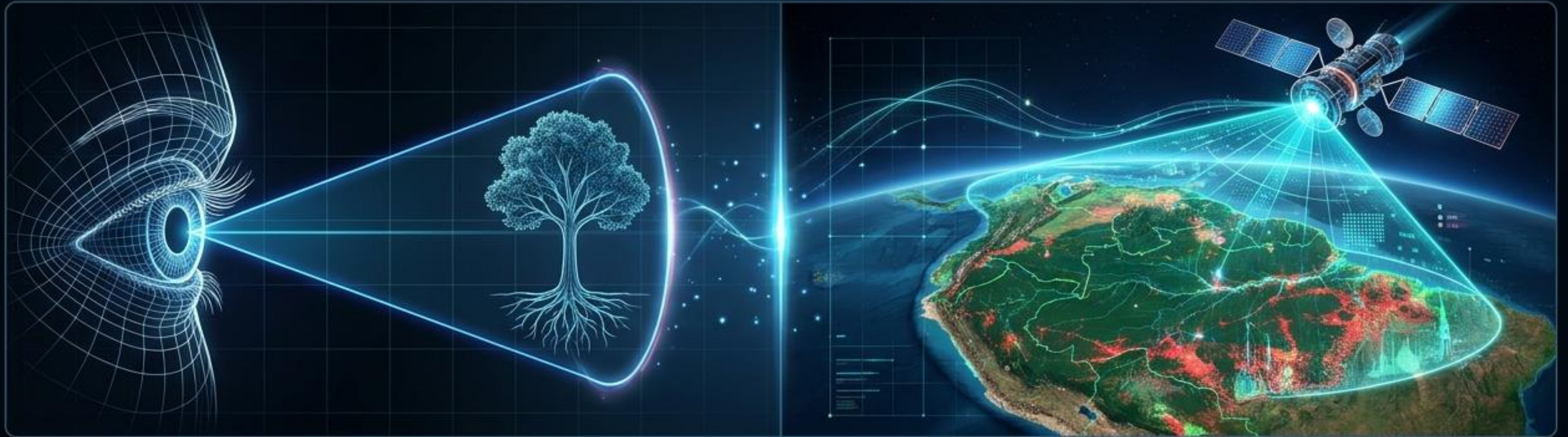
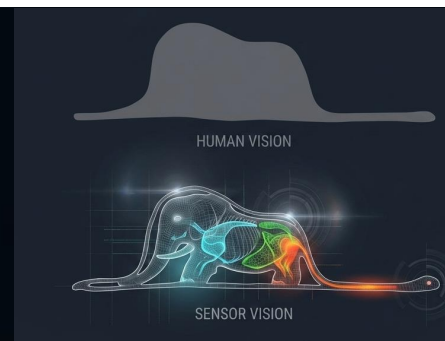


Basics of Remote Sensing

Principles, Platforms, Sensors, Resolution, and Environmental Applications

Measuring the Earth without physical contact



LIMITED HUMAN VISION

ADVANCED SATELLITE REMOTE SENSING

The Core Definition

Remote sensing is the collection of data about an object or region without being in physical contact with it.

The Mechanism

It detects energy reflected or emitted from the Earth, transforming invisible signals (heat, microwaves) into human-readable data sets.

The Purpose

Enables mapping of remote, inaccessible areas and provides a macro-perspective on planetary health.

Earth communicates across the invisible electromagnetic spectrum

Visible Light

The narrow band where human eyes and traditional photography operate.

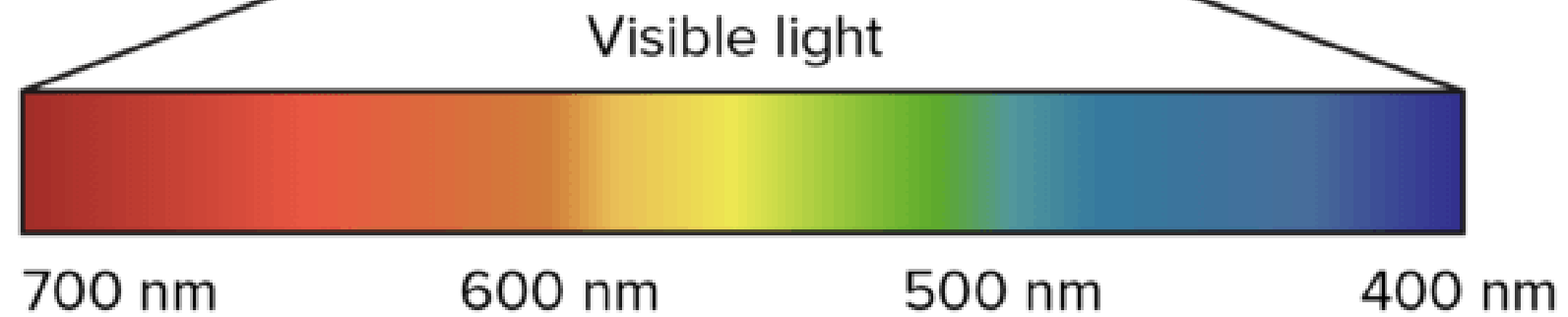
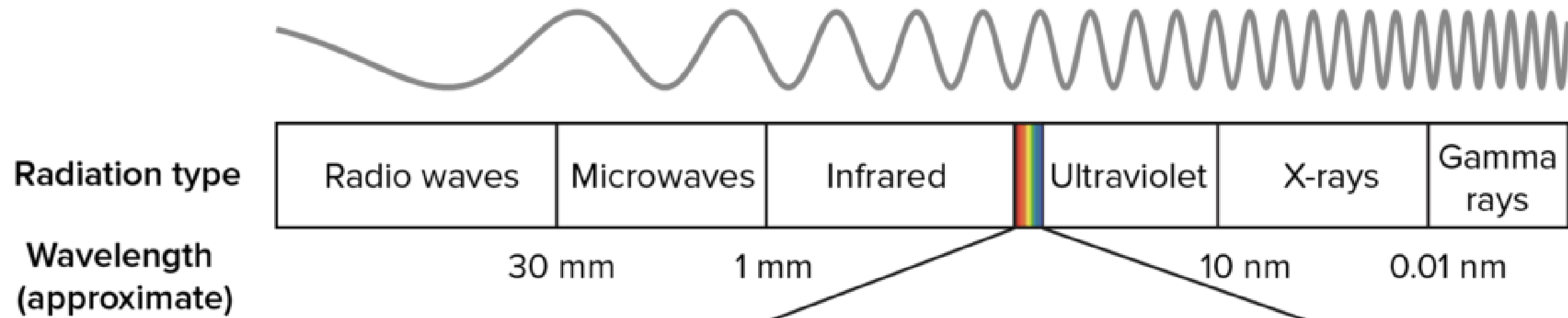
Infrared (NIR, SWIR, TIR)

