**SCAMPER**

SCAMPER is a method of generating ideas by differentiating the proposed idea from current industry solutions. The proposal differs by using the SFP as a laser generator in free space optical communication in a much cheaper solution. SCAMPER stands for substitute, combine, adapt, modify, put to other use, eliminate, and rearrange. The SCAMPER below is based off previous free-space optical communication systems in the industry. The proposed solution substitutes an SFP for the laser generator, combines the laser with cheap DJ scanners, adapts the SFP for use in free space, modifies existing hobbyist solutions like KORUZA, and puts free space optical systems to other use in dynamic systems. It does not eliminate or rearrange free space optical components from the system.

S: SFP as laser source

C: scanner combined with SFP

A: SFP as free space optical communication system

M: modifying KORUZA free space optical communication system

P: hobbyists, navy at larger scale, consumer electronics

E: no

R: no

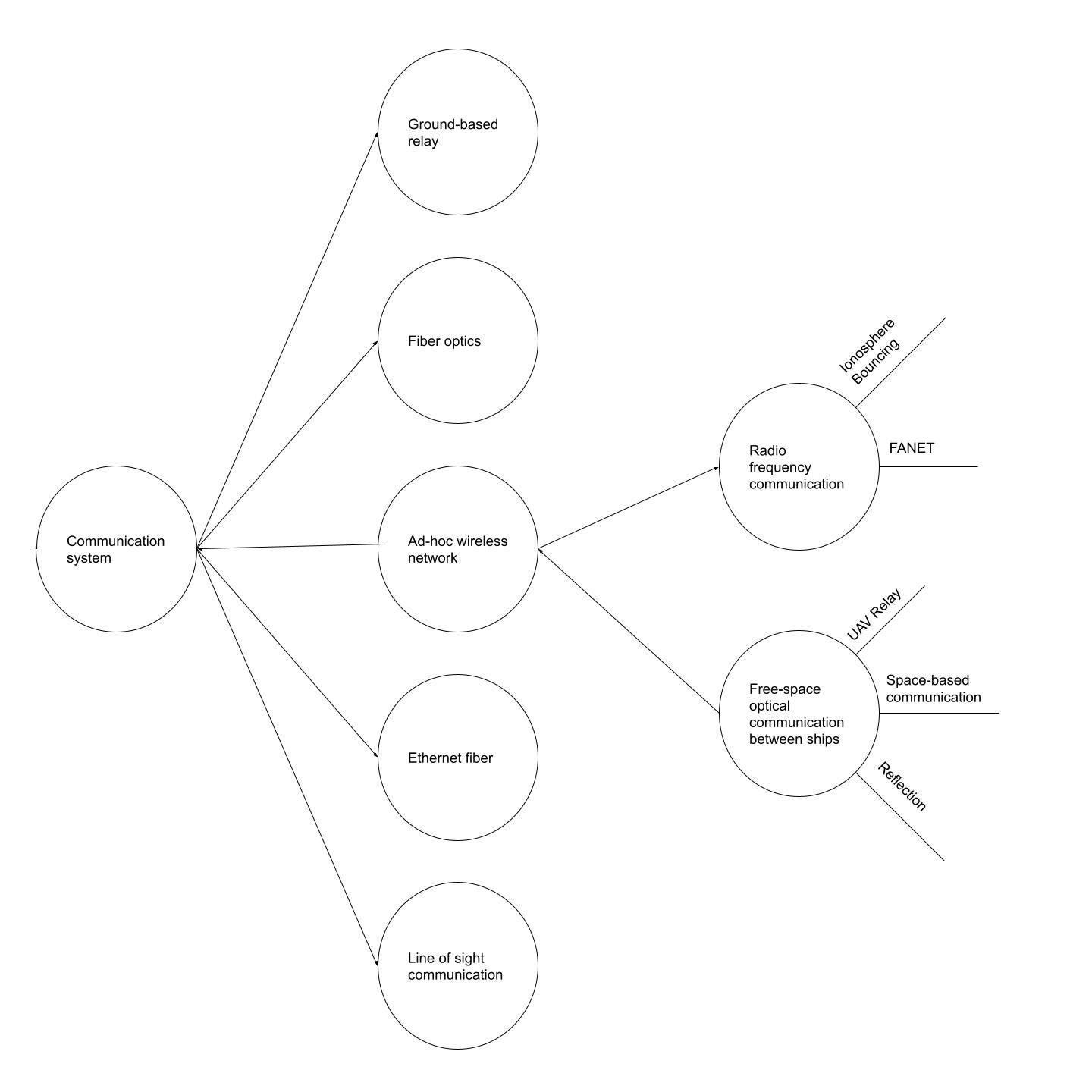
**Concept Table**

The system is composed of an aiming mechanism, transceiver, computer connection, and software driver. Additionally, the operating wavelength must be chosen, and other transmit/receive options weighed. Ultimately, a scanner was chosen for aiming; SFP was chosen for the transceiver; Ethernet/Thunderbolt were both chosen for connecting; IR was chosen for wavelength; and C++ and Python were chosen for software.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Aiming | Transceiver | Connector | Wavelength | Detector | Software |
| Scanner | SFP | Thunderbolt 3 | Near IR | SFP | C++ |
| Stepper motor | SFP+ | Ethernet | Far IR | Photo detector | Python |
| Servo motor | Laser | SATA | Visible | Antenna | Java |
|  | Radio | LC/SC |  |  | JavaScript |

