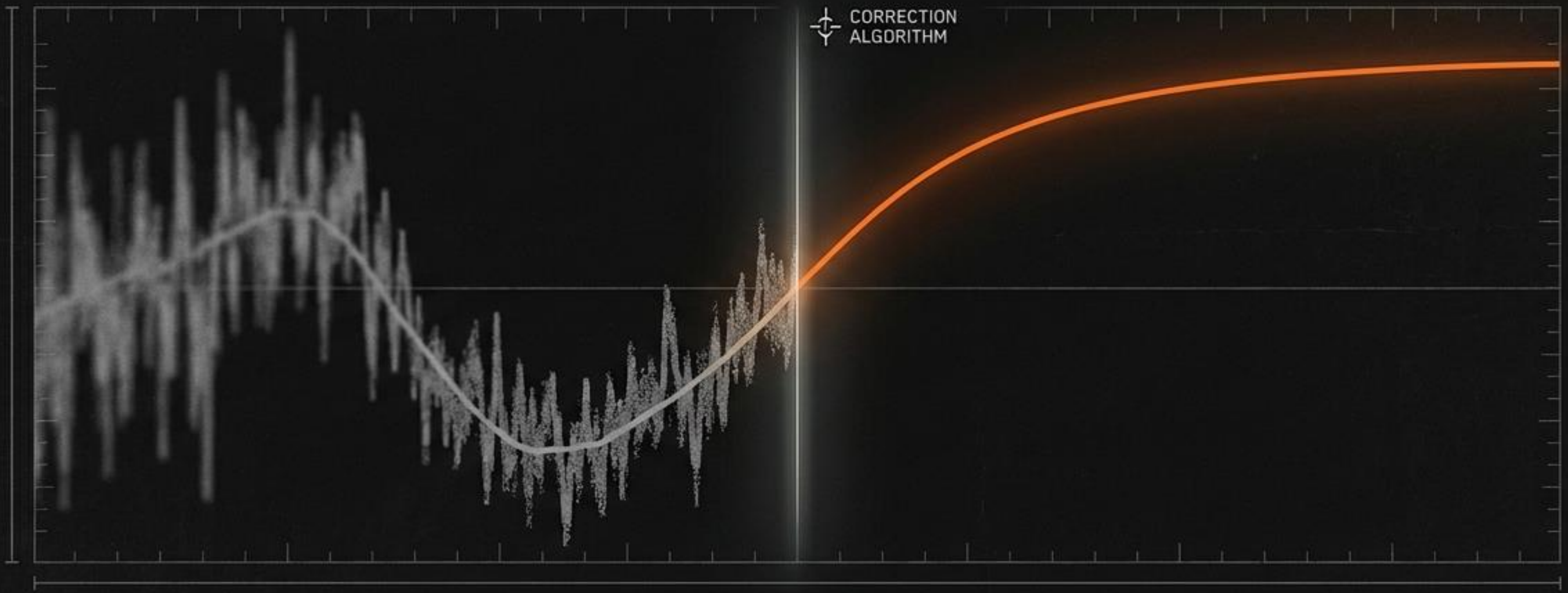
DECLASSIFIED TECHNICAL ENGINEERING REPORT

PROJECT CODES (DG.KEY)

