Project Objective

* Background information

The US Department of Navy (DoN) requires high-bandwidth secure communication in radio frequency (RF) denied environments. DoN surface vessels collect large amounts of data that must be immediately shared fleetwide. For example, the Cooperative Engagement Capability and AEGIS systems of the DoN send large amounts of data between surface vessels. RF communication suffers from issues that make free space optical (FSO) a better option than traditional radio communication. First, RF communication suffers from high side lobe, sending signals in undesired directions. This undesired radiation allows for other vessels to receive the signal, including enemy ships. With the increasing importance of data in modern warfare, denial of enemy reception of data is paramount. Second, RF communication requires larger bandwidths to match the transmission rate of FSO systems. Larger bandwidths introduce issues of interference as RF bands become increasingly occupied by commercial interests. Third, the RF space has become contested through electronic warfare. Electronic attack systems are being investigated by multiple nations with the intention of disrupting RF systems. Making systems resilient to electronic attacks is vital to national security. Fourth, enemy vessels can track ships emitting RF through electronic surveillance systems. FSO systems operate in line of sight and emit primarily in a single direction, reducing the ability of enemy ships to track through surveillance systems.

However, despite these advantages, FSO systems suffer from the limitation of line-of-sight communication. Over the horizon communication is sometimes necessary for certain fleet configurations. Space-based FSO relays are available; however, they suffer from other issues. They face interference from weather phenomena like clouds. Communication systems in military applications must be resilient to weather. Space-based communication faces additional difficulty as orbits might not always line up well, increasing project costs significantly as more satellites are required for relays.

Therefore, UAVs offer the ability to relay optical communication in areas where space-based relays are unavailable. They can be weather resilient and integrate well into the existing Navy infrastructure. The Navy has extensive air operation infrastructure in its aircraft carrier fleets, and most fleets have the capability to launch small fixed-wing aircraft. The US Airforce and US Navy both operate extensive UAV fleets that can be easily transitioned to data relays without significant interruption to their primary missions.

**Customer requirements**

1. High Bitrate: The Navy requires upwards of 1Gbps communication links
2. Low-Sidelobe: The Navy requires no-/low-sidelobe
3. Over the Horizon Communication: The Navy requires over-the-horizon communication
4. Weather Resilient: The Navy requires systems that can handle inclement weather
5. Continuous Connection: The Navy requires continuous connections with low bit errors
6. Duplex Communication: The Navy must share information between two ships and their sensors bidirectionally.

**Technical Requirements**

Our system will have:

1. Software drivers that can operate at 10Ghz
2. Operating frequency in the infrared range (1270nm/1310nm) in the eye-safe power range
3. Transmit/receive speed of 10 Gbps of data but we will most likely be working with 1 Gbps
4. A tracking device capable of tracking a device at 100m with tangential velocity up to 92m/s within 20mm
5. System to adjust tracking based on live data to account for variable distance and speed of the receiver
6. Two-way simultaneous communication
7. Costs less than $500 to build
8. System will have the ability to network with other UAVs to create a FANET

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| Marketing Requirements | Engineering Requirements | Justification |
| 1 | Software drivers that can operate at 10Ghz | Software to test these links must operate at a frequency greater than or equal to the rate of communication to properly test the speed of the communication link. |
| 1, 2 | Operating frequency in the infrared range in the eye-safe power range | The eye safe requirement is purely for testing in academic facilities/public areas. The infrared wavelength was chosen because near-optical communication has low-sidelobe and high bitrates. |
| 1 | Transmit/receive speed of 1 Gbps of data but we will most likely be working with 1 Gbps | 1 Gbps is the baseline identified in Naval request for proposals in early FSO systems. Faster systems are outside of the budget. |
| 3 | A tracking device capable of tracking a device at 100m with tangential velocity up to 92m/s within 20mm | 45m/s tangential velocity is the maximum speed for consumer UAVs in the US by FAA rules. Our system must operate on two drones with up to 2m/s turbulence to prove it is able to communicate with drones operating in consumer regulations as proof of concept. |
| 5 | System to adjust tracking based on live data to account for variable distance and speed of the receiver | Minor turbulence and real-world effects on the system cannot interrupt the transmission of data |
| 6 | Two-way simultaneous communication | Two-way communication is required so that both ships are aware of the other ship and its sensors/actions. |
| None | Costs less than $500 to build | This budget limit was placed by LMU’s EECE department. |
| 3, 4, 5 | System will have the ability to network with other UAVs to create a FANET | Relays and FANETs are required to create large distance connections where one drone cannot suffice. Additionally, FANETs allow for shorter link distances with the usage of more drones per km. |
| Marketing Requirement:   1. High bitrate: The Navy requires upwards of 1Gbps communication links 2. Low-sidelobe: The Navy requires no-/low-sidelobe 3. Over the horizon: The Navy requires over-the-horizon communication 4. Weather resilient: The Navy requires systems that can handle inclement weather 5. Continuous Connection: The Navy requires continuous connections with low bit errors 6. Duplex Communication: The Navy must share information between two ships and their sensors bidirectionally. | | |