Captures heat emissions, calculates vegetation health, and identifies mineral compositions.

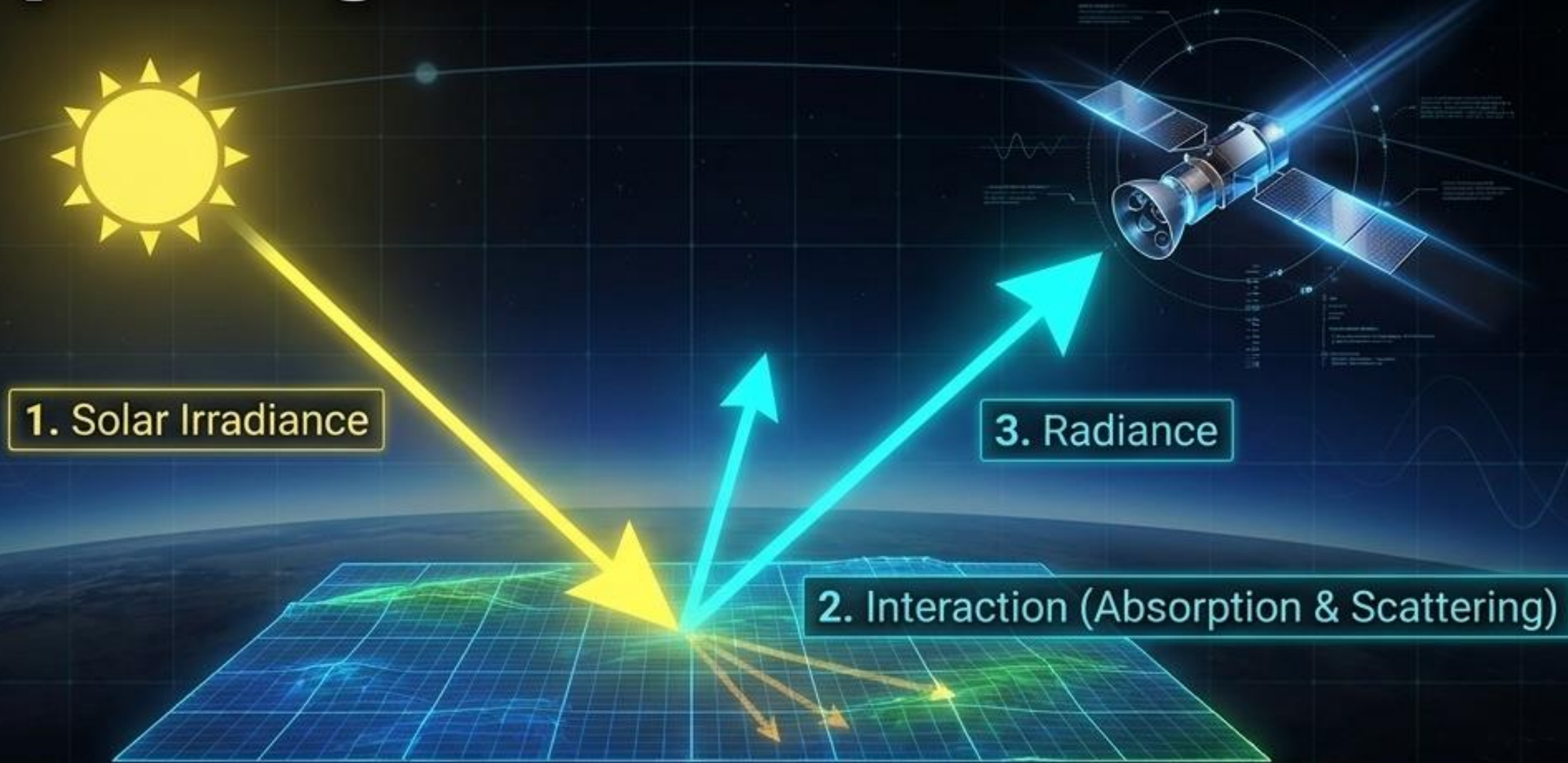
Microwaves & Radio

Penetrates clouds to capture soil moisture, ocean salinity, and surface topology.

