



ECE 495 – Electromagnetic Warfare and Survivability

Block 1: Radar Fundamentals

Lesson 1: Introduction

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This course studies how modern aircraft **survive in contested airspace**.

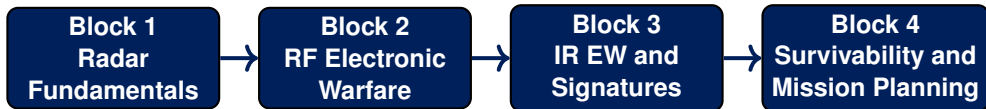
- Radar physics, RF electronic warfare, infrared warfare, signature management, and integrated mission planning
- Centered on a single operational thread: the **B-21 Raider**
- Class style: short lectures, Socratic discussion, in-class interactive demos, group results presentations

If the aircraft can be killed, none of the rest of the avionics matters.

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

- Place this course in the broader **EW and survivability** landscape
- Describe the **threat kill chain** and identify where each survivability discipline acts
- Explain the **ES / EP / EA** framework and classify common tactics
- State the **fourth-power law** and why large RCS cuts buy modest range cuts
- Recognize how the **four Blocks** of this course build toward integrated survivability

Course Roadmap: Four Blocks, 41 Lessons



- **B1–B3** each end with an **individual homework**, a **group project + presentation**, and a **project quiz**
- **B4** closes with the **individual Final Project** — in lieu of a final exam
- **Pre-flight** worked before every class — you present yours at the board 2–3 times
- Today we set the stage; the rest of B1 builds the radar physics you need

- Long-range **penetrating strike** bomber
- **All-aspect, broadband** low observability — a defining design choice
- Mission profile stresses *every* survivability discipline at once:
 - Detection avoidance across radar bands and aspects
 - Passive RF cueing against fielded IADS
 - IR signature management against modern seekers
 - Long-route planning under layered threats

Every project this semester is a B-21 scenario. The platform is the thread that ties the math back to a real mission.

The Air Threat Kill Chain



- Every kill requires that the threat complete **every link** in sequence
- Break **any one link** and the aircraft survives
- This is the organizing principle for the entire course

Survivability is breaking the chain before it breaks you.

Who Breaks Which Link?



- **Detect** — Low observability, EMCON, signature management, **noise jamming (EA)**
 - B2 brings the jamming; B3 and B4 build the signature side
- **Track / Identify** — EW deception and protection (ES, EP, EA)
 - B2 builds the RF side; B3 adds IR
- **Engage** — Tactics, maneuver, decoys, countermeasures
 - Block 4 brings it together
- **Kill** — Hardening, redundancy (out of scope here, but worth knowing it exists)

Every link broken is a kill prevented.

Goal of EW: control the EM spectrum for our use, deny it to the enemy.

- **ES — Electromagnetic Support** (situational awareness)
 - Know what is emitting, where, and what it is
 - Examples: Radar Warning Receiver (RWR), ELINT
- **EP — Electromagnetic Protect** (protect our use of spectrum)
 - Make our radios and radars resistant to the threat
 - Examples: LPI waveforms, frequency hopping, EMCON
- **EA — Electromagnetic Attack** (deny enemy use of spectrum)
 - Jam, deceive, or destroy threat sensors
 - Examples: noise jamming, DRFM, chaff, towed decoys

“Electronic” is the legacy term; “Electromagnetic” is the current Joint term.

- **Everyone is a player.** Friendly, neutral, and adversary systems all touch the same spectrum
- **Crowded and contested.** Wideband, dense, shared use; commercial overlay
- **Multi- and hyper-spectral.** Many bands active at once, often beyond a single receiver's BW
- **Information-rich.** Massive data flows; constant emissions are also constant opportunities
- **Extremely dynamic.** Move and counter-move on tactical timescales — chess with strategy, tactics, and adaptation

EW is decided as much by speed of adaptation as by hardware.

Quick Exercise / Type-along: dB in Your Head



Open MATLAB. Type this with me — twelve lines, no toolboxes.

```
% L1 type-along -- dB is a language for ratios
clear; clc
ratios = [2 4 16 1000];           % power ratios worth memorizing
dB      = 10*log10(ratios);        % ratio -> dB
for k = 1:numel(ratios)
    fprintf('x%-5g = %6.2f dB\n', ratios(k), dB(k));
end
rcs_cut_dB = -12;                  % the B-21 shaves 12 dB off its RCS
range_dB   = rcs_cut_dB/4;         % fourth-power law:  $R \sim \sigma^{1/4}$ 
range_factor = 10^(range_dB/10);  % dB -> plain ratio
fprintf('RCS %+d dB -> range %+1f dB -> R_max x %.3f\n', ...
        rcs_cut_dB, range_dB, range_factor);
```

What do you notice?

How This Course Works



- **Pre-flight** worked before every class
 - A short problem set on the lesson — do it before you walk in
 - Called at random 2–3 times a semester to present yours
 - That recitation is the 10% **participation** grade
- **In class** — short lecture, Socratic discussion, in-class interactive demos
 - Bring a laptop with MATLAB
- **B1–B3:** individual homework, group project, individual project quiz
 - Projects end with a **group results presentation** — innovation bonus available
 - **B4** swaps the group project for the **individual Final Project**
- **Out of class:** online companion book with reading, flashcards, and interactive demos

Category	Weight
Group Projects (B1–B3)	30%
Final Project — individual, in lieu of a final exam	20%
Individual Homeworks	20%
Individual Project Quizzes	20%
Participation (pre-flight board recitation)	10%
Total	100%

- Homework: **binary** rubric (1 / 0); one resubmission per question
- Projects: category rubric; **innovation bonus** available; no regrades
- Project quizzes: open book, 15 min, related to project work and topics
- Participation: graded on the pre-flight you present, not on attendance

On the course site. Two halves, and they are wired together.

- **Walk the chain.** Click any link to see the disciplines that break it and a few example tactics
- **Drill the framework.** Twelve scenarios: call ES / EP / EA, then click the link it most directly affects
- Every answer comes back with the reasoning — get one wrong on purpose

Companion script: `L1_FourthPowerLaw.m` — a reference script that plots $R_{\max} \propto \sigma^{1/4}$ across a 60 dB RCS range. Run it on your own; we will return to the full radar range equation in L3.

Key ideas:

- Survivability = **breaking the kill chain** (Detect, Track, Identify, Engage, Kill)
- EW operates in three pillars: **ES** (sense), **EP** (protect), **EA** (attack)
- Four Blocks, three group projects, an individual Final Project capstone

Next lesson:

- **L2: EM spectrum, propagation, polarization, and antenna basics**
- Work the L2 pre-flight before class — you could be the one up front