1. Using the RADAR distance equation, if a signal returns after 573.3 µsec, how far away is the detected object?

   The pulse travels out and back, so the range is half of the distance it covers:

   $$R = \frac{ct}{2} = \frac{(3 \times 10^8 \text{ m/s})(573.3 \times 10^{-6} \text{ s})}{2} = 85{,}995 \text{ m} \approx 86 \text{ km}$$

   R = 86 km

2. During an exercise, a UAS is used to gather information on the red forces. The red team has deployed a mobile RADAR unit and the signal from the RADAR takes 133.3 us to return. How far away is the UAS?

   $$R = \frac{ct}{2} = \frac{(3 \times 10^8 \text{ m/s})(133.3 \times 10^{-6} \text{ s})}{2} = 19{,}995 \text{ m} \approx 20.0 \text{ km}$$

   R = 20.0 km

3. A squadron of planes is approaching a RADAR installation. The squadron has the following characteristics:

   $\sigma = 8\text{m}^2$
   $G_R = 3.2$
   $P_{r,\text{min, RWR}} = 400\text{nW}$
   altitude = 3500ft, AGL

   The RADAR installation has the following characteristics:

   $f = 900\text{MHz}$
   $G_T = 250$
   $P_T = 9\text{kW}$
   $P_{r,\text{min,RADAR}} = 15\text{fW}$
   altitude = 175ft, AGL

   (a) For the conditions specified, what will be the maximum line of sight distance between the RADAR and the lead aircraft?

   R_{LOS} = 165 km

   $R_{LOS,mi} = \sqrt{2(3500)} + \sqrt{2(175)}$
   $= 83.666 + 18.708 = 102.374$ mi
   $102.374 \text{ mi} \times 1.61 \text{ km/mi} = 164.8 \text{ km} \approx 165 \text{ km}$

(b) What is the maximum distance from which the lead aircraft's RWR will detect the RADAR?

R_{RWR} = 113 km

One-way, so Friis: the RADAR transmits ($G_T = 250$) and the RWR receives ($G_R = 3.2$, $P_{R,\min} = 400$ nW).

$\lambda = c/f = (3 \times 10^8)/(900 \times 10^6) = 0.3333$ m

$$R_{RWR} = \frac{\lambda}{4\pi}\sqrt{\frac{P_T G_T G_R}{P_{R,\min}}}$$

$$= \frac{0.3333}{4\pi}\sqrt{\frac{(9000)(250)(3.2)}{400 \times 10^{-9}}} = 1.125 \times 10^5 \text{ m}$$

$= 112.5$ km ≈ 113 km, inside the 165 km LOS

(c) What is the maximum distance from which the RADAR will detect the planes?

R_{RADAR} = 64.0 km

Two-way, so the radar range equation: the RADAR's gain squared and the RADAR's own $P_{R,\min} = 15$ fW.

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

$$= \left(\frac{(9000)(250)^2(8)(0.3333)^2}{(4\pi)^3(15 \times 10^{-15})}\right)^{1/4}$$

$= (1.680 \times 10^{19})^{1/4} = 6.402 \times 10^4$ m $= 64.0$ km

(d) Who will see who first, and at what range?

Answer = Planes at 113km

Both ranges are inside the 165 km LOS of (a), so the horizon caps neither. The longer range detects first: 113 km > 64.0 km.

The planes' RWR hears the RADAR at 113 km, about 49 km before the RADAR can see them.

4. For the data given in Problem 3, what would be the planes' new altitude so that the line-of-sight distance matches the RWR detection distance?

Altitude = 1,310 ft

Set R_{LOS} equal to $R_{\text{RWR}} = 112.54$ km and solve the LOS row for the planes' height. The RADAR stays at 175 ft.

$112.54 \text{ km} \div 1.61 \text{ km/mi} = 69.90 \text{ mi}$

$\sqrt{2h_{ft}} = 69.90 - \sqrt{2(175)} = 69.90 - 18.71 = 51.19$

$h_{ft} = (51.19)^2/2 = 1{,}310 \text{ ft}$

5. For the data given in Problem 3, what is the minimum RCS value (σ) required for the RADAR to be able to detect the plane at the original LOS distance?