Electromagnetic Spectrum



Capturing the echoes of the sun



The Core Equation

Reflectance is the ratio of the electromagnetic energy coming down (Irradiance) to the energy bouncing back (Radiance). The exact ratio dictates the unique spectral signature of the material.

The Core Equation

Two architectures of perception: Passive vs. Active

Passive Sensors (Radiometers, Optical Cameras)



Energy Source: Relies on natural sunlight or Earth's thermal emissions.

Limitations: Blinded by clouds and weather; mostly inactive at night.

Active Sensors (SAR, Lidar, Altimeters)

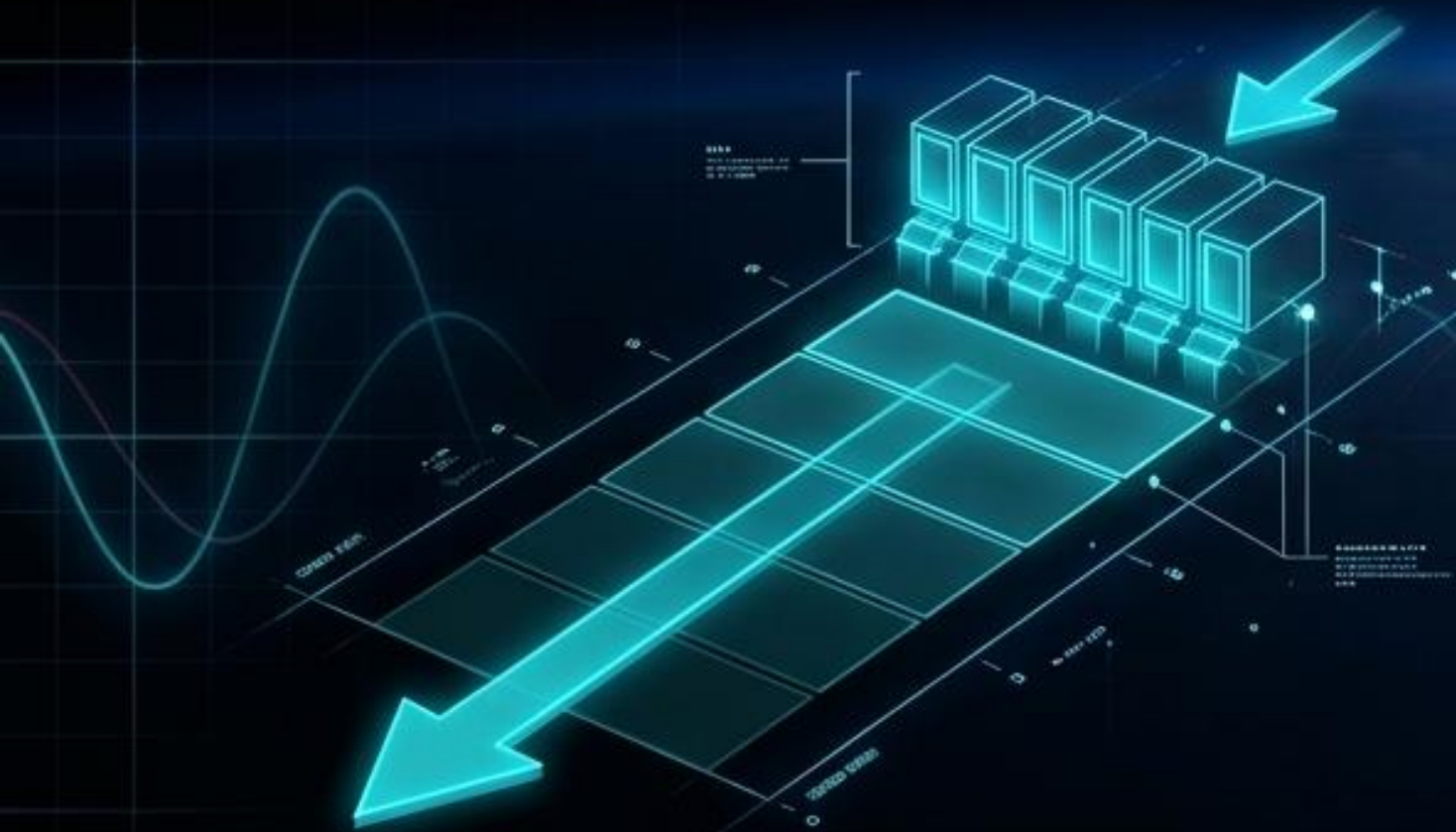


Energy Source: Self-illuminating. Emits its own energy (microwave pulses or lasers) and measures the backscattered return signal.