DECLASSIFIED

THE CLEAR SIGNAL

A DIAGNOSTIC DEPLOYMENT GUIDE TO HYPERSPECTRAL ATMOSPHERIC CORRECTION

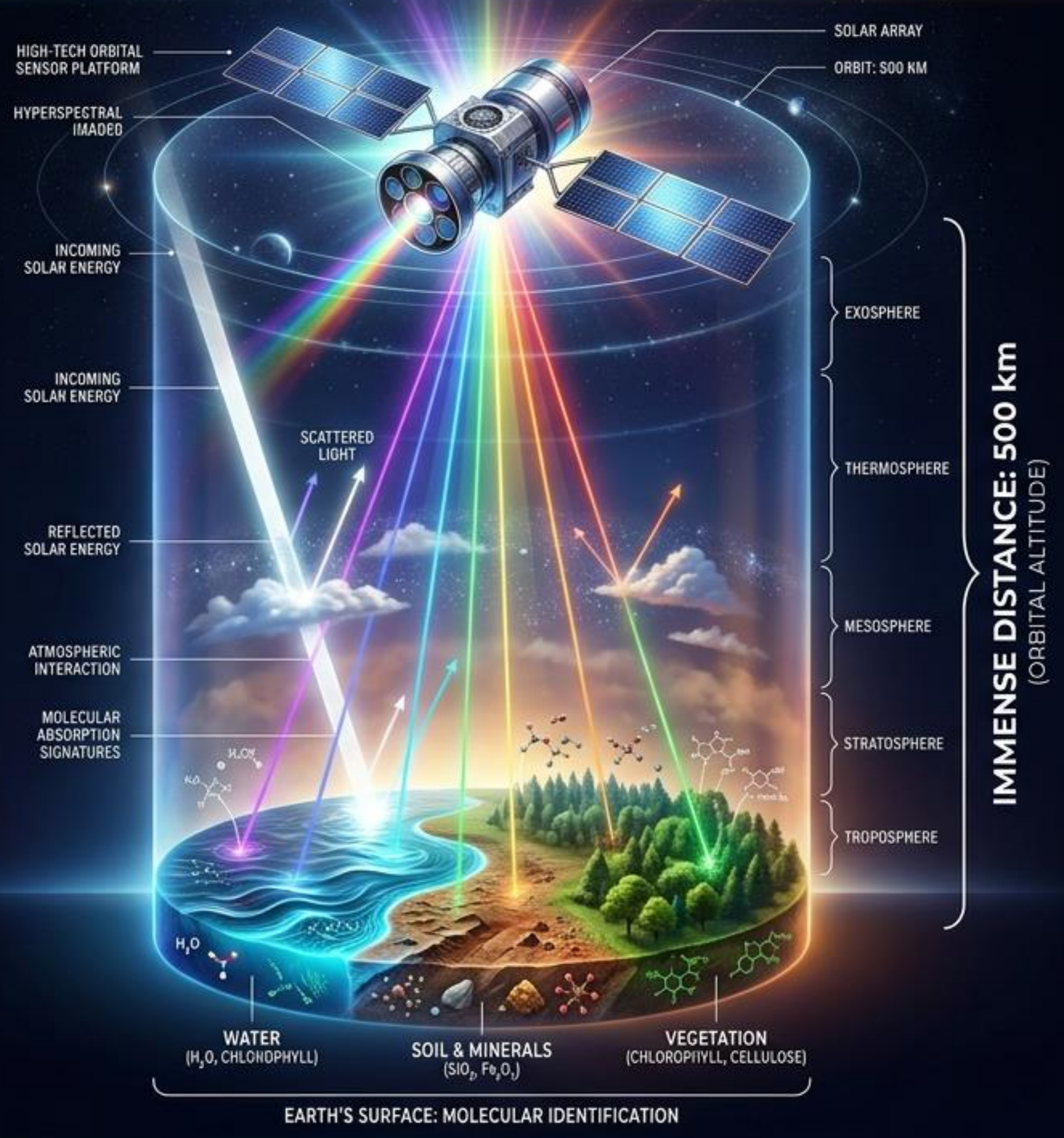


DATAUGSAET	S80I:D MHz
BRSG-ORANGE	8.23Y.4 MHz
SDRA	58.068 MHz
VOLIOBE	12:37.7 MHz
NDVI	2128.9 KHz

PROJECT CODE
6OCKJAOPBE4123

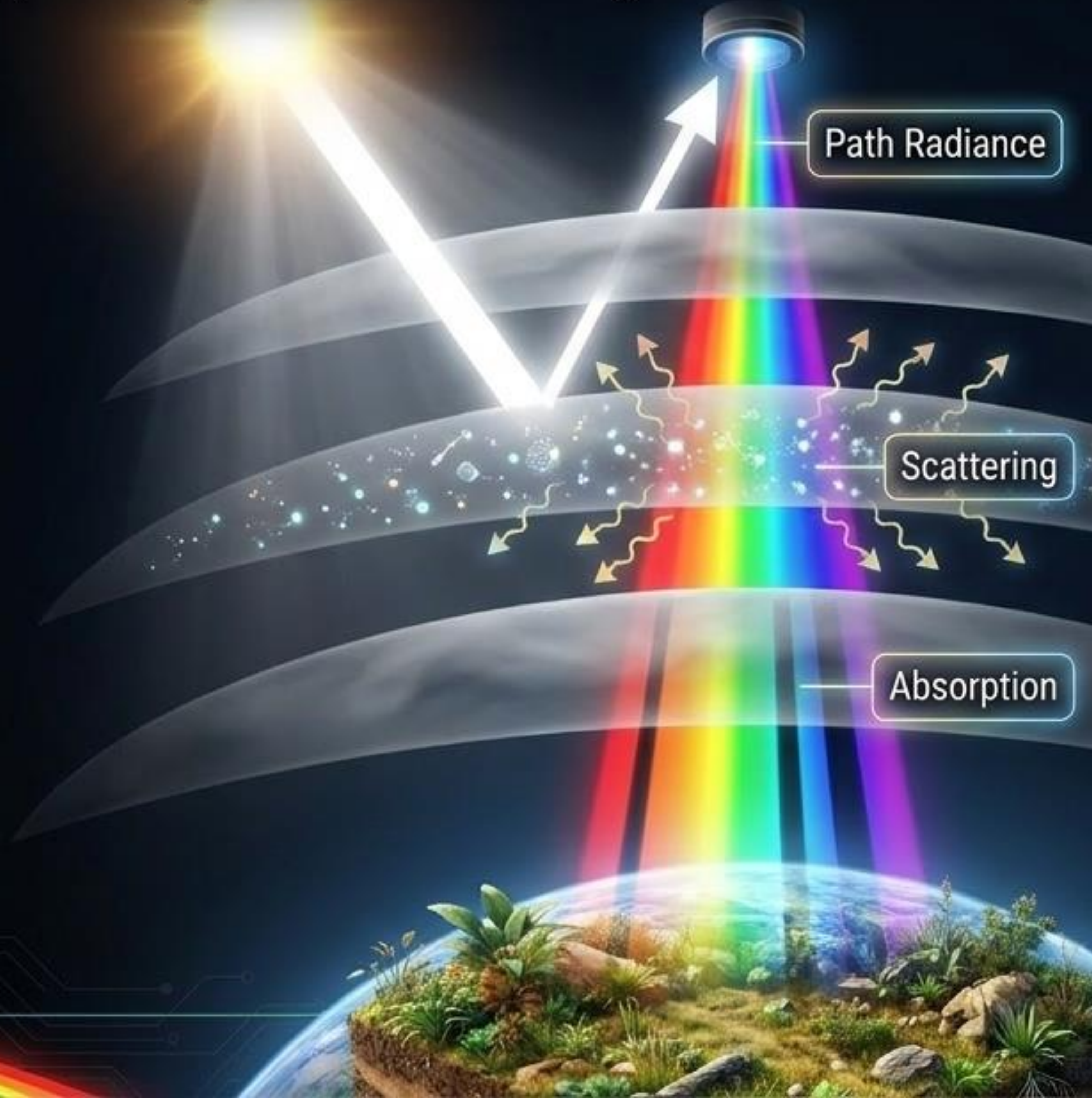
THE ULTIMATE GOAL OF HYPERSPECTRAL OBSERVATION

Every material on Earth absorbs and reflects solar energy uniquely. By capturing this scattered light from orbit, we can map the molecular composition of the planet without ever touching the ground.



