ECE 215/S – Principles of Electronic Cyber Warfare
Project 3 — Radar Design Lab: Buy the Radar

scenario v1.1

This is a **group project** for teams of **two** cadets. Review the course policies in your ECE 215/S syllabus regarding absences, collaboration, and documentation.

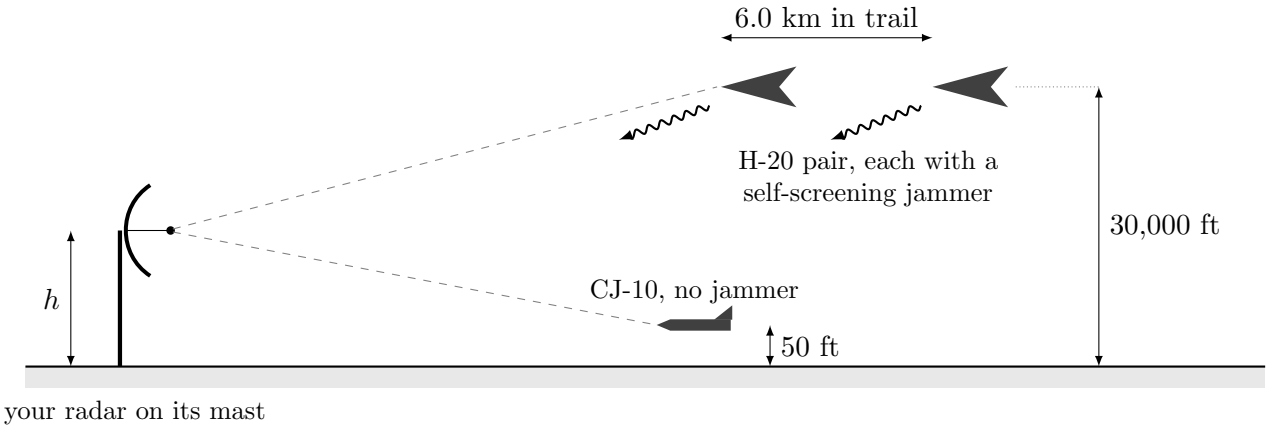
At a glance. One radar, six catalog choices, three requirements and a budget. **3 project points**: 2 group points from your team's design file, due **Friday 4 December at 2359** (the T-day of Lesson 39), and 1 individual point from the individual questions, due **Thursday 10 December at 2359** (the T-day of Lesson 41). **GenAI is not authorized for any part of Project 3. No extensions.**

The Mission.

An adversary can strike the site you defend in two ways, and your team buys **one** ground-based radar to see both coming:

- **Threat 1: two H-20 stealth bombers** flying in trail, one behind the other along your radar's line of sight, at 30,000 ft. Each carries a **self-screening noise jammer**.
- **Threat 2: a CJ-10 land-attack cruise missile** flying low and terrain-following, at 50 ft. It carries **no jammer**.

You build the radar from the catalog below: one **band**, one **transmitter**, one **dish**, one **receiver**, one **mast** and one **pulse width**. The band and the pulse width cost nothing; you pay for the other four. Design the radar on paper, check it in the ECE 215 page of the EW Simulator, and submit the design file the simulator exports.



Schematic, not to scale.

This is an educational exercise and does not represent actual aircraft, missile or radar specifications.

Requirements.

Your design passes only if it meets all four rows. Every comparison is inclusive: a value exactly at a limit passes.

Requirement	What it means	Passes when
REQ 1	Detect an H-20. Either aircraft counts: they are identical and fly at the same altitude.	detection range $\geqslant$ 235 km
REQ 2	Resolve the two H-20s in range. They fly 6.0 km apart in trail.	$\Delta R \leqslant$ 6.0 km
REQ 3	Detect the CJ-10.	detection range $\geqslant$ 30 km
Budget	Transmitter + dish + receiver + mast. The band and the pulse width are free.	total cost $\leqslant$ \$1,200,000

The Threats. Both H-20s fly at the same altitude, one directly behind the other, so REQ 2 asks your radar to tell them apart in range. Each H-20's self-screening jammer jams your radar **only if your band lies inside one of its two jamming bands**, edges included. Use one jammer for an H-20 echo: the two aircraft's jammers do not add. The CJ-10 carries no jammer and is never jammed.