**Concept Fan**

The below shows a concept fan to weigh various problems and solutions stemming from the proposal. Ultimately, the chosen solution best solves the issue at hand as mitigating solutions are not possible.



**Pugh Concept Selection**

The Pugh concept selection tables compare various solutions for the system components based on their relative performance in criteria based on the requirements of the system. From the weighted sum of the performances, the best option is selected.

*Aiming*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Solutions \ Criterion | Speed | Accuracy | Weight | Implementation | Cost | Total |  |
| 3 | 3 | 1 | 1 | 4 |  |  |
| Scanner | - | - | - | - | 0 | 0 | YES |
| Motor | -1 | -1 | -1 | 1 | 1 | -2 | NO |

*Transceiver*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Solutions\Criterion | Distance | Safety | Cost | Total |  |
| 1 | 2 | 3 |  |  |
| Multimode SFP | - | - | - | 0 | YES |
| Singlemode SFP | 0 | 0 | -1 | -3 | NO |
| Waveshare Receiver/Transmitter | 1 | -1 | -1 | -4 | NO |

*Wavelength*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Solution \ Criterion | Safety | Weather Resilience | SFP Availability | Cost | Total |  |
| 1 | 2 | 3 | 4 |  |  |
| Visible | -1 | -1 | -1 | 1 | -2 | NO |
| Near IR (850nm) | - | - | - | - | 0 | YES |
| IR (1300nm) | 1 | 1 | 0 | -1 | -1 | NO |

*Computer Connector*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Solutions\Criterion | Speed | PC Connection | Power Provided | Cost | Total |  |
| 1 | 1 | 1 | 5 |  |  |
| SATA | -1 | 0 | -1 | -1 | -7 | NO |
| RJ45 | - | - | - | - | 0 | YES |
| Thunderbolt 3 | 1 | 0 | 1 | -1 | -3 | NO |

**Decision Matrices**

The decision matrices show the selection of a solution for each subsystem of the proposed system. Each solution is rated on a scale of 0 to 1 based on its performance in a criterion and the weighted sum of these performance ratings are compared to select a solution. The criteria are selected based on the requirements of the system.