Phase 2: Atmospheric Contamination

The upward journey distorts the signal before it reaches space.

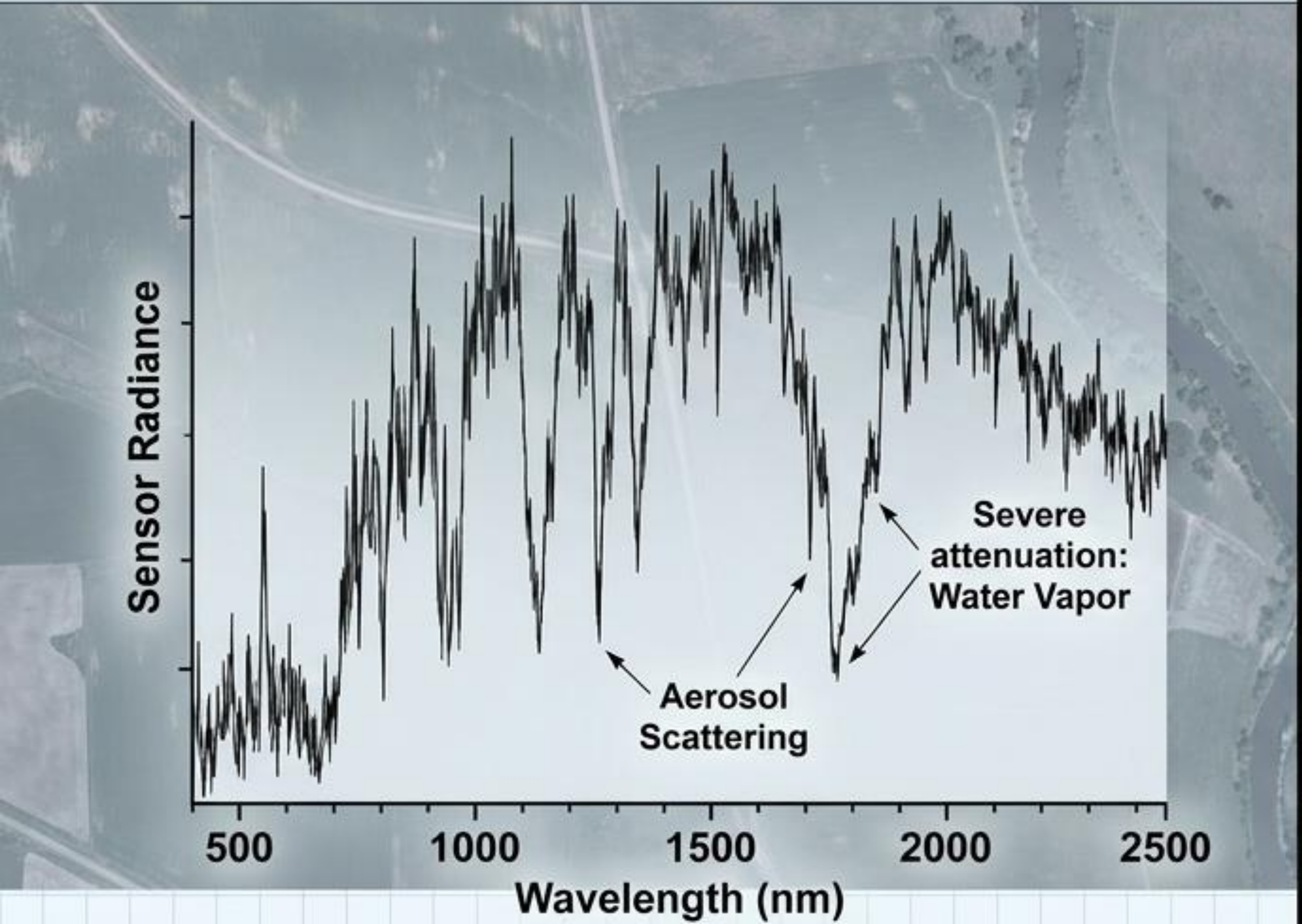


- **Path Radiance:** Solar energy scattered directly into the sensor by the atmosphere, never having touched the Earth's surface.
- **Scattering:** Aerosols and particulate matter diffuse the light, redirecting photons and adding noise to the upward signal.
- **Absorption:** Gases in the atmosphere (Water vapor, CO_2, Ozone) absorb specific wavelengths of light, creating dark "absorption bands" in the spectrum.

