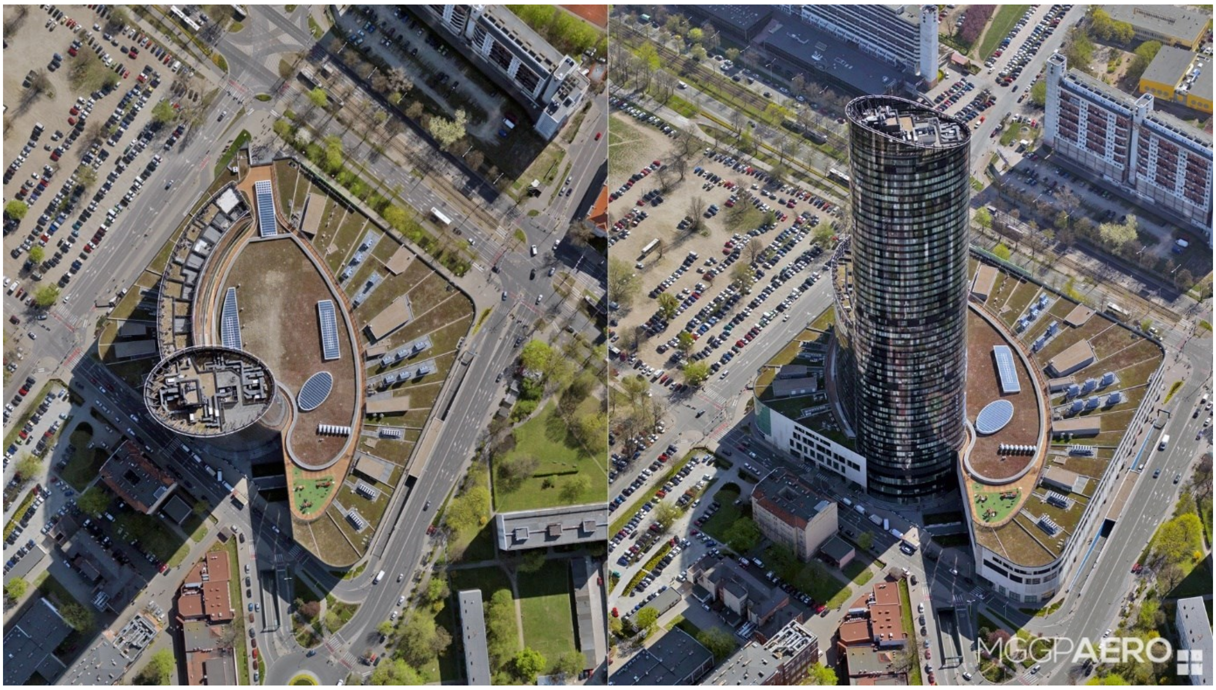


Figure 14 In the oblique images we can for example measure the building height or count the floors.

Nadir images

+	-
Almost the same scale on the whole image – measure of distances is easy	Target has to be overflown directly
Similar to a map, easy to overlay with a map	Vertical lines and surfaces cannot be seen
Almost no covert areas	Hard to identify or distinguish ground forms, e.g. is object A higher than object B…

Oblique images

+	-
More area coverable	Spatial resolution decreases, especially to the horizon
Some objects are easier to describe, e.g. bridges	Distance measurements are hard to make
Measuring of heights	Lots of covert areas
Target does not have to be overflown directly	Hard to overlay with a map

❖ GSD & swath

The better the GSD, the easier it is to identify certain targets, but the swath (how much area the image covers) is smaller and we may not be able to cover the whole area of interest..

Figure 15 A higher GSD leads to less coverage/ a smaller image

❖ Shadow

Shadow can be an advantage or a disadvantage. Shadow can tell us something about the vertical structure of an object or it might be possible to retrieve the object height through its shadow. But of course, a large shadow can also cover targets and the enemy can take advantage of it as a camouflage tool.