Strengths: Operates day and night; penetrates cloud cover and severe weather.

Painting the grid: Pushbroom vs. Whiskbroom scanning

PUSHBROOM ARRAY



A linear array of detectors sweeps forward along the orbital path like a broom head. Features fewer moving parts and higher pixel dwell time.

Examples: Sentinel-2 MSI, SPOT.

WHISKBROOM SCANNER



A mirror oscillates rapidly side-to-side, sweeping individual pixels across the swath perpendicular to flight.

Examples: Landsat 7 ETM+, MODIS.

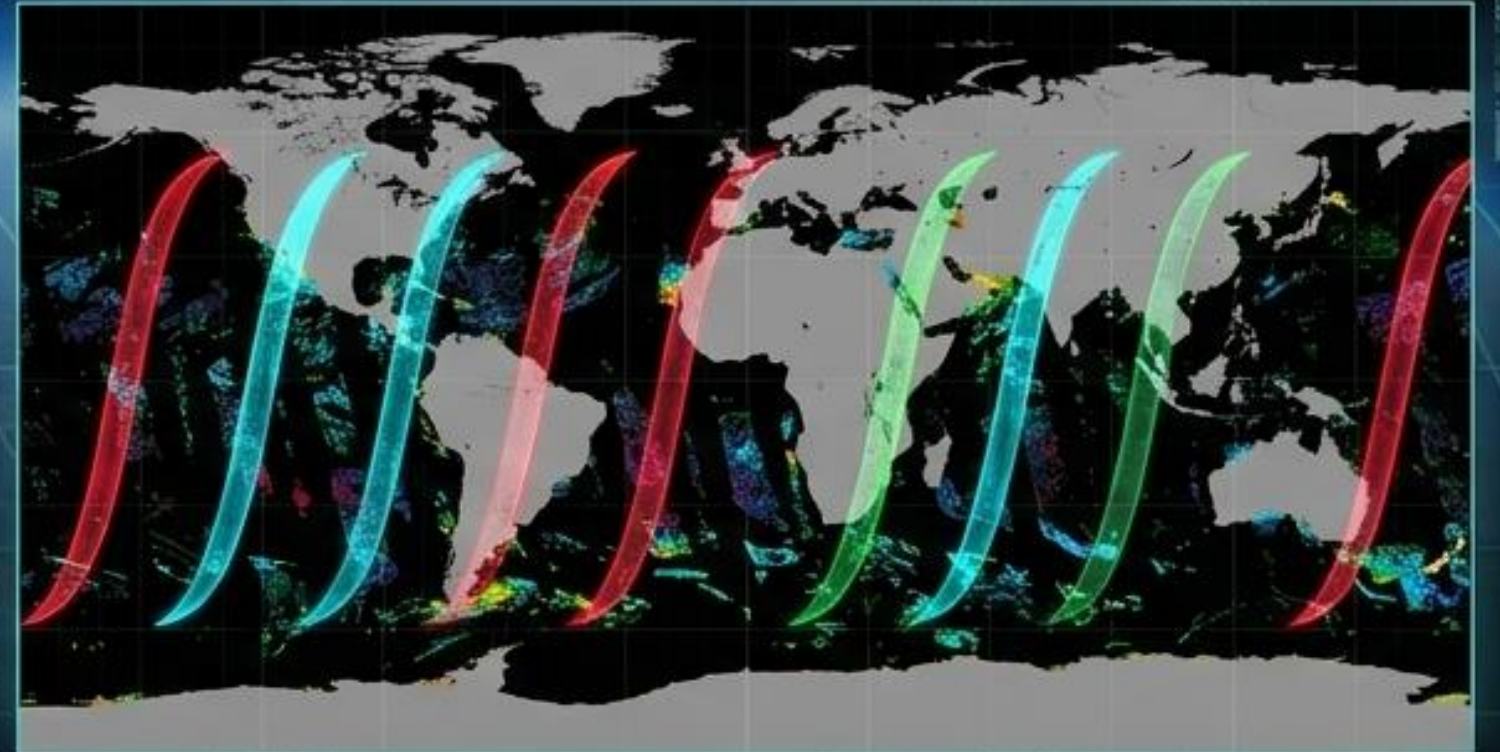
The orbital dichotomy determines what we can see

Geostationary Orbits (GEO)



Hover at ~36,000 km matching Earth's rotation.
Provides continuous, real-time monitoring
of a single hemisphere.
Ideal for meteorology and weather tracking.

Polar & Sun-Synchronous Orbits (LEO)



Orbit at 160–2,000 km hugging the globe.
Sweeps the planet in vertical strips (swaths).
Sun-synchronous tracks ensure visits to the
same spot at the exact same local solar time.

1. Spatial

The physical size and granularity of the grid on the ground.

