ECE 495 – Electromagnetic Warfare and Survivability

Block 3: IR EW and Signature Management
Lesson 23: IR Seekers, IRST, and FLIR

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Where We Left Off

L22 dissected the target: **five components**, ranked by $\varepsilon\, A\, f_{\text{band}}(T)\, \sigma T^4$, with the winner set by band, aspect, and time of day.

Today we cross to the other side of the duel. *Who is looking, and how?*

Three sensors exploit that signature: the **seeker** guides a missile, the **IRST** hunts like a passive radar, and the **FLIR** builds a picture for a human.

Lesson Objectives

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

- Distinguish **seekers**, **IRST**, and **FLIR** by job, field of view, and who reads the output
- Explain how a **reticle seeker** turns a target image into a steering signal
- Argue why **imaging seekers** changed the countermeasure game
- Estimate passive detection range with $R_{\max} \propto \sqrt{J\,\tau/\mathrm{NEI}}$ and contrast it with radar scaling

Three Jobs, Three Sensors

	Seeker	IRST	FLIR
Job	put a weapon on target	search and track	image the scene
Instant. FOV	narrow	narrow (scans wide)	selectable
Resolution	just enough to home	low	high
Output reads	guidance loop	computer	human

- All three are **passive**: they collect the L22 signature and emit nothing
- Same physics, different jobs — the job dictates the design, not the other way around

Reticle Seekers: Homing Without a Picture

How do you track with **one detector** and no image? Spin a patterned disk in front of it:

- The reticle **chops** the target's energy into an **AM signal**; the modulation reveals where the target sits off boresight
- Guidance nulls the error; **conical scan** refines it with a nutating image and PWM
- Cheap, simple, 1950s-proof — this is the seeker of the classic MANPADS
- Weakness: it sees a **point of energy**, not a shape

To a reticle seeker, a flare is just a better target.

Seeker Evolution: From Tail-Chase to All-Aspect

The seeker story is a **band-and-aspect** story — straight from L22:

- **First generation:** uncooled SWIR detectors saw only **hot metal** — rear hemisphere, tail-chase shots
- **Cooled MWIR** unlocked the **plume** ($\sim$4.3 μm): the missile went **all-aspect**
- Modern seekers bias the aim point off the plume toward the airframe
- Guidance rides **proportional navigation**: null the line-of-sight rate, not the tail

Imaging Seekers: Why the Picture Changed Everything

Replace the reticle with a staring **focal plane array** and the seeker sees a *scene*:

- The target is now a **shape** with edges and structure, not a blinking point
- Seeker logic can weigh **spectral**, **spatial**, and **temporal** cues — does it look, glow, and move like an aircraft?
- That is exactly the information a decoy struggles to fake
- Rosette and pseudo-imaging scans paved the way; the FPA finished the job

IRST: The Passive Radar

An **IR search and track** system does a surveillance radar's job without transmitting:

- Scans a **wide** field of regard, tracks autonomously, presents a radar-like display
- **Silent**: the target's RWR hears nothing — there is no beam to detect
- The catch: angles come easy, **range does not** — passive ranging needs kinematics or a wingman's geometry
- Low resolution is fine; the computer needs a track, not a portrait

How Far Can a Passive Sensor See?

The sensor triggers when the target's irradiance beats its noise floor:

$$\frac{J \cdot \tau(R)}{R^2} \geq \text{NEI} \quad \Longrightarrow \quad R_{\max} \propto \sqrt{\frac{J\,\tau}{\text{NEI}}}$$

- J — the target's **in-band intensity**: exactly what L22 taught you to rank
- τ — **atmospheric transmittance**: the tax collector from L21, worse with range
- **NEI** — the sensor's noise floor: cooling and detector material set it
- Radar scales as $R_{\max} \propto \sigma^{1/4}$: stealth starves the radar, not the plume

Stealth moves the radar duel into the IRST's backyard.

FLIR: The Picture for the Human

Forward-looking infrared optimizes for interpretation, not homing:

- **High resolution**, selectable field of view — wide to find, narrow to identify
- Operator tools shape the image: **gain and level**, white-hot / black-hot polarity
- A **video tracker** closes the loop: centroid and correlation logic hold the aimpoint
- Navigation, targeting pods, reconnaissance, search and rescue — one family, many missions

Where This Is Headed: Fighting the Seeker

Every sensor today defined a vulnerability — exploiting them is Lesson 24:

- **Flares** seduce a reticle seeker: hotter point wins the modulation contest
- **Imaging seekers** shrug flares off — so countermeasures must get smarter too
- **DIRCM** puts modulated laser energy into the seeker to break its lock
- **Suppression** attacks J itself — shrink the intensity, shrink every $R_{\max}$ in the sky

For the B-21 the goal is simpler: never give the seeker enough J to start the duel.

Quick Exercise / Type-along: Pick the Sensor, Pick the Weakness

For each situation, name the **sensor** best suited to it and its **key limitation**. Call it out.

1. Detect a fighter at long range **without alerting** its RWR
2. Guide a MANPADS launched at a helicopter from **behind**
3. Let an operator **identify** a vehicle from a targeting pod at night
4. Home on a fighter that is **dispensing flares**

Today's Interactive Demo: IR Detection Range

Today's interactive demo.

- Give the target two L22-style intensities: **stern** (plume + hot parts) and **beam** (skin)
- Apply atmospheric loss $\tau(R)$ and compute irradiance at the sensor vs range
- Find where each aspect crosses the sensor's **NEI** — that is $R_{\max}$
- Compare against the vacuum $\sqrt{J}$ prediction: *where did the stern advantage go?*

Companion script: `L23_IRDetectionRange.m`

In L24 we fight back: flares, DIRCM, and plume suppression.

Wrap-Up

Key ideas:

- Three jobs, three passive sensors: **seeker** homes, **IRST** hunts silently, **FLIR** shows a human
- **Reticle** seekers track a chopped point of energy; **imaging** seekers track a shape — and shapes are hard to fake
- Seeker history = detector history: cooled MWIR turned tail-chase into **all-aspect**
- $R_{\max} \propto \sqrt{J\,\tau/\mathrm{NEI}}$ — and unlike RCS, the plume ignores your stealth budget

Next lesson:

- **L24: IRCM** — flares, DIRCM, and plume suppression against everything we met today
- Pre-flight quiz for L24 due before class