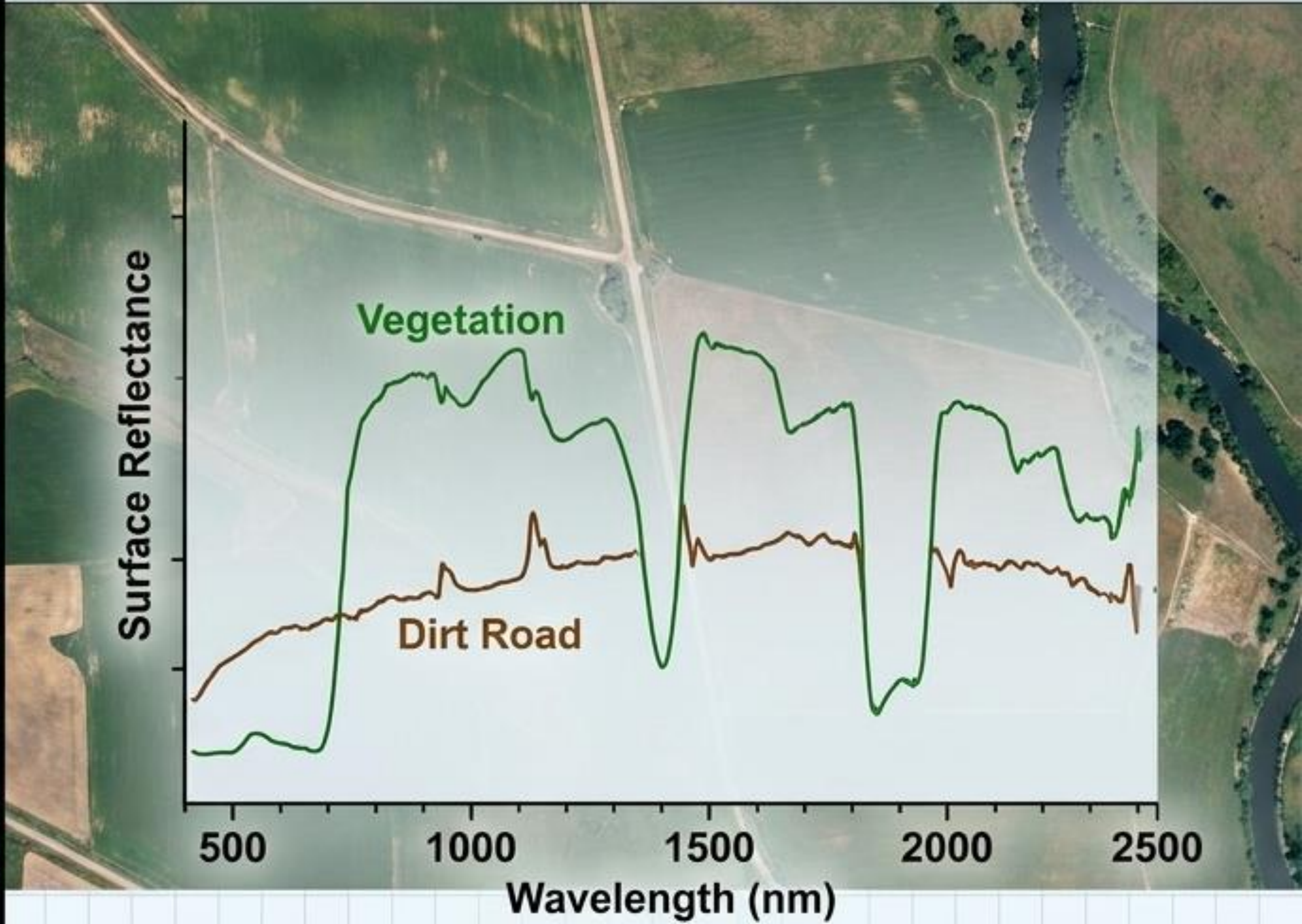
Stripping Away the Noise

Relative corrections fail in hyperspectral environments. Absolute, physics-based, or empirical algorithms are required to retrieve inherent spectral signatures.

Top of Atmosphere (TOA) Radiance



Bottom of Atmosphere (BOA) Reflectance



The Correction Arsenal

Commercial (Physics-Based)

- **Tools:**
  FLAASH, ATCOR (2 & 3), ACORN
- **Mechanism:**
  Radiative Transfer Models (MODTRAN)
- **Profile:**
  High accuracy, computationally heavy.

