This packet is the reference for Quiz 9: the questions cite its tables and figures by number. The questions and their answer boxes are in Gradescope, and you may read this packet ahead of time.

1 Scenario Description

You are a graduate of the United States Air Force Weapons School and have been assigned to a task force conducting Mission Engineering analysis for the F-47, Loyal Wingman, and B-21 platforms. The focus of this effort is a comprehensive Link Budget Analysis for the communications links.

To support your analysis, the Air Force Red Team has developed a representative mission scenario that serves as the design reference, including the expected operational ranges and environmental conditions for each platform. Additionally, the respective System Program Offices (SPOs) for each aircraft and associated satellite systems have provided projected performance parameters for systems still in development.

Your task is to evaluate the performance and feasibility of the communication links under the provided scenario and identify any technical risks, performance limitations, or operational concerns. The results of your assessment will inform senior decision-makers, including the Vice Chairman of the Joint Chiefs of Staff (VCJCS) and the respective SPO System Program Directors (SPDs).

As an orientation for Figure 1, begin in the bottom right with the F-47 operating at 35,000 feet MSL. The two-ship formation is controlling four Loyal Wingman platforms via Ka-band communications, with data links established among all six aircraft. The F-47 is also communicating to a low-cost CUBESAT operating in Low Earth Orbit (LEO) at an altitude of 200 km. The CUBESAT maintains a laser communications link with a geostationary (GEO) military communications satellite (MILCOM) positioned at 35,786 km. The MILCOM, in turn, maintains an X-band link with the B-21, which is operating at 40,000 feet MSL. This entire communications chain enables shared sensor data and voice communications among the B-21, F-47, and Loyal Wingman platforms. All antenna gains in this quiz are linear ratios (not dB).

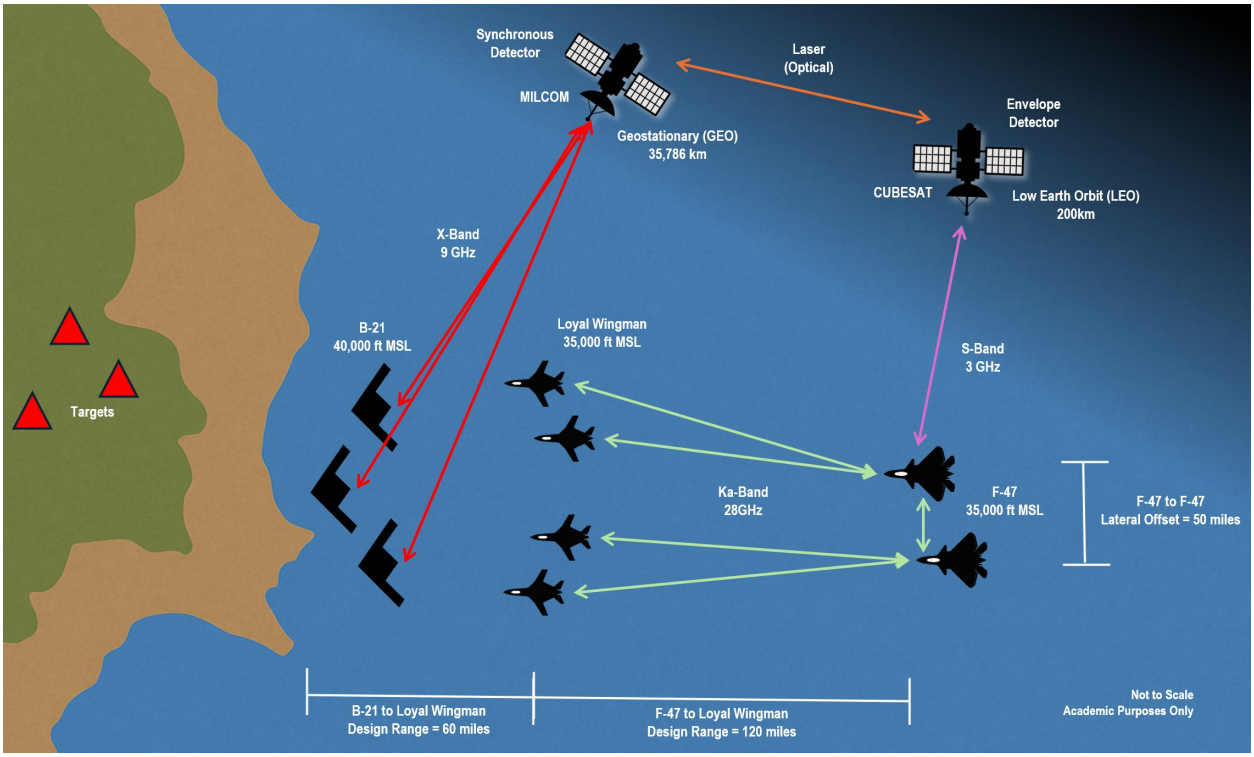


Figure 1: Air Force Red Team Design Reference

2 Systems Design Specifications

1. F-47 Line of Sight Aircraft to Aircraft Communications System Specifications

   The projected aircraft to aircraft communication specifications for the F-47, including links with other F-47 aircraft and the Loyal Wingman, are provided in Table 1 and illustrated in Figure 2.