*Aiming*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Solutions \ Criterion | Speed | Accuracy | Weight | Implementation | Cost | Total |
| Scanner | 1 | 1 | 0.8 | 0.2 | 0.2 | 2.76 |
| Motor | 0.2 | 0.5 | 0.3 | 1 | 0.4 | 2.05 |
| Weight | 1 | 1 | 0.5 | 0.8 | 1 |  |

*Light Wavelength*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Solution \ Criterion | Safety | Weather Resilience | SFP Availability | Cost | Total |
| Visible | 0.2 | 0 | 0.1 | 0.9 | 0.85 |
| Near IR (850nm) | 0.5 | 1 | 0.9 | 0.5 | 1.85 |
| IR (1300nm) | 0.7 | 1 | 1 | 0.1 | 1.79 |
| Weight | 0.6 | 0.3 | 1 | 0.7 |  |

*Data Connection*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Solutions\Criterion | Speed | PC Connection | Power Provided | Cost | Total |
| SATA | 0.15 | 0.5 | 0 | 0.6 | 1.025 |
| RJ45 | 0.25 | 1 | 1 | 1 | 2.025 |
| Thunderbolt 3 | 1 | 1 | 1 | 0.2 | 1.6 |
| Weight | 0.5 | 0.7 | 0.2 | 1 |  |

*Transceiver*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Solutions\Criterion | Distance | Safety | Cost | Total |
| Multimode SFP | 0.7 | 0.8 | 0.7 | 1.67 |
| Singlemode SFP | 1 | 1 | 0.3 | 1.6 |
| Waveshare Receiver/Transmitter | 0.2 | 1 | 0.5 | 1.24 |
| Weight | 0.7 | 0.6 | 1 |  |

*SFP*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Solutions \ Criterion | Speed | Precision | Complexity | Eye Safe | Cost |  |
| SFP | 0.1 | 0.5 | 1 | 1 | 1 | 2.95 |
| SFP+ | 1 | 0.5 | 1 | 1 | 0.35 | 2.75 |
| FSO Laser - Edmonds | 0.8 | 1 | 0.5 | 0 | 0.04 | 1.49 |
| Weight | 0.5 | 0.8 | 0.5 | 1 | 1 |  |

**Purchase Matrices**

The purchase matrices are derived from the selected decision matrix solutions. One purchase matrix is created for each essential part of the relay system. Within each matrix, various alternative components are compared based on the chosen solution.

*SFP*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SFP | Speed | Precision | Cost | Mode | Compatibility | Speed of Delivery | Link |
| 1000Base-SX SFP | 1G | Class 1 | $28 | MMF | Ubiquiti/Meraki/Mikrotik/Netgear | ~2 day | [Amazon](https://www.amazon.com/10Gtek-GLC-SX-MMD-GLC-SX-MM-Transceiver-1000Base-SX/dp/B00U77VPX2/ref=sr_1_3?dchild=1&keywords=sfp+1000base-sx&qid=1633822790&sr=8-3) |
| 1000Base-SX SFP | 1G | Class 1 | $25.00 | MMF | Cisco | 2 weeks | [FS](https://www.fs.com/products/11774.html) |

*RJ45 to USB-C Converter*

|  |  |  |
| --- | --- | --- |
| Speed | Cost | Link |
| 1G | 13.59 | [Amazon](https://www.amazon.com/Ethernet-Adapter-atolla-Thunderbolt-Compatible/dp/B09893WP6F/ref=sr_1_1_sspa?crid=2SRNZGRLFBFHW&dchild=1&keywords=ethernet+to+usb+c&qid=1633817668&refinements=p_36%3A-2000&rnid=386442011&sprefix=ethernet+to+usb%2Caps%2C237&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzTVQ5STlRWVVYQkhGJmVuY3J5cHRlZElkPUEwMzI0MjIzMktYNFJGNjUwQU1HTiZlbmNyeXB0ZWRBZElkPUEwODQ0NDM1RDZWQUtROUNTVUJSJndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==) |
| 1G | 20.99 | Amazon |
| 1G | 22.99 | [Amazon](https://www.amazon.com/Anker-Ethernet-PowerExpand-Aluminum-Portable/dp/B08CK9X9Z8/ref=sr_1_2_sspa?dchild=1&keywords=ethernet+to+usb+c&qid=1633817883&sr=8-2-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyVkZISUpTSllQNDIzJmVuY3J5cHRlZElkPUEwNjM0NTA5MUpXUjJOQ1U3RklIVyZlbmNyeXB0ZWRBZElkPUEwMTI1ODMxMzRaMlpGUDJLUjhBViZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=) |