Jammer band	**Covers (edges included)**	$P_{T,jam}$	$G_{T,jam}$
Band 1	100 MHz to 2.35 GHz	100 W	10
Band 2	5.1 GHz to 6.1 GHz	500 W	10

Each threat's radar cross section (RCS, nose-on) depends on the band:

Band	**Frequency** f	**H-20 RCS**	**CJ-10 RCS**
L	1.30 GHz	0.04540 m^2	0.25 m^2
S	3.60 GHz	0.01738 m^2	0.15 m^2
C	5.50 GHz	0.03609 m^2	0.12 m^2
X	10.0 GHz	0.003583 m^2	0.10 m^2

The Catalog. Choose exactly one option from each of the six lists: the band (frequency f), the transmitter (peak power P_T), the dish (diameter D), the receiver (system noise temperature T_{sys}), the mast (height h of your radar's antenna above the ground) and the pulse width τ. The **same dish** transmits and receives.

Band (free)	
Option	f
L	1.30 GHz
S	3.60 GHz
C	5.50 GHz
X	10.0 GHz

Transmitter		
Option	P_T	**Price**
TX1	25 kW	\$150,000
TX2	50 kW	\$250,000
TX3	100 kW	\$400,000
TX4	200 kW	\$700,000
TX5	400 kW	\$1,300,000

Dish		
Option	D	**Price**
ANT1	3 m	\$50,000
ANT2	4 m	\$100,000
ANT3	5 m	\$175,000
ANT4	6 m	\$300,000
ANT5	8 m	\$650,000

Receiver		
Option	T_{sys}	**Price**
RX1	1000 K	\$15,000
RX2	600 K	\$40,000
RX3	400 K	\$90,000
RX4	250 K	\$175,000
RX5	150 K	\$400,000

Mast		
Option	h	**Price**
MAST1	15 ft	\$15,000
MAST2	30 ft	\$40,000
MAST3	50 ft	\$80,000
MAST4	75 ft	\$180,000
MAST5	100 ft	\$300,000

Pulse width (free)	
Option	τ
PW1	10 µs
PW2	20 µs
PW3	30 µs
PW4	50 µs
PW5	80 µs

Total cost = transmitter + dish + receiver + mast.

Constants. Every gain and ratio in this project is a plain (linear) ratio. Do not use decibels.

Constant	**Value**
Speed of light	$c = 3 \times 10^8$ m/s
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ J/K
Dish efficiency	$\eta = 0.6$
Minimum signal-to-noise ratio (linear)	$SNR_{min} = 15$
Miles to kilometers	1 mi = 1.61 km

The Model. These equations are the whole model; the autograder and the simulator use exactly these. R_{noise} is the sheet's radar range equation with $P_R = P_{R,min}$.

Wavelength	$\lambda = \dfrac{c}{f}$
Dish gain	$G_{dish} = \left(\dfrac{2\pi r_{dish}}{\lambda}\right)^2 \cdot \eta, \quad$ with $r_{dish} = \dfrac{D}{2}$ and $G_T = G_{dish}$
Receiver bandwidth	$BW = \dfrac{1}{\tau}$
Sensitivity	$P_{R,min} = SNR_{min} \cdot k \cdot T_{sys} \cdot BW$
Noise-limited range	$R_{noise} = \left(\dfrac{P_T G_T^2 (RCS) \lambda^2}{(4\pi)^3 P_{R,min}}\right)^{1/4}$
Line of sight	$R_{LOS,mi} = \sqrt{2 \cdot h_{ft,1}} + \sqrt{2 \cdot h_{ft,2}}, \quad$ then 1 mi = 1.61 km
Burn-through range	$R_{BT} = \sqrt{\dfrac{P_T G_T (RCS)}{P_{T,jam}\, G_{T,jam}\, 4\pi\, SNR_{min}}}$ (only when jammed)
Detection range	the **smallest** limit that applies: $\min(R_{noise}, R_{LOS})$, or $\min(R_{noise}, R_{LOS}, R_{BT})$ when jammed
Range resolution	$\Delta R = \dfrac{c \cdot \tau}{2}$

In the line-of-sight row, $h_{ft,1}$ is your mast height and $h_{ft,2}$ the threat's altitude, **both in feet**: do not convert them to meters; convert only the result, from miles to kilometers. R_{BT} uses the $P_{T,jam}$ and $G_{T,jam}$ of the jamming band that covers your band, and assumes the jammer flies with the target (self-screening), as it does here.