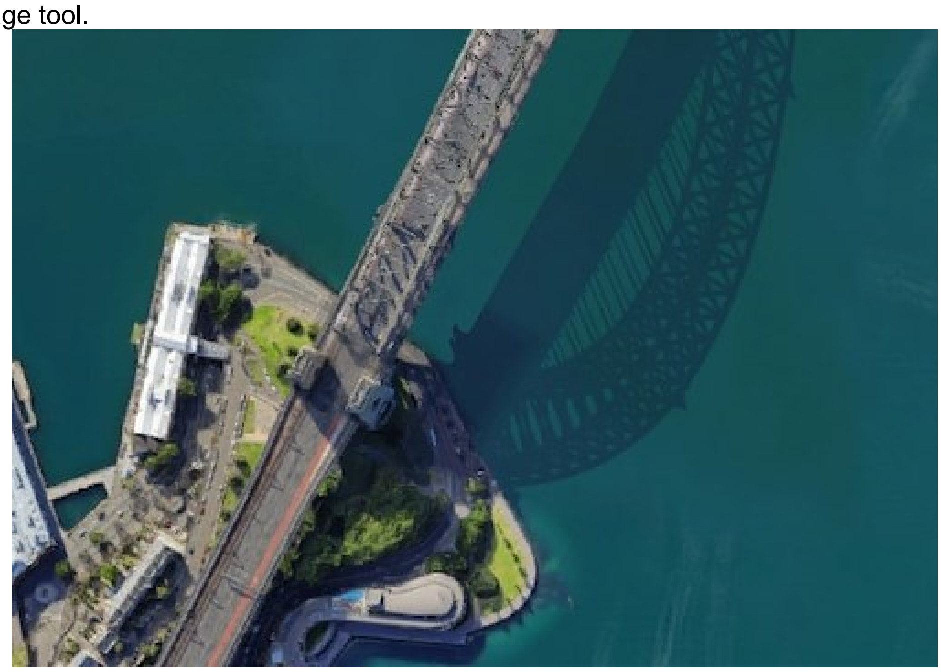


Figure 16 The shadow of the bridge tells us something about its structure

❖

Figure 17 Russians on the Engels airbase painted bomber silhouettes on the tarmac. However, thanks to the shadow of a real plane on the right we can definitely say the left one is fake.

❖ Time (Daytime and season)

Vegetation, trees with leaf on or leaf off, snow, light conditions, moisture etc. All can affect our IMINT analysis.

Figure 18 Season can have a big impact, e.g., with leaf off conditions we can see underneath structures.

❖ Weather

Clouds, fog, rain can have a high impact on our image, especially with optical sensors. In SAR images these effects are mostly neglectable.

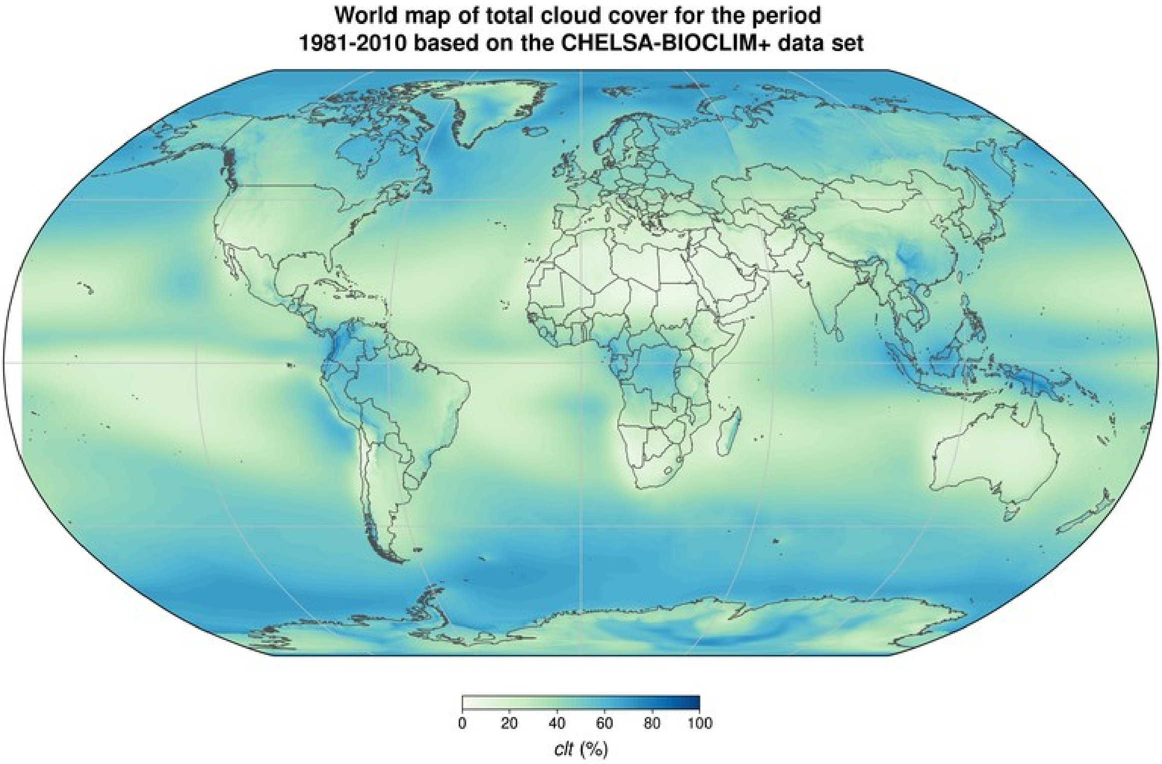


Figure 19 Optical sensors are highly weather-dependent, especially in regions with high cloud coverage, like the equators, northern Europe or South East Asia.