2. Spectral

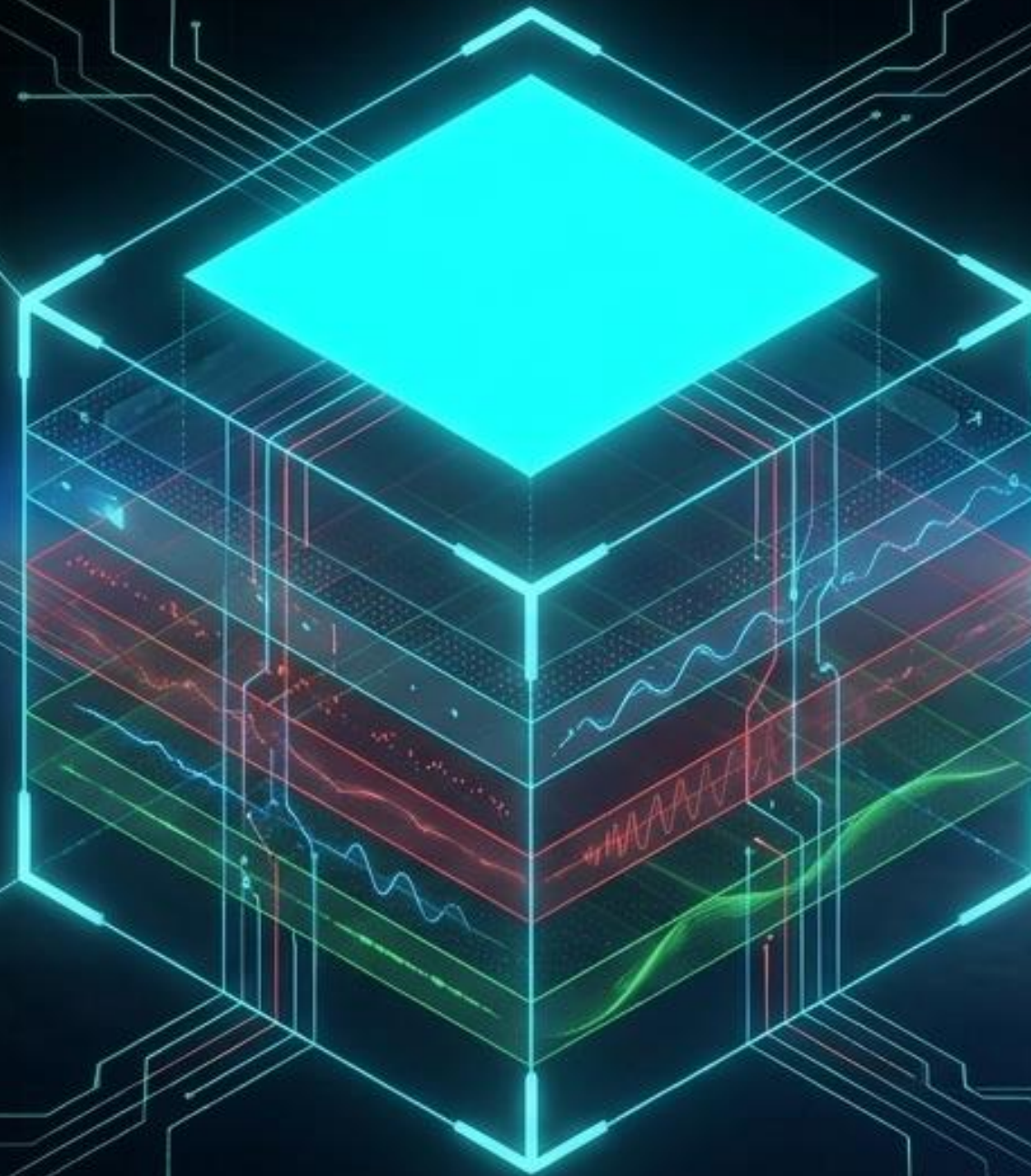
The specific slices of the electromagnetic light spectrum captured.

3. Radiometric

The depth of sensitivity, bit-depth, and contrast available.

4. Temporal

The pulse of time and the frequency of the revisit cycle.



A satellite image is not a flat photograph; it is a four-dimensional data cube.