Table 1: F-47 Aircraft to Aircraft Communications System Specifications

Specification	**Value**
Power $_{\text{Transmitter}}$	1.00 kW
Sensitivity $_{P_{R,min}}$	3.00 pW
Frequency	28.0 GHz
Gain $_{\text{Nose}}$	See Figure 2
Gain $_{\text{Side}}$	See Figure 2

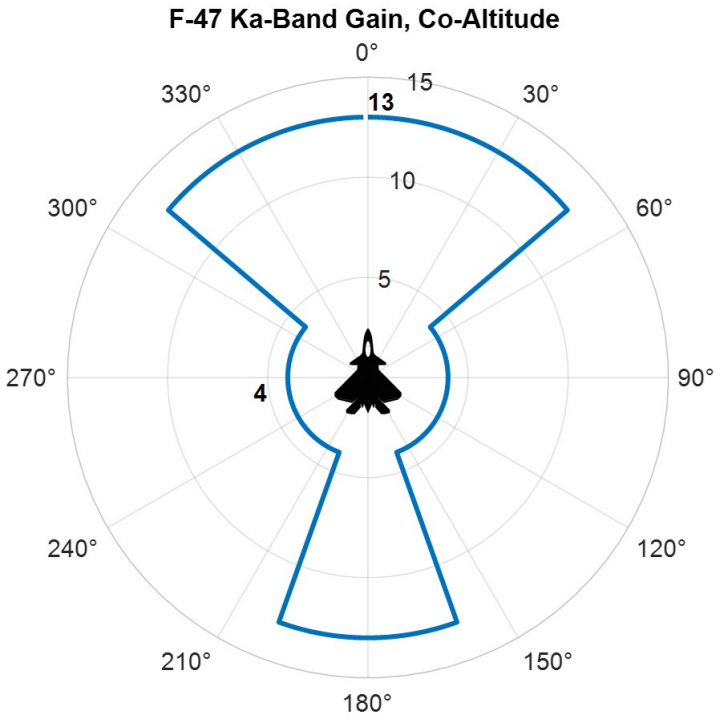


Figure 2: F-47 Aircraft to Aircraft Gain Polar Plot

2. F-47 Satellite Communications System Specifications

   The projected satellite communication specifications for the F-47, to the CUBESAT are provided in Table 2 and illustrated in Figure 3.

Table 2: F-47 Satellite Communications System Specifications

Specification	Value
Power $_{\text{Transmitter}}$	200 W
Sensitivity $_{P_{R,min}}$	22.0 pW
Frequency	3.00 GHz
Gain $_{\text{High Elevation}}$	See Figure 3
Gain $_{\text{Low Elevation}}$	See Figure 3

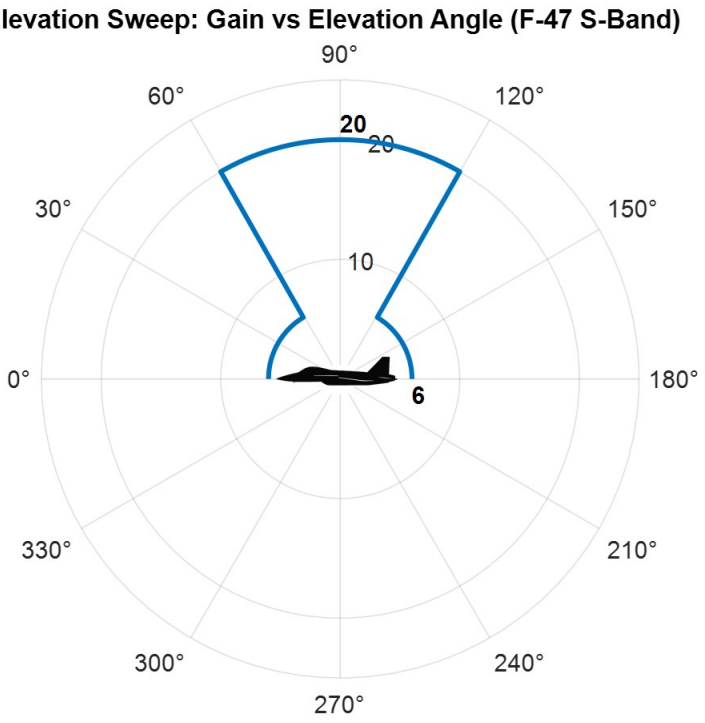


Figure 3: F-47 Satellite Gain Polar Plot

3. CUBESAT Communications System Specifications

   The projected communication specifications for the CUBESAT to the F-47 are provided in Table 3.

Table 3: CUBESAT Communications System Specifications

Specification	Value
Power $_{\text{Transmitter}}$	200 W
Sensitivity $_{P_{R,min}}$	20.0 fW
Frequency	3.00 GHz
Gain (Omni)	3.00

4. B-21 Satellite Communications System Specifications

   The deployed satellite communication specifications for the B-21, to the MILCOM are provided in Table 4 and illustrated in Figure 4.