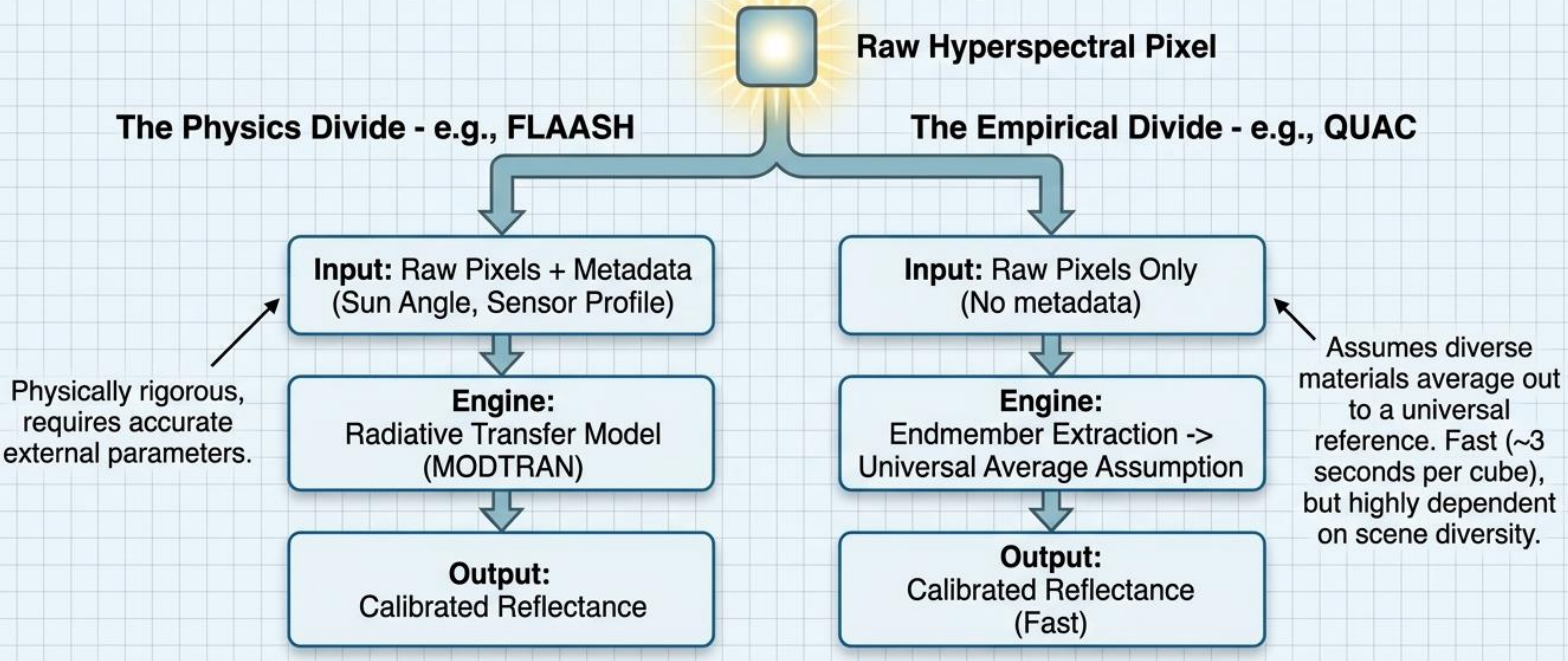
Fast / Empirical

- **Tools:**
  QUAC, DOS
- **Mechanism:**
  In-Scene Statistics
- **Profile:**
  High speed, zero metadata, situational reliability.

Open-Source RTMs

- **Tools:**
  6S/6SV, libRadtran
- **Mechanism:**
  First-Principles Physics + External Data
- **Profile:**
  Highly customizable, complex parameterization.

First-Principles vs. In-Scene Empirical



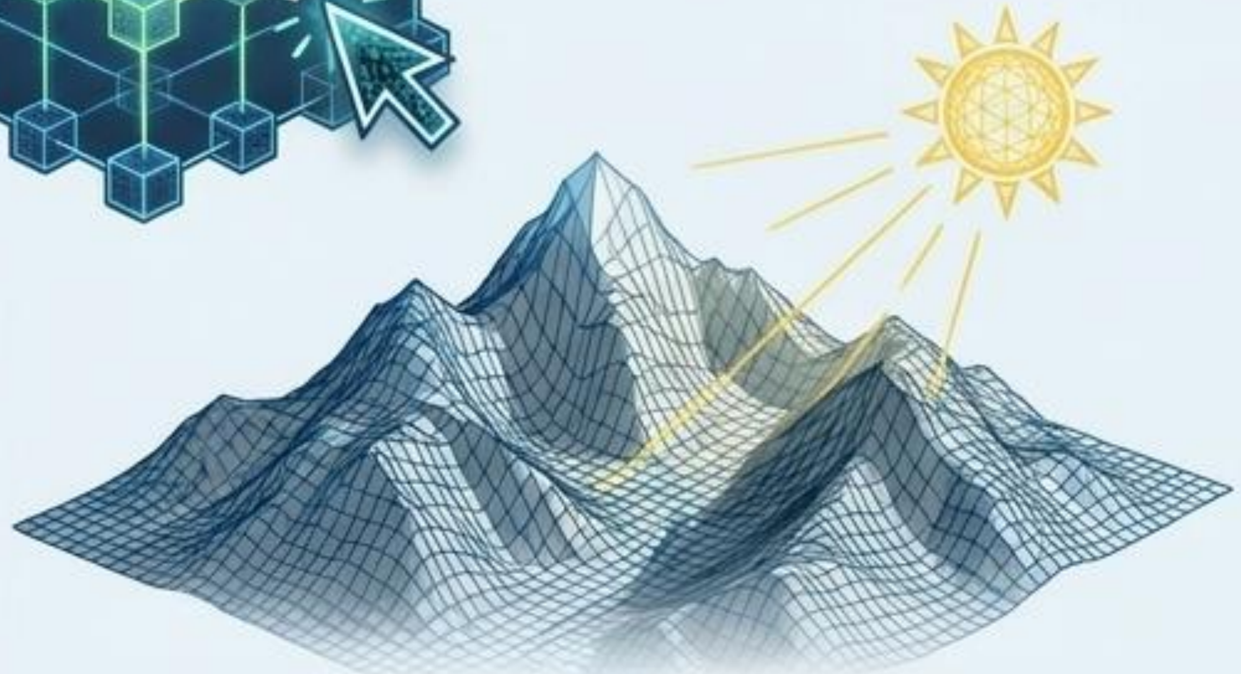
The MODTRAN Engines: FLAASH vs. ATCOR

FLAASH - Dynamic Modeling

Calculates MODTRAN dynamically for that specific image. Highly adaptable to off-nadir viewing, long baselines, and heavy aerosol loads (e.g., forest fires).

ATCOR - LUT Interpolation

- Uses a pre-calculated Look-Up Table (LUT).
- Fast interpolation via the GALGA algorithm.



ATCOR3: Integrates a Digital Elevation Model (DEM) for rugged terrain correction, adjusting for slope and illumination angles.

CASE 1: Lithological & Mineral Mapping

Target: Central Anatolia, Turkey

Environment: Sparse vegetation, continental climate, intimate mixtures of granitic rocks, marble, and schists.