❖ Technical Parameters e.g., sensor type

There are more favorable and less favorable sensors and parameters like zoom level for a certain mission, but most of the time we have not a big selection due to time and technical limits. And in general, it is definitely better to have several images from several sensor types to address an IMINT mission.

Platforms

Airborne (Aircrafts (Fixed-Wing, Helicopters), Drones, Airships etc.)

Basically, we can put a sensor on all different types of airborne platforms. Fixed-wing aircrafts are very versatile we can fly from very high and fast to very low and slow. Drones are used more and more often, especially for IMINT, but also airships – more or less zeppelins or balloons flying at very high altitudes.

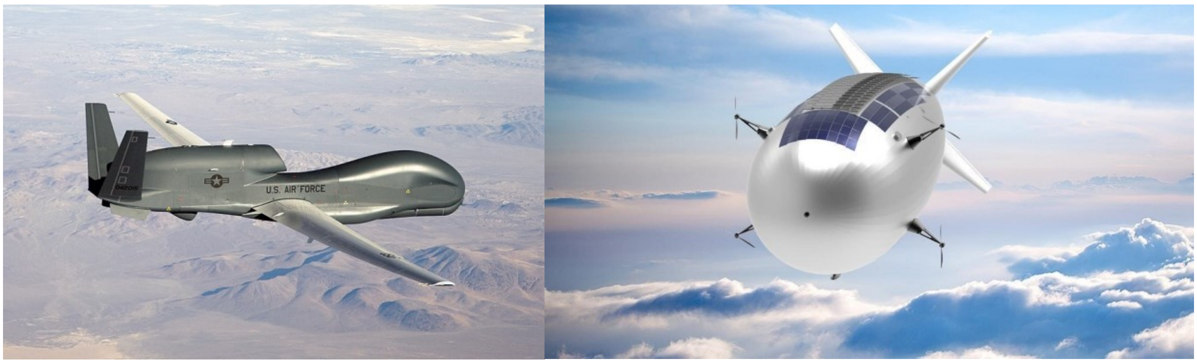



Figure 20 Different aerial IMINT platforms

Spaceborne (Satellites)

Satellites are very common IMINT platforms since the cold war, because they can acquire images of the whole earth without infringing any foreign airspaces.

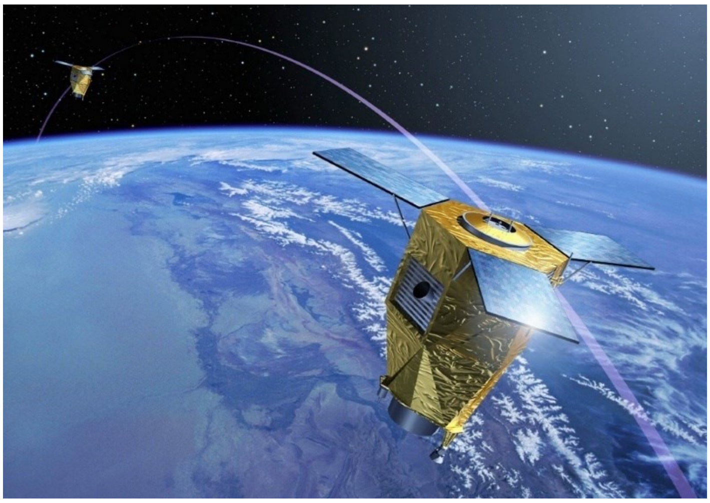


Figure 21 Illustration of an IMINT satellite in its orbit around the Earth

These satellites have a more or less fixed orbit, where they have a so-called repeat-cycle, a time span, after which the satellite is at the same position over the Earth again. Usually, IMINT satellites are in a SSO (sun-synchronous-orbit) at a height of 300 to 800 km above the Earth's surface and follow the sun to take images at preferable sunlight conditions, for example to always take images at 11:00 local time. They have some maneuverability to also take oblique images to some degree and adjust their orbits. Typically, these satellites can take an image of the same object around 1 time a day or maybe every 2 days. However, for optical satellites, if the weather is bad then our image cannot be used and depending on the location, we very often have cloudy conditions.