Table 4: B-21 Satellite Communications System Specifications

Specification	**Value**
Power $_{\text{Transmitter}}$	10.0 kW
Sensitivity $_{P_{R,min}}$	16.0 pW
Frequency	9.00 GHz
Gain $_{\text{High Elevation}}$	See Figure 4
Gain $_{\text{Low Elevation}}$	See Figure 4

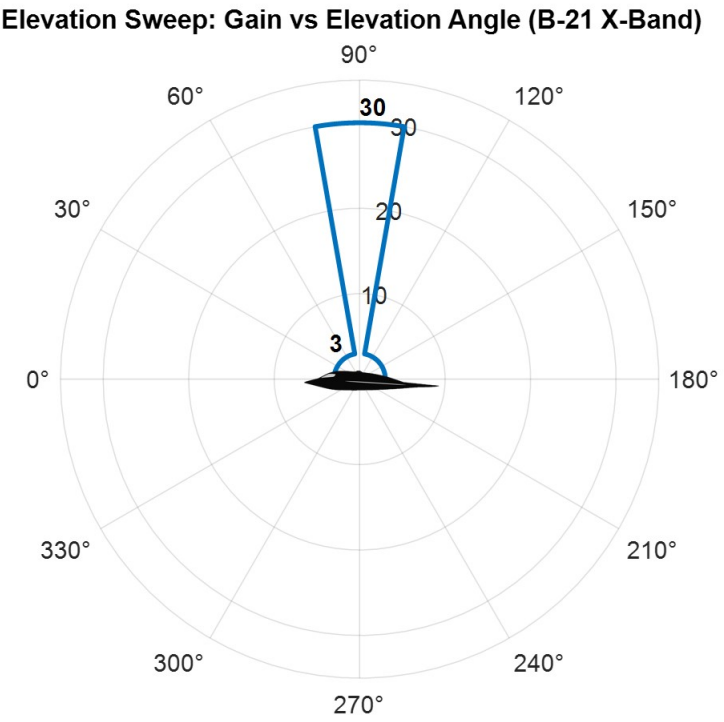


Figure 4: B-21 Satellite Gain Polar Plot

5. MILCOM Communications System Specifications

   The deployed communication specifications for the MILCOM to the B-21 are provided in Table 5.

Table 5: MILCOM Communications System Specifications

Specification	**Value**
Power $_{\text{Transmitter}}$	10.0 kW
Sensitivity $_{P_{R,min}}$	16.0 pW
Frequency	9.00 GHz
Gain (Parabolic)	10,000

6. Loyal Wingman Aircraft to Aircraft Communications System Specifications

   The projected aircraft to aircraft communication specifications for the Loyal Wingman, including links with the F-47 aircraft are provided in Table 6 and illustrated in Figure 5.

Table 6: Loyal Wingman Aircraft to Aircraft Communications System Specifications

Specification	**Value**
Power $_{\text{Transmitter}}$	1.00 kW
Sensitivity $P_{R,min}$	3.00 pW
Frequency	28.0 GHz
Gain $_{\text{Nose}}$	18 (see Figure 5)
Gain $_{\text{Side}}$	2 (see Figure 5)
Gain $_{\text{Tail}}$	18 (see Figure 5)

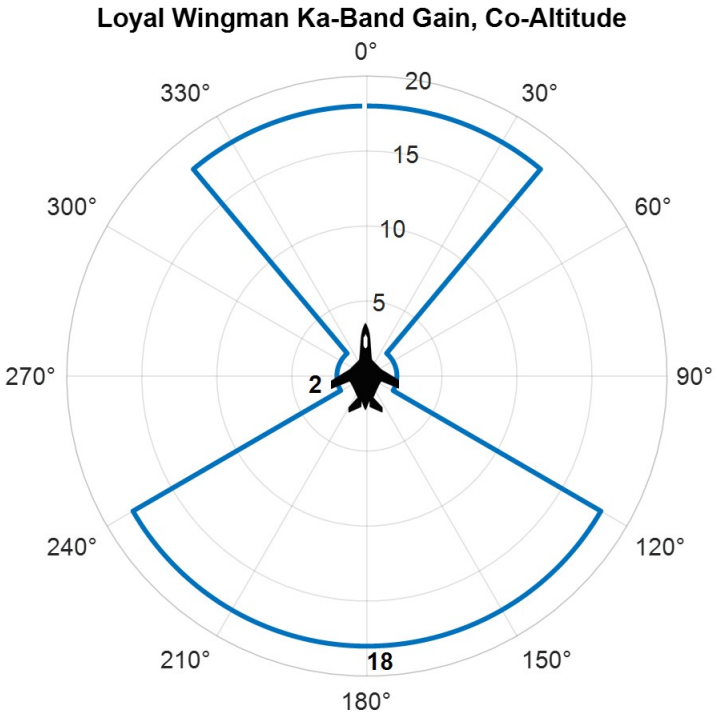


Figure 5: Loyal Wingman Aircraft to Aircraft Gain Polar Plot