ECE 495 – Electromagnetic Warfare and Survivability

Block 3: IR EW and Signature Management
Lesson 22: IR Emitters

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Where We Left Off

L21 gave you the physics: everything warm glows, hot parts peak in the **MWIR** and cool ones in the **LWIR**, and a thermal sensor lives on **contrast**.

Today we point that physics at the aircraft itself. *What, exactly, is glowing?*

We break the IR signature into **five components**, learn a quick rule to rank them, and watch which one dominates change with **band**, **aspect**, and even **time of day**.

Lesson Objectives

By the end of this lesson, you will be able to:

- Name the **five components** of an aircraft IR signature and place each in its band
- Rank components with a light **in-band intensity** rule: emissivity, area, and temperature
- Explain how **aspect** and look-geometry change which component dominates
- Predict the **thermal crossover** where the skin term vanishes in the LWIR

The Five Components of an IR Signature

Component	Mechanism	Primary band
Hot parts (nozzle, turbine)	emission	MWIR
Exhaust plume (CO_2, H_2O)	emission	MWIR ($\sim$4.3 μm)
Airframe skin (aero-heated)	emission	LWIR
Reflected sunlight	reflection	VIS–MWIR (day)
Reflected sky / earthshine	reflection	MWIR / LWIR

- Three **emitters** (the aircraft's own heat) and two **reflectors** (borrowed light)
- The first two shout in the MWIR; the skin owns the LWIR; reflections only matter by day

How Loud Is Each Part?

What a band-limited sensor collects from one part:

$$I_{\text{band}} \propto \varepsilon \cdot A \cdot f_{\text{band}}(T) \cdot \sigma T^4$$

- ε — **emissivity**: how efficiently the surface radiates (coatings can lower it)
- A — **projected area** the sensor actually sees: this is where *aspect* enters
- $f_{\text{band}}(T)$ — **band fraction**: how much of the glow lands in *your* band (Wien decides)
- σT^4 — **total output**: explodes with temperature, so hot parts win per unit area

Temperature, area, emissivity — change any one and you change the signature.

Hot Parts and the Plume: the MWIR Stars

- **Hot parts** — the nozzle and turbine face run hot ($\sim$700–900 K). Small area, but the T^4 term makes them brilliant in the MWIR
- **Plume** — exhaust gas radiates in the **CO_2 band near 4.3 μm**, squarely in the MWIR; large but diffuse
- Both are strongest from the **rear**: a tail-chase sensor looks straight up the tailpipe
- This is why classic heat-seekers are MWIR and love the stern hemisphere

Tail-on, an engine is the loudest thing in the sky.

The Airframe Skin: the All-Aspect LWIR Term

- **Aerodynamic heating** warms the skin; even unheated, the skin radiates at near-ambient temperature in the **LWIR**
- Lower intensity than the plume, but spread over a **large area** and visible from *every* aspect — not just the tail
- Speed drives it: a fast jet's skin can run hot, while a **subsonic penetrator** keeps the skin term modest
- This is the component you cannot point away from — it sets the broadside and head-on signature

The Reflections You Forget

The skin does not only emit — it **reflects**:

- **Sunlight:** by day, reflected solar in the **MWIR** can rival a warm graybody; in the **LWIR** it is negligible
- **Sky:** deep sky is very *cold*, so upward-facing surfaces read cold — a warm target on cold sky is easy to catch
- **Earthshine:** the warm ground lights the underside from below
- Reflections flip with **geometry**: look-up, look-level, and look-down are three different problems

It Depends on Aspect and Geometry

The same aircraft has many signatures — the sensor's vantage picks which:

- **Stern aspect:** plume and hot parts dominate — a bright MWIR target
- **Beam** / **nose aspect:** those hide; the **skin (LWIR)** carries the signature
- **Look-up** (target on cold sky): high contrast, easy detection
- **Look-down** (target on warm, cluttered terrain): low contrast, hard — this is the penetrator's friend

The Diurnal Trap: Thermal Crossover

Skin and background do not heat and cool together:

- **Midday:** sun-baked terrain runs *hotter* than the skin — the target reads **cold** against the ground
- **Night:** terrain radiates to the cold sky and drops *below* the skin — the target reads **warm**
- In between — about an hour after sunrise and after sunset — they are **equal**: LWIR contrast goes to zero

Twice a day, the airframe vanishes into its own background.

Where This Is Headed: Every Component Has a Counter

You manage an IR signature **component by component** — that is Lesson 24:

- **Hot parts** — shield or block line-of-sight to the nozzle; avoid afterburner
- **Plume** — mix exhaust with bypass air to cool it; route it over the airframe
- **Skin** — low-emissivity coatings and paints
- **Reflections** — manage geometry and finish to kill sunglint

For an LO bomber like the B-21, these choices are baked into the airframe, not bolted on.

Quick Exercise / Type-along: Which Component Wins?

For each case, name the **dominant component** and the **band** it shows up in. Call it out.

1. A subsonic B-21, viewed from **dead astern**, at night
2. The same B-21, viewed from the **beam**, at night
3. A fighter in **afterburner**, head-on
4. A cruise missile photographed from above at **noon** over desert

Today's Interactive Demo: Thermal Crossover

Today's interactive demo.

- Model the **skin** and the **terrain background** temperature over a 24-hour day
- Plot the **LWIR contrast** (ΔT = skin $-$ background) across the day
- Find the two **crossover** times where the contrast passes through zero
- Ask the operational question: *when is the airframe hardest to catch in the LWIR?*

Companion script: `L22_ThermalCrossover.m`

In L23 we meet the sensors that exploit all of this: seekers, IRST, and FLIR.

Wrap-Up

Key ideas:

- An aircraft IR signature has **five components**: hot parts, plume, skin, plus reflected sun and sky/earth
- Rank any of them with $I_{\text{band}} \propto \varepsilon\, A\, f_{\text{band}}(T)\, \sigma T^4$ — temperature dominates, area sets aspect
- **Stern** shows plume and hot parts in MWIR; **beam**/**nose** shows skin in LWIR
- **Thermal crossover** zeroes the LWIR skin contrast twice a day — but the MWIR plume does not care

Next lesson:

- **L23: IR Seekers, IRST, and FLIR** — the sensors that turn these components into a track
- Pre-flight quiz for L23 due before class