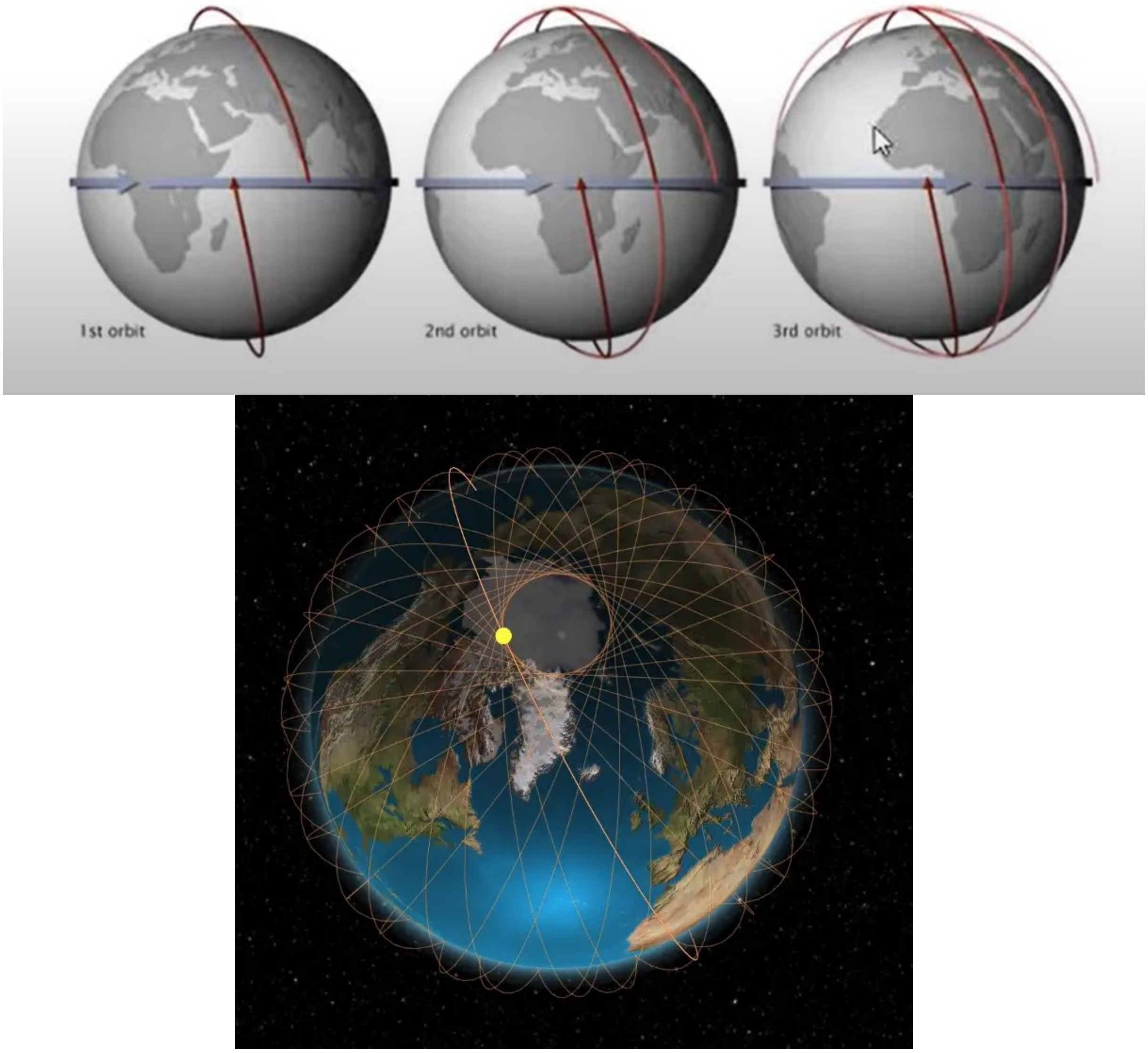


Figure 22 Example of a sun-synchronous orbit

Nowadays even commercial IMINT satellites exist, even quite a lot. Basically, everyone can buy such scenes with spatial resolutions up to 0.3 m. Check out spymesat.com for example.

Last but definitely not least: IMINT, especially spaceborne IMINT does not work like in the movies. We do not have a live-view and especially not a live-video-view, where we can even identify a vehicles' license plate. The image has to be acquired and then sent via data link to a ground station – the whole process might take several 10ths of minutes up to hours. And the best spatial resolution possible nowadays is probably the KH11 satellite from the US, where it is thought to have a spatial resolution of about 0.08 m. But most high resolution IMINT satellites are in the range of 0.3 to 0.5 m and even with a 0.08 m resolution we could not identify a license plate, we can barely tell if the object is a human or a trash can. And again, satellites have their fixed-orbits, we cannot hover over an object, or can see the whole world at the same time.
You can check out our satellite tracking site, where you can see the time when it is possible for the satellites to take an image at certain locations: guerillamap.com/satellite-tracking