$\sigma =$ 351 m^2

Solve the radar range equation for σ at $R = R_{LOS} = 164.82$ km, with the echo right at the RADAR's $P_{R,\text{min}} = 15$ fW:

$$\sigma = \frac{P_{R,\text{min}}(4\pi)^3 R^4}{P_T G_T^2 \lambda^2}$$

$$= \frac{(15 \times 10^{-15})(4\pi)^3 (164{,}820)^4}{(9000)(250)^2(0.3333)^2} = 351 \text{ m}^2$$

That is about 44 times the squadron's 8 m^2.

6. The RCS of a fighter is approximately 20 square meters. The RCS of a missile is approximately 0.2 square meters. How many times farther away can the fighter be detected than the missile?

Answer = 3.16 times farther

Same RADAR and same $P_{R,\text{min}}$, so only the RCS changes, and it sits under the fourth root:

$R \propto (RCS)^{1/4}$

$$\frac{R_{fighter}}{R_{missile}} = \left(\frac{20}{0.2}\right)^{1/4} = (100)^{1/4} = 3.16$$

7. During an exercise, a UAS is used to gather information on the red forces. The red team has deployed a mobile RADAR unit, with the following parameters:

RADAR unit	UAS
Frequency = 450 MHz	RCS = 0.4 m^2
Transmit Power = 1.5kW	Receive antenna gain = 3
Antenna gain = 200	Minimum power received = 1.25 μW
Minimum power received = 1 fW	Altitude = 435 ft, AGL

(a) If the RADAR signal takes 133.3 us to return, how far away is the UAS?

$R =$ 20.0 km

$R = \frac{ct}{2} = \frac{(3 \times 10^8)(133.3 \times 10^{-6})}{2} = 19{,}995$ m

≈ 20.0 km

(b) How much power is received by the RADAR if the UAS is 30 km from the RADAR?

$P_R =$ 6.64 fW

$\lambda = c/f = (3 \times 10^8)/(450 \times 10^6) = 0.6667$ m

$P_R = \frac{P_T G_T^2 (RCS) \lambda^2}{(4\pi)^3 R^4}$

$= \frac{(1500)(200)^2(0.4)(0.6667)^2}{(4\pi)^3(30{,}000)^4}$

$= 6.64 \times 10^{-15}$ W = 6.64 fW

(c) For the conditions specified, what will be the maximum line of sight distance between the RADAR and the UAS?

$R_{LOS} =$ 47.49 km

The mobile RADAR is on the ground, so its term is zero:

$R_{LOS,mi} = \sqrt{2(435)} + \sqrt{2(0)} = 29.496$ mi

29.496 mi $\times$ 1.61 km/mi = 47.49 km

(d) What is the maximum distance from which the UAS RWR will detect the RADAR?

$R_{RWR} =$ 45.02 km

One-way, so Friis, with the UAS's $G_R = 3$ and its own $P_{R,\min} = 1.25$ μW:

$R_{\text{RWR}} = \frac{\lambda}{4\pi}\sqrt{\frac{P_T G_T G_R}{P_{R,\min}}}$

$= \frac{0.6667}{4\pi}\sqrt{\frac{(1500)(200)(3)}{1.25 \times 10^{-6}}}$

$= 4.502 \times 10^4$ m = 45.02 km

(e) What is the maximum distance from which the RADAR will detect the UAS?

R_{RADAR} = 48.15 km

Two-way, so the radar range equation, with the RADAR's own $P_{R,\min} = 1$ fW:

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

$$= \left(\frac{(1500)(200)^2 (0.4)(0.6667)^2}{(4\pi)^3 (1 \times 10^{-15})} \right)^{1/4}$$

$$= (5.375 \times 10^{18})^{1/4} = 4.815 \times 10^4 \text{ m} = 48.15 \text{ km}$$

(f) Who will see who first, and at what range?

Answer = RADAR at 47.49km (LOS-limited)

Nobody detects beyond the 47.49 km LOS of (c), so take the smaller of each power range and the LOS.

RADAR: the smaller of 48.15 km and 47.49 km is 47.49 km (LOS-limited). RWR: the smaller of 45.02 km and 47.49 km is 45.02 km.

The longer range detects first: the RADAR sees the UAS at 47.49 km, before the UAS's RWR hears it at 45.02 km.