Sensor: EO-1 Hyperion (196 channels used)

Objective: Correct absolute reflectance to identify exact mineral absorption features.

ACORN | FLAASH | ATCOR2 | ATCOR3

Lithology Scorecard: ACORN's Superiority

Algorithm	Features Successfully Extracted	Success Rate
ACORN	**28 / 35**	**75.68%**
FLAASH	21 / 35	56.76%
ATCOR3	20 / 35	54.05%
ATCOR2	12 / 35	32.43%

Insight: Despite lower overall spectral correlation on some individual samples, ACORN is uniquely capable of preserving the specific narrow absorption wavelengths critical for discriminating natural earth materials and intimately mixed minerals.

Sample	Wavelength (nm)	ACORN	ATCOR2	ATCOR3	FLAASH
A1	2150.70	✓	✓	✓	✓
A2	2150.70	✓	✓	✓	✓
A3	2155.50	✓	✓	✓	1
A4	2187.75	0	✗	0	✗
	2232.30	✗	✗	0	✗
A6	1482.30	1	✗	1	1
	1600.00	✗	✗	○	1
A7	2155.35	✓	✗	1	1
A8	2224.45	1	✗	1	1
A9	2155.35	✗	✗	0	✗
	2155.45	0	✗	0	✗
B2	2150.70*	✓	✗	1	1
	2187.45	✓	○	○	○
B5	2147.70	✓	○	1	1
B10	1482.30	✓	○	○	○
	2152.50	✓	1	1	1
	2230.80	✓	1	1	1
	2230.80	✓	1	1	1
B12	1482.50	✗	✗	0	✗
	1700.50	0	✗	0	✗
B13	1700.00	✓	1	1	1
	2221.50*	✓	1	1	1
	1439.99	✓	○	○	○
	1652.35	✓	✓	○	1
B17	2160.00	✓	1	○	1
	2240.00	✓	1	1	1
B20	1482.30	✓	✗	1	1
	1652.50	✓	✗	1	1
	2152.50	✓	✗	1	1
	2201.65	✓	✗	✓	✓

The Empirical Arsenal: Speed vs. Danger

QUAC (QUick Atmospheric Correction)

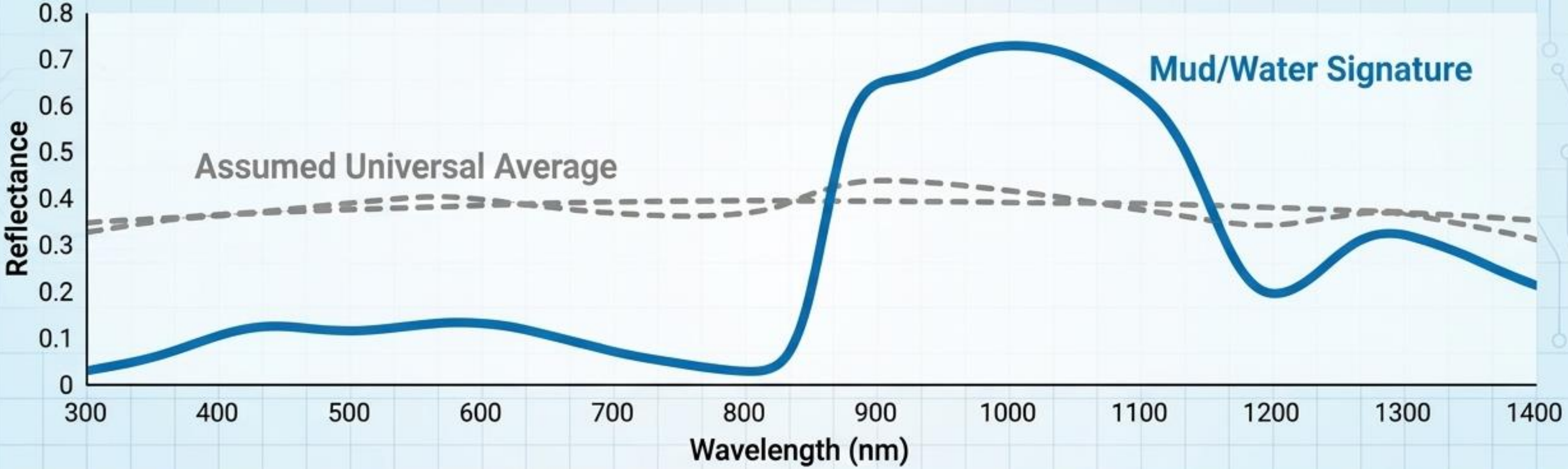
- **Specs:** ~3 seconds per AVIRIS data cube.
- **Strength:** Zero metadata needed. Highly resilient to uncalibrated sensors.
- **Accuracy:** Generally within ~15% of rigorous FLAASH results in ideal scenes.

DOS (Dark Object Subtraction)

- **Mechanism:** Finds the darkest pixel, assumes 0% reflectance, subtracts from all.
- **The Fatal Flaw:** While effective for simple haze in multispectral imagery, it assumes flat atmospheric scattering. It completely warps complex hyperspectral signatures.
- **Verdict:** **STRICTLY CONTRAINDICATED FOR HYPERSPECTRAL DATA.**

The QUAC Failure Model: Mud and Water

The Problem: QUAC assumes the average reflectance of a scene's materials equals a universal standard. Highly structured, dominant materials (like mud) skew this average, destroying the calibration.