Model Rules.

- **Each threat on its own.** Work each threat with its own RCS in your band and its own altitude. R_{noise} and R_{LOS} always apply; R_{BT} applies only to an H-20, and only when its jammer covers your band.
- **Inclusive comparisons.** A detection range equal to the requirement passes, a ΔR equal to the trail spacing passes, and a cost equal to the budget passes.
- **One jammer per echo.** The two H-20s' jammers do not add.
- **Nothing else.** No losses of any kind (atmosphere, rain, hardware, processing), no clutter, no multipath. One pulse, one look.
- **Linear only.** $SNR_{min} = 15$ is a plain ratio, not decibels.
- **Three significant figures.** Carry at least three in hand work: a rounded gain can flip a verdict on paper. The autograder recomputes from your six choices, so rounding never changes your grade.

Burn-through: 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).

Using the EW Simulator. Open https://usafa-ece.org/apps/ew-simulator/choose.html and choose **ECE 215**. That page runs this handout's scenario and model. As you pick your six options, it shows each requirement's verdict (PASS or FAIL) and your total cost, live. It never shows whether a cheaper design exists. Work the design on paper first, then check it here.

1. Type your team's **documentation statement** in the page. It begins with "Documentation:"; write "Documentation: None" if there is nothing to document.
2. Click **Export design**. The simulator saves `ece215_project3_design.json`: your six choices and your documentation statement.
3. Upload that file to the Gradescope assignment **"Project 3"**.

Grading.

Project 3 is worth **3 project points**: 2 group points and 1 individual point.

Group — Gradescope "Project 3" (2 points, autograded). The autograder recomputes every number from your six choices and the scenario; it trusts nothing the simulator computed and never prints the lowest cost. It runs two tests:

- **Design meets every requirement** (1 point). Shown when you submit, with each requirement's PASS or FAIL and your total cost.
- **Lowest-cost design** (1 point). Shown **only after the due date**. Earned only by the lowest-cost design that meets every requirement.

What to submit. One submission per team:

☐ **One** `.json` file: the simulator's export (any name ending in `.json`).

☐ Your documentation statement, typed in the simulator before you export. **A file with no documentation statement is not graded** (0 of 2).

☐ Both names: one partner submits and adds the other to the submission.

You may resubmit as often as you like until the deadline. **Late submissions are off**: Gradescope accepts nothing after the deadline.

Individual — Gradescope "Project 3 Individual Questions" (1 point). A Gradescope Online Assignment, auto-graded and **individual**: no collaboration. It opens after the design is due, you work it in class at Lesson 40, and it is due **Thursday 10 December at 2359** (the T-day of Lesson 41). Each of its 10 parts is worth one tenth of this point, so 8 of 10 earns 0.8. The questions refer to the lowest-cost design, so they are not printed here.

Timeline.

Gradescope is authoritative for every deadline.

When	What happens
Lesson 37	Project 3 introduced; this handout and the simulator's ECE 215 page open.
Thanksgiving	Gradescope "Project 3" opens.
Lesson 38	Project 3 Workday: team work time in class.
Lesson 39	**Design due Friday 4 December at 2359** (T-day): one `.json` per team.
Lesson 40	Project 3 Discussion: debrief, the lowest-cost design, individual questions in class.
Lesson 41	**Individual questions due Thursday 10 December at 2359** (T-day).

Ground Rules.

For the **team design** you may use 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; and extra instruction (EI) from ECE 215/S instructors. For the **individual questions**: the same, minus any collaboration (EI from ECE 215/S instructors is still allowed). **GenAI is not authorized for any part of Project 3.**

No extensions on any part of Project 3: not the design, not the individual questions. **No corrections**: both are final at their deadlines, an exception to the syllabus's one-week correction, because the lowest-cost design is revealed after the design deadline.