*RJ45 Cable*

|  |  |  |
| --- | --- | --- |
| Speed | Cost | Link |
| 10GBps | 7.99 | [Amazon](https://www.amazon.com/Ethernet-DanYee-Braided-Professional-Plated/dp/B073RZRBR1/ref=sr_1_1_sspa?crid=1RO7ON5IJT26B&dchild=1&keywords=1g+ethernet+cable&qid=1633818123&sprefix=1G+ethe%2Caps%2C243&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzRVAwS0FaNkNJTkVaJmVuY3J5cHRlZElkPUEwOTg4MDE5MlZNSzY0NTU0RzVETCZlbmNyeXB0ZWRBZElkPUEwMzUxNTE5MzY0UFhQTTRWV0ZGOSZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=) |
| 40GBps | 6.99 | [Amazon](https://www.amazon.com/Ethernet-Network-Outdoor-Shielded-Connector/dp/B08F7DH1DG/ref=sr_1_2_sspa?crid=1RO7ON5IJT26B&dchild=1&keywords=1g+ethernet+cable&qid=1633818123&sprefix=1G+ethe%2Caps%2C243&sr=8-2-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzRVAwS0FaNkNJTkVaJmVuY3J5cHRlZElkPUEwOTg4MDE5MlZNSzY0NTU0RzVETCZlbmNyeXB0ZWRBZElkPUEwMTc4NzAzMTdHUFExTTk3NENCVCZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=) |
| 40GBps | 8.99 | [Amazon](https://www.amazon.com/Ethernet-Outdoor-Connector-Weatherproof-Resistant/dp/B07QLXC6QR/ref=sr_1_3?crid=1RO7ON5IJT26B&dchild=1&keywords=1g+ethernet+cable&qid=1633818123&sprefix=1G+ethe%2Caps%2C243&sr=8-3) |
| 40GBps | 2.99 | [Amazon](https://www.amazon.com/Ethernet-2000Mhz-Internet-Connector-Netword/dp/B098TLR9LH/ref=sr_1_3?dchild=1&keywords=ethernet+cat8&qid=1633818580&sr=8-3) |

*Aiming Laser*

|  |  |  |
| --- | --- | --- |
| Cost | Rating | Link |
| 18.99 | IIIA | [Amazon](https://www.amazon.com/Pointer-Rechargeable-Adjustable-Suitable-Projector/dp/B09D9KM3V3/ref=sr_1_5?dchild=1&keywords=laser+pointer&qid=1633824727&sr=8-5) |
| 17.99 | IIIA | [Amazon](https://www.amazon.com/Tactical-Flashligh-Charging-Adjustable-Astronomy/dp/B09DPVN5P3/ref=sr_1_3?dchild=1&keywords=usb+laser&qid=1633824639&sr=8-3) |

*Aiming Camera*

|  |  |  |
| --- | --- | --- |
| Cost | Resolution | Link |
| $49 | 1080p | [Amazon](https://www.amazon.com/Raspberry-Pi-NoIR-Camera-Module/dp/B01ER2SMHY) |
| $26.72 | 1080p | [Amazon](https://www.amazon.com/Arducam-Camera-Raspberry-Infrared-Sensitive/dp/B07SPRQMCW/ref=dp_fod_1?pd_rd_i=B07SPRQMCW&psc=1) |

*Media Converter*

|  |  |  |  |
| --- | --- | --- | --- |
| Speed | Cost | SFP Ports | Link |
| 1G | $19.88 | 1 | [Amazon](https://www.amazon.com/Gigabit-Ethernet-Converter-1000Base-T-1000Mbps/dp/B06XKNNB48/ref=dp_fod_1?pd_rd_i=B06XKNNB48&psc=1) |
| 1G | 20.35 | 1 | [Amazon](https://www.amazon.com/gp/product/B003CFATL0/ref=as_li_tl?ie=UTF8&tag=tpusbuynow-20&camp=1789&creative=9325&linkCode=as2&creativeASIN=B003CFATL0&linkId=a2f1d173f3104a0c97b610ed5efa65ec) |