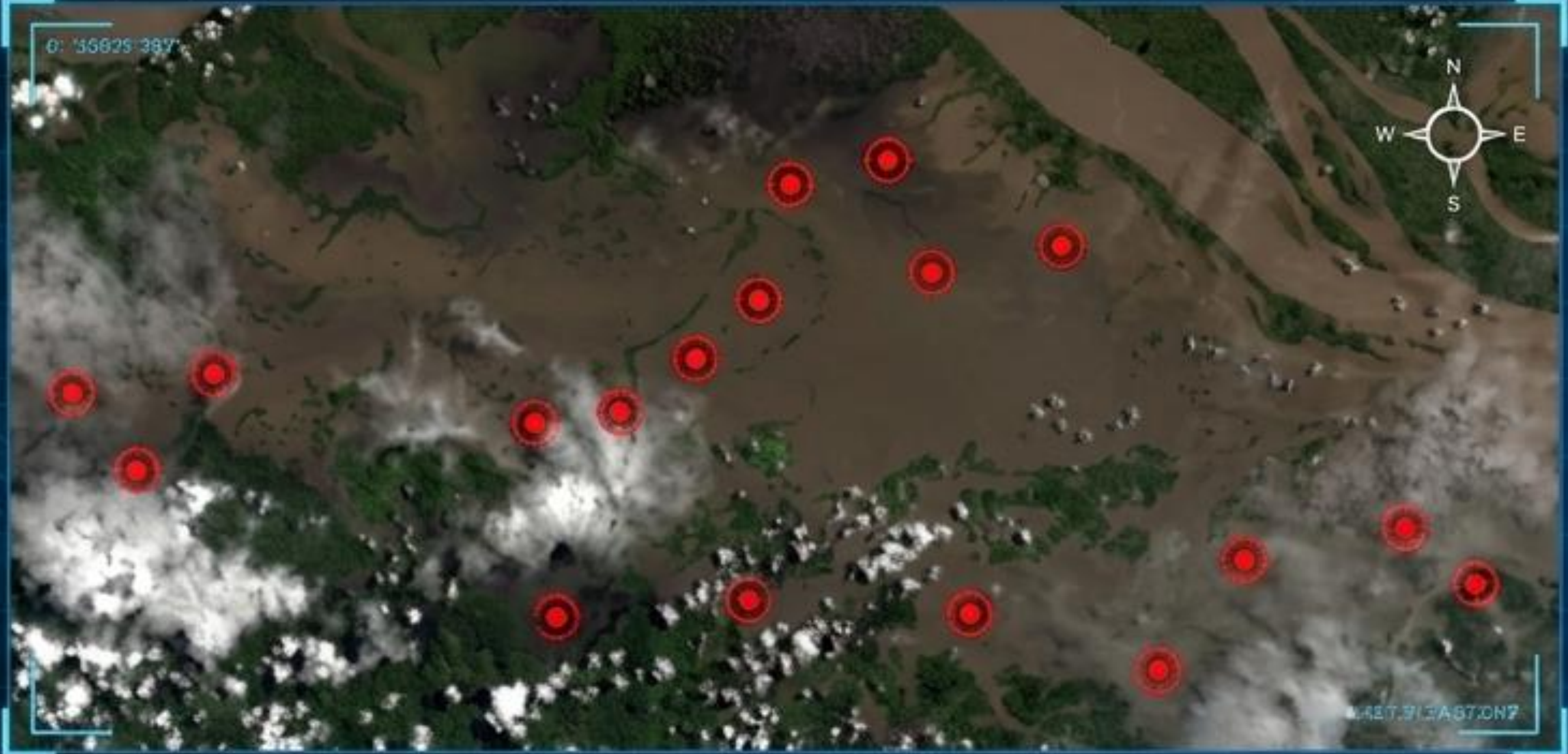


NDVI Filter (> 0.17) - Throws out vegetation pixels.

NDMI Filter (> 0.3) - Normalized Difference Mud Index. specifically built because the 'blue edge' of mud (~900nm) severely confuses the algorithm.

Operational Warning: Do not deploy QUAC in all-water, all-desert, or highly homogeneous scenes. The algorithm requires diversity to survive.

CASE 2: Turbid & Coastal Waters



Mission Parameters

- **Target**: Amazon floodplain lakes (Lago Grande do Curuai)
- **Environment**: High CDOM (Colored Dissolved Organic Matter) and heavy detritus.
- **The Trap**: The standard "black-pixel assumption" (that water absorbs all NIR light) fails here due to backscattering sediment.

Deployment Results

Deploy: FLAASH & 6S ✓

Highest accuracy. Successfully navigate complex scattering.

⚠ Avoid: QUAC ✕

Fails. Underestimates surface reflectance because increasing sediment concentrations alter the spectral slope, breaking QUAC's empirical assumptions.

CASE 3: Above-Ground Forest Biomass

Mission Parameters

Target: Gongju and Sejong regions, South Korea.

Objective: Above-Ground Biomass (AGB) estimation via k-Nearest Neighbor (kNN) mapping.

