Floating InterNet (FIN) Module

A SEA4G Presentation

