

ECE 215/S – Principles of Electronic Cyber Warfare

Block 3: Communication Systems, Radar, and Electronic Warfare

Lesson 38: Project 3 Workday

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Today's Plan

Welcome back. Lesson 37 ended on the **burn-through range**, seen from the jammer's side. In Project 3 you own the radar.

- **First 15 minutes** — the project, the simulator, the model, and a method
- **Rest of class** — team work time, instructors circulating
- **Last 5 minutes** — checkpoint
- The **Project 3 design** is due **Fri 4 Dec, 2359** (L39 T-day)

Quiz 10 (Objectives 3.5–3.9) is due tonight.

Project 3 — Radar Design Lab

Your team of **two** buys **one ground radar** to defend a site. An adversary attacks it with two threats.

- **Threat 1:** two **H-20** bombers in trail, 6.0 km apart, at 30,000 ft. Each carries a **self-screening jammer**
- **Threat 2:** a **CJ-10** cruise missile flying low, at 50 ft. No jammer

REQ 1	Detect an H-20 at **235 km or more**
REQ 2	Range resolution **6.0 km or less**
REQ 3	Detect the CJ-10 at **30 km or more**
Budget	Total cost **$1,200,000 or less**

- REQ 2 is what lets you **resolve the two H-20s**: two echoes, not one
- **3 points:** 2 group points, autograded from your design; 1 individual point, the individual questions at Lesson 40
- **GenAI is not authorized for any part of Project 3.**

Educational exercise. Does not represent actual aircraft, missile, or radar specifications.

The EW Simulator's ECE 215 Page

usafa-ece.org/apps/ew-simulator/choose.html → choose **ECE 215**

- **Six choices:** band and pulse width are free; transmitter, dish, receiver and mast are priced. The handout on the Project 3 page has the catalog
- As you set them, the page shows **each requirement's verdict** and the **total cost**, live
- It never shows whether a **cheaper** design exists. Finding that is the engineering
- Use it to **check** your paper numbers, not to replace them: a disagreement means a step to find
- Type your team's **documentation statement** in the page. It begins "Documentation:" — write "Documentation: None" if there is nothing to declare
- **Export design** saves `ece215_project3_design.json`: your six choices and your statement. That file is what you upload
- Change a choice later? Export again and **resubmit**

The Model (1 of 2): Noise-Limited Range

Wavelength and dish gain (Lesson 31)

$$\lambda = \frac{c}{f} \qquad G_{\text{dish}} = \left(\frac{2\pi r_{\text{dish}}}{\lambda}\right)^2 \eta$$

$\eta = 0.6$ and $r_{\text{dish}} = D/2$: the catalog lists the **diameter**. One dish transmits and receives, so $G_T = G_{\text{dish}}$

Sensitivity $P_{R,\min}$ (Lesson 36)

$$P_{R,\min} = SNR_{\min}\, k\, T_{\text{sys}}\, BW \qquad BW = \frac{1}{\tau}$$

$SNR_{\min} = 15$, a plain ratio, and $k = 1.38 \times 10^{-23}$ J/K. The receiver's bandwidth is matched to the pulse

Noise-limited range — the radar range equation with $P_R = P_{R,\min}$ (Lesson 34):

$$R_{\text{noise}} = \left(\frac{P_T\, G_T^2\, (RCS)\, \lambda^2}{(4\pi)^3\, P_{R,\min}}\right)^{1/4}$$

Each threat has its **own RCS in each band** (the handout's table). Every gain and ratio is linear: no decibels.

The Model (2 of 2): Every Other Limit

Line of sight (Lesson 32) — heights in **feet**

$$R_{LOS,mi} = \sqrt{2h_{\text{ft},1}} + \sqrt{2h_{\text{ft},2}}$$

the mast and the threat's altitude; then 1 mi $=$ 1.61 km

Burn-through (Lesson 37), in meters — **only** if your band lies inside one of the H-20 jammer's bands, edges included

$$R_{BT} = \sqrt{\frac{P_T\, G_T\, (RCS)}{P_{T,\text{jam}}\, G_{T,\text{jam}}\, 4\pi\, SNR_{\min}}}$$

Range resolution (Lesson 35)

$$\Delta R = \frac{c\,\tau}{2}$$

Total cost $=$ transmitter $+$ dish $+$ receiver $+$ mast. Band and pulse width are free

Detection range for a threat: the **smallest** of the limits that apply — R_{noise} and R_{LOS} always, R_{BT} too when jammed

Every comparison is inclusive ($\geq$, $\leq$). No losses, no clutter, no multipath; one pulse.