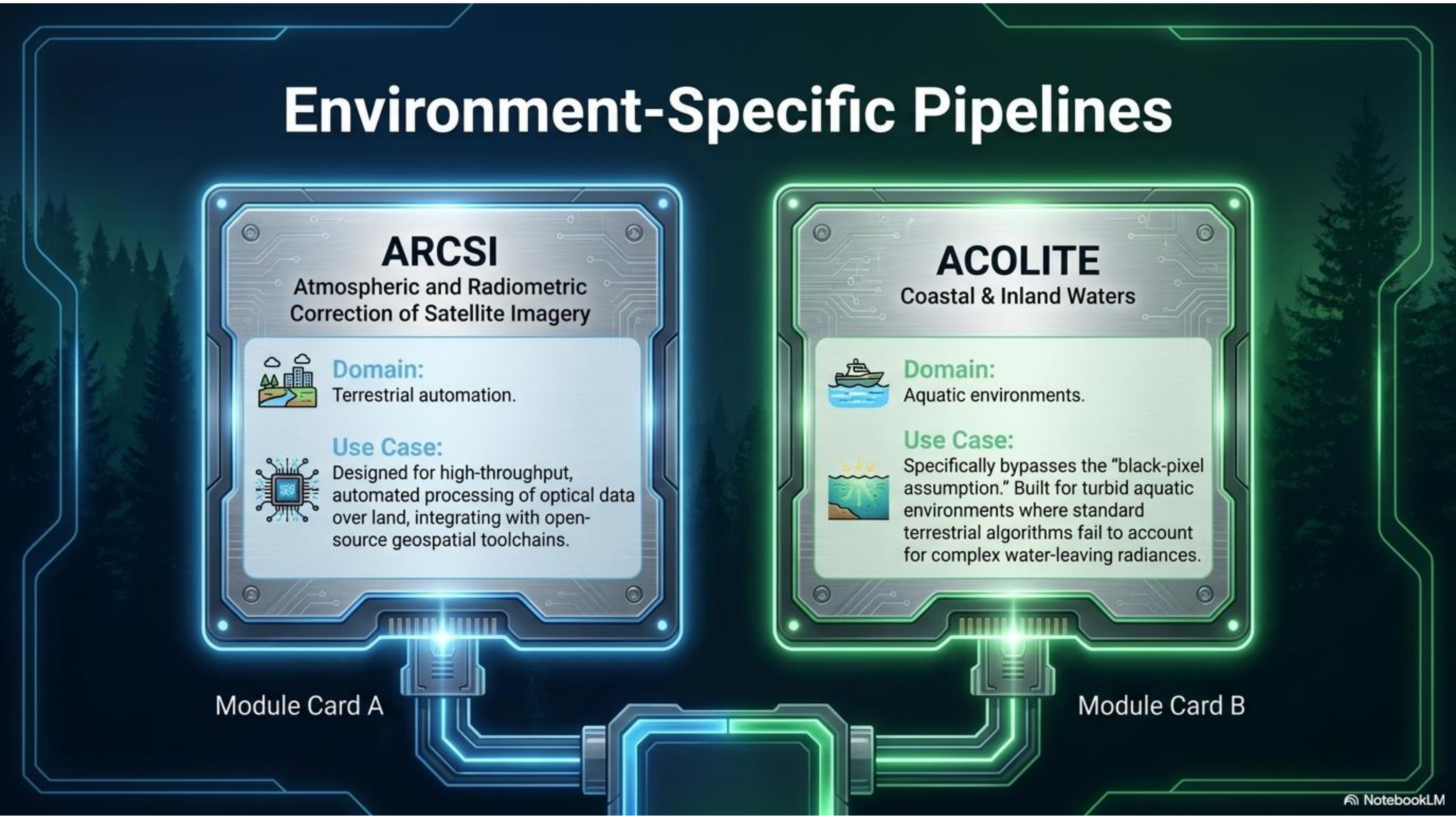
The Challenge: Vegetated targets are non-bright objects. Atmospheric absorption and scattering effects are severely amplified over dark canopies, demanding pristine correction in the vital infrared bands.

The 6S Advantage: Dynamic Integration

The Victory: 6S (Second Simulation of Satellite Signal in the Solar Spectrum) achieves the lowest RMSE (~19.5 tonC/ha) in biomass estimation, beating FLAASH and DOS.

The Mechanics of the Win:

1. **Vector Modeling:** Accounts for light polarization, whereas MODTRAN4/FLAASH solves in scalar form.
2. **External Injection:** Directly integrates MODIS satellite data for exact, localized atmospheric profiles.
3. **The Seasonal Sweet Spot:** Accuracy spikes during Summer collections (full canopy development, highest water vapor), dominating the vital infrared bands.


Environment-Specific Pipelines
ARCSI
Atmospheric and Radiometric Correction of Satellite Imagery
Domain:
Terrestrial automation.
Use Case:
Designed for high-throughput, automated processing of optical data over land, integrating with open-source geospatial toolchains.
Module Card A
ACOLITE
Coastal & Inland Waters
Domain:
Aquatic environments.
Use Case:
Specifically bypasses the "black-pixel assumption." Built for turbid aquatic environments where standard terrestrial algorithms fail to account for complex water-leaving radiances.
Module Card B
NotebookLM

The Deployment Matrix

Environment / Constraint	Action	Tool	Key Reason
Arid / Lithology	DEPLOY	ACORN	Preserves 75%+ of narrow mineral absorption features.
Forest Biomass (Summer)	DEPLOY	6S / 6SV Runner up: FLAASH	MODIS aerosol/water vapor integration + polarization modeling.
Turbid Waters	DEPLOY	FLAASH or 6S Avoid: QUAC	Handles complex sediment scattering.
Unknown Metadata/ Fast Triage	DEPLOY	QUAC	3-second processing, purely in-scene. (Must ensure scene diversity).
Any Hyperspectral Data	DO NOT USE	DOS	Destroys complex spectral signatures.

Calibrate to the Target

There is no universal “best” atmospheric corrector. Algorithm superiority is entirely defined by the **physical characteristics** of the **target environment** and the operational constraints of the mission.

Match the physics of the algorithm to the physics of the scene.
Isolate the signal. Reveal the truth.