*Scanner*

|  |  |  |
| --- | --- | --- |
| Speed | Cost | Link |
| 20 kpps | $186.22 | [eBay](https://www.ebay.com/itm/224345859812?_trkparms=amclksrc%3DITM%26aid%3D1110006%26algo%3DHOMESPLICE.SIM%26ao%3D1%26asc%3D20201210111452%26meid%3D3d0a67d8ce5e4524abb7358d03df2920%26pid%3D101196%26rk%3D1%26rkt%3D3%26sd%3D201997704968%26itm%3D224345859812%26pmt%3D1%26noa%3D0%26pg%3D2047675%26algv%3DSimplAMLv5PairwiseWebWithBBEV2bAndUBSourceDemotionWithUltimatelyBoughtOfCoviewV1&_trksid=p2047675.c101196.m2219&amdata=cksum%3A2243458598123d0a67d8ce5e4524abb7358d03df2920%7Cenc%3AAQAGAAACMLAKOcgikT4bLij%252FxRK%252FtSkTYe4YbCw5%252FPV7Z8Mmdg9sEd47P99%252FeNtclTc8TlLlRQpg%252Fz5m3WZPlqn7qGYCNTgBkJVpnZ5LB76U2zg8tKnTx1i3%252FTr%252FUsvSOEJv67VdWim8io%252BT%252B1e1amr2kZhd0va4DGSvz7Nec9m6l%252BVvJdOgAiuV91HMHOFCnePD9jNvGFjrNCv4ipxM2vKY4sHPbUszl59vbm7tUahn7SB8gK0ER7NrsDulQeec6svEQZ2ls05CmtQT6p8MDbbJ9HjYtHFWCV00i8%252Fp875WnfSDXY4dJ1OyC92xpIkhSKedp4KpwblEA5xIcjoJcaXMu5DJZEUbs33kcrcqrl7Jftvm%252FbDO6JW78t2YdoqlyQiMunPjvoXeZCNCPL0Kmo0JXtOVxcJVSPWrCOjRLL%252F5r61iyKaEVPLgvoTD9rrrBNVuN4XjfhZGhDtb3NyOK%252Fz3GsB%252FmxQw0eU%252FkVwXE3aFAqcxuK6A%252BFl009iIC2s8dzQVLfZ67GjzJOWZa%252BM6odPdDCXsPASH8L5Iy1NcaI8qltTdvxGLGmlMzIP768U0pklPAbgel8zXO22g49d7c2zj8j5qiDpczeHWKLNtS%252Biw7ttJwtto49bmR%252FTTcOnuEFAm9brf61e8Zgk4ZYWz26qsnPz3vbp42Vq64j6Kuj7OMnV9hUHyLzw1l441QfNdUlUuzKQpqhcO%252BknEI%252Fi%252BxNnpOyYGoP27G6uJeMxhd8b%252BUJTUwTPI%7Campid%3APL_CLK%7Cclp%3A2047675) |
| 30 kpps | $221.61 | [AliExpress](https://www.aliexpress.com/item/32848473475.html?src=google&aff_fcid=7f009a856c01417089772c5dcf838263-1633818099674-06575-UneMJZVf&aff_fsk=UneMJZVf&aff_platform=aaf&sk=UneMJZVf&aff_trace_key=7f009a856c01417089772c5dcf838263-1633818099674-06575-UneMJZVf&terminal_id=4ca9c0c2f2e541c4a05486634af64b1f) |
| 20 kpps | $175.06 | [Amazon](https://www.amazon.com/380nm-700nm-Digital-Galvanometer-Optical-Scanner/dp/B085P1619X/ref=sr_1_2?dchild=1&keywords=Galvanometer+scanner&qid=1634060887&sr=8-2) |

*Lens*

|  |  |  |
| --- | --- | --- |
| Size | Cost | Link |
| 50 mm Diameter, 100 mm FL | $17.32 | [Amazon](https://www.amazon.com/Plano-convex-lens-Dia-Eisco/dp/B071NZLNGS) |
| 51 mm Diameter, 100 mm FL | $24.32 | [Lab Pro Inc.](https://labproinc.com/products/plano-convex-lens-50mm-dia-100mm-fl-lpv504?variant=37110324035753) |