Method: Design on Paper First

1. **Map each requirement to its equations.** REQ 1: R_{noise}, R_{LOS}, and R_{BT} if jammed. REQ 2: ΔR. REQ 3: R_{noise} and R_{LOS}
2. **List the knobs in each equation.** Which of the six choices appear in it, and which do not?
3. **Start with the free choices.** What does the band change? The pulse width, besides ΔR?
4. **Compute every limit for one candidate**, each threat with its own RCS and altitude. Which limit binds, and which knob moves it?
5. **In a jammed band, compute R_{BT} before you spend money there**
6. **Price it,** then try the next-cheaper option for each purchase. Does every requirement still pass? Confirm in the simulator

The smallest limit wins. Pay only to move the one that binds.

Common Pitfalls

- **Heights stay in feet.** The line-of-sight row takes feet and returns miles; then $\times 1.61$. Converting heights to meters first breaks the rule
- R_{BT} **often comes out in meters**, not kilometers. That is not a units error: compare it with how close the jammer can ever come (Lesson 37)
- **One jammer.** An H-20's echo faces one jammer's $P_{T,\text{jam}}$ and $G_{T,\text{jam}}$; the two aircraft's jammers do not add
- **Radius, not diameter.** The catalog lists D; the gain row uses $r_{\text{dish}} = D/2$
- **Fourth roots.** R_{noise} goes as the fourth root: twice the transmitter power buys $2^{1/4} = 1.19$ times the range
- $BW = 1/\tau$**.** A shorter pulse sharpens ΔR, but it also widens the bandwidth — and that raises the noise floor
- **Three significant figures**, at least, in hand work. A rounded gain can flip a verdict on paper; the grader recomputes from your choices

Submitting: Gradescope “Project 3”

- **One group submission**, teams of two: add your teammate. Upload **one** `.json` file, the exported design, unedited (any name ending `.json`)
- **No documentation statement, no grade** — 0 of 2. Type it in the simulator before you export
- **Resubmit** as often as you like until the deadline. **Late submissions are off**

Two autograder tests, 1 point each:

- **Design meets every requirement** — REQ 1, REQ 2, REQ 3 and Budget all PASS. Shown on submission, with each PASS/FAIL and the total cost
- **Lowest-cost design** — earned only by the lowest-cost design that meets every requirement. Shown **only after the due date**

The third point is individual: **Project 3 Individual Questions**, opened after the design is due, started in class at Lesson 40, due **Thu 10 Dec, 2359** (L41 T-day). Each of its 10 parts is worth one tenth of that point.

Authorized Resources

- **Team design:** a calculator; the ECE 215/S equation sheet; slides, class notes, the readings and practice problems; the EW Simulator; spreadsheets and code you write yourself (MATLAB, Python, etc.), with every AI assistant and AI autocomplete turned off; collaboration with the cadets in your team only; EI from ECE 215/S instructors
- **Individual questions** (Lesson 40): the same, minus any collaboration; EI is still allowed
- **No extensions and no corrections:** the design and the individual questions are final at their deadlines
- **Documentation statement:** required, typed in the simulator before export — "Documentation: None" if there is nothing to declare

GenAI is not authorized for any part of Project 3.

This is **stricter** than Project 2. Check the policy for each assignment.

Checkpoint for Today

By the end of class your team should have:

- ☐ Every limit computed **by hand** for one candidate design: R_{noise} and R_{LOS} for both threats, R_{BT} if your band is jammed, and ΔR
- ☐ Those numbers **checked** against the simulator, and every disagreement explained
- ☐ A **first submission** to Gradescope “Project 3”, documentation statement included, to read its PASS/FAIL report
- ☐ For each purchase, the **next-cheaper option** tried on paper

Gradescope shows PASS/FAIL and the total cost now. Whether a cheaper design exists, you learn after the due date.

Wrap-Up

Reminders:

- **Quiz 10** (Objectives 3.5–3.9) is due **tonight**
- **Project 3 design** is due **Fri 4 Dec, 2359** (L39 T-day): the exported `.json` to Gradescope "Project 3"
- Teams of 2. **No GenAI** for any part of Project 3. Collaborate only with the cadets in your team

Next lessons:

- **Lesson 39 — Course Review.** Final exam preparation across all three blocks
- **Lesson 40 — Project 3 Discussion**, in our classroom: the debrief, then the individual questions (due Thu 10 Dec, 2359, L41 T-day)