Spatial Resolution: The granularity of the grid



1 km pixel (Low) | e.g. MODIS



300 m pixel (Medium) | e.g. MERIS



30 m pixel (High) | e.g. Landsat-8

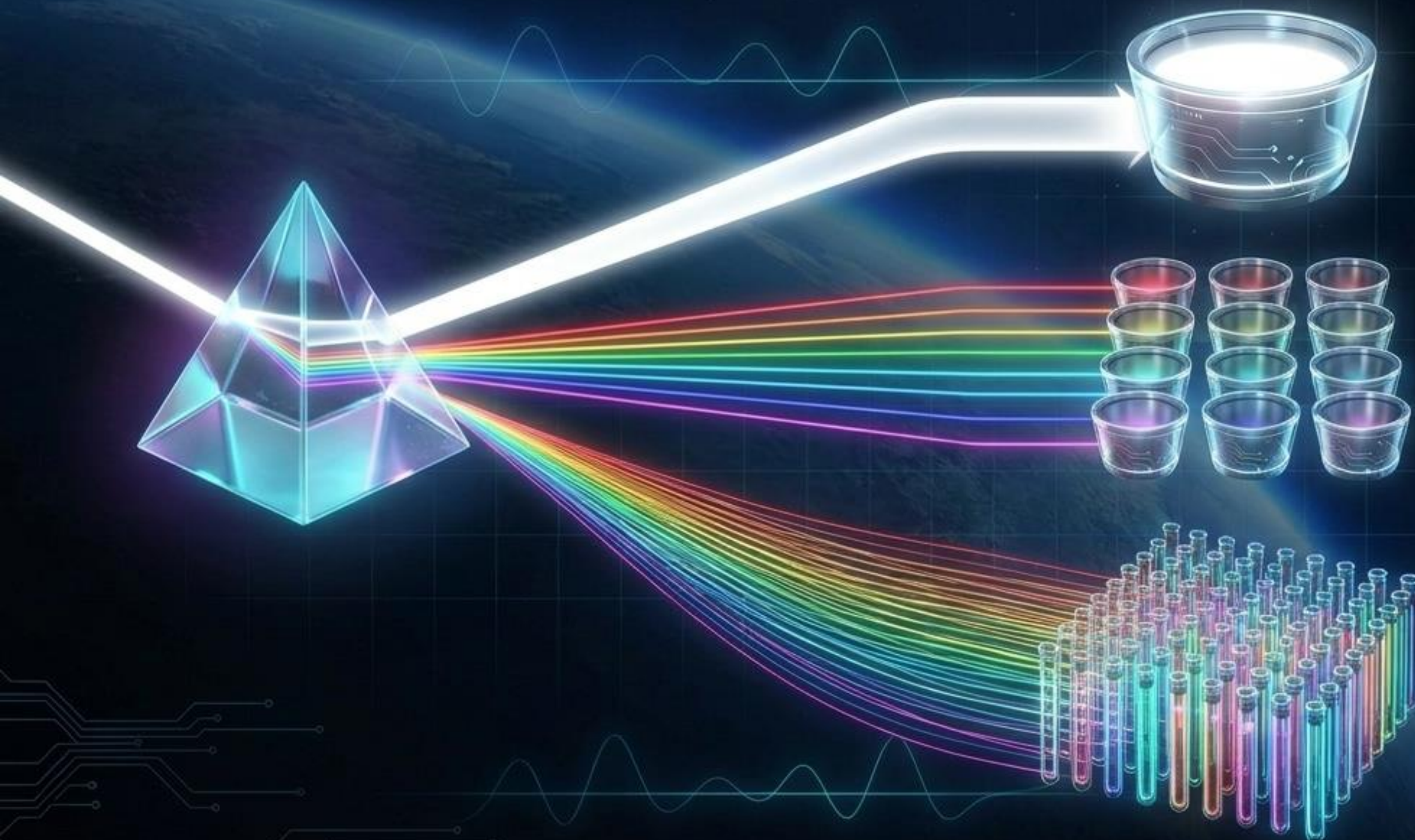


0.6 m pixel (Very High) | e.g. QuickBird

Definition: The size of the smallest object visible on Earth.

The Spectrum: Ranges from 1 km for global ocean temperatures down to <1m for mapping urban infrastructure.

Spectral Resolution: **Slicing the light**



Panchromatic

One broad band capturing the full visible range. Yields the highest spatial detail but zero color or chemical data.

Multispectral

Data collected across several distinct, isolated wavebands (e.g., Sentinel-2's 13 bands) combined to create true and false-color composites.

Hyperspectral

Hundreds of continuous, narrow bands that create a precise chemical and physical fingerprint of a target area.

Radiometric Resolution: **The depth of the data**

8-bit Depth: 256 absolute values

14-bit Depth: 16,384 absolute values

Definition

The sensitivity of the sensor to variations in energy magnitude, determined by bit depth.

Impact

Higher bit-depth allows differentiation of subtle features. Upgrading from a 6-bit sensor to a 14-bit sensor (like VIIRS) reveals entirely new layers of detail in low-light and nighttime imagery.

Temporal Resolution: The pulse of the planet



The Swath Factor

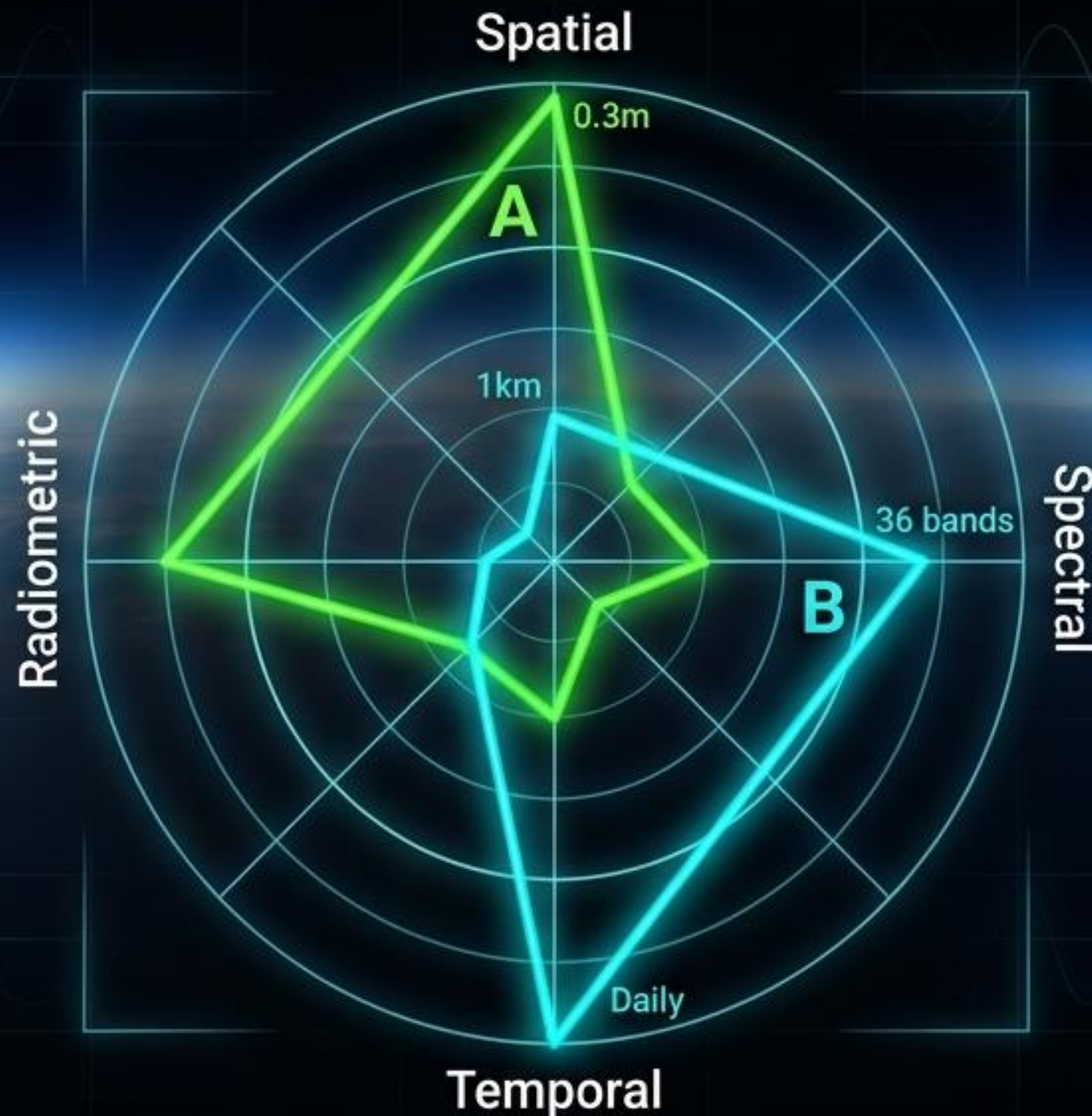
Temporal resolution is defined as the revisit cycle—how long it takes to return to the exact same location. It is dictated entirely by swath width. Wider swaths enable rapid daily coverage, while narrow swaths demand weeks to map the full globe.

The inevitable trade-off of remote sensing

The Law of Compromise

You cannot build a 0.3m spatial, 200-band spectral, daily-revisit satellite.

Data storage limits, downlink bandwidth, and physical optics demand a severe trade-off.

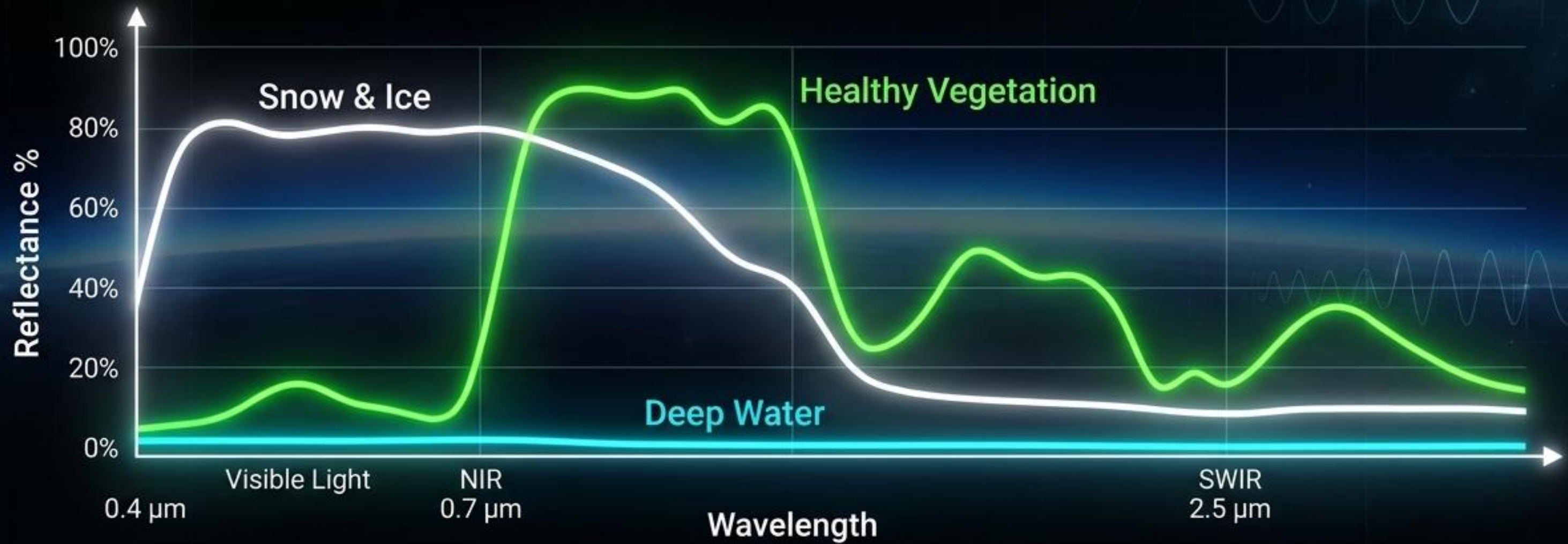


Examples

MODIS sacrifices spatial detail to achieve daily temporal revisit and high spectral depth.

WorldView sacrifices temporal revisit and swath width to achieve ultra-high spatial clarity.

Decoding the environment through spectral signatures



The Fingerprint

Every material absorbs and reflects light differently across the electromagnetic spectrum. By targeting **specific combinations of wavebands**, we can isolate and measure distinct environmental domains with total precision.

Mapping the biosphere: Vegetation & Agriculture

True Color (Visible Light)



False Color (Near-Infrared)



| The Red Edge

| **Healthy plants** absorb red visible light to power photosynthesis, but aggressively reflect Near-Infrared (NIR) energy to avoid overheating.

| **Applications:** By mapping NIR reflectance, we can calculate total crop health, biomass volume, and the fraction of absorbed photosynthetically active radiation (fAPAR).

Reading the hydrosphere: Water & Oceans

Optical Dynamics

Pure water absorbs almost all infrared light, appearing pitch black to sensors. However, visible bands can map suspended sediment plumes and chlorophyll concentrations in shallow or coastal waters.

Passive Microwaves

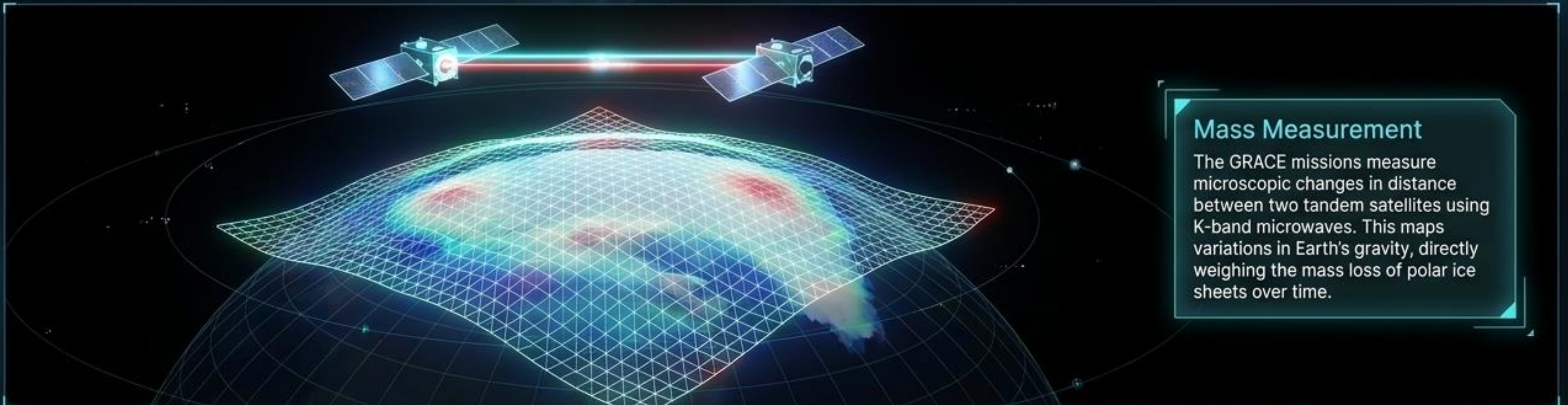
Instruments like the ESA SMOS satellite use passive radiometers to detect natural microwave emissions. This allows us to calculate absolute oceanic salt levels and deep land moisture.

Weighing the cryosphere: Snow & Ice



Surface Mapping

Optical and IR sensors track exact snow cover extent and differentiate between atmospheric clouds and high-albedo ice sheets.



Mass Measurement

The GRACE missions measure microscopic changes in distance between two tandem satellites using K-band microwaves. This maps variations in Earth's gravity, directly weighing the mass loss of polar ice sheets over time.

Penetrating the smoke: Fire & Thermal Dynamics



Tracking the human footprint: Urban Environments

Night Lights (VIIRS)

Captures 14-bit low-light imagery, tracking urban sprawl, power grid health, and economic activity via night-time radiance.

Synthetic Aperture Radar (SAR)

Active radar pulses bounce off rigid human infrastructure. Because rough surfaces produce stronger returns, SAR perfectly maps city topologies regardless of weather or cloud cover.

The convergence of the spectrum and the grid



Massive Constellations

Networks of 200+ nanosatellites now offer daily, high-resolution imagery of every landmass on Earth, functionally eliminating the spatial vs. temporal trade-off.

Atmospheric Platforms (HAPS)

Airships operating 20km in the stratosphere provide continuous, geostationary-like observation with LEO-like resolution.

The Result

A continuous, real-time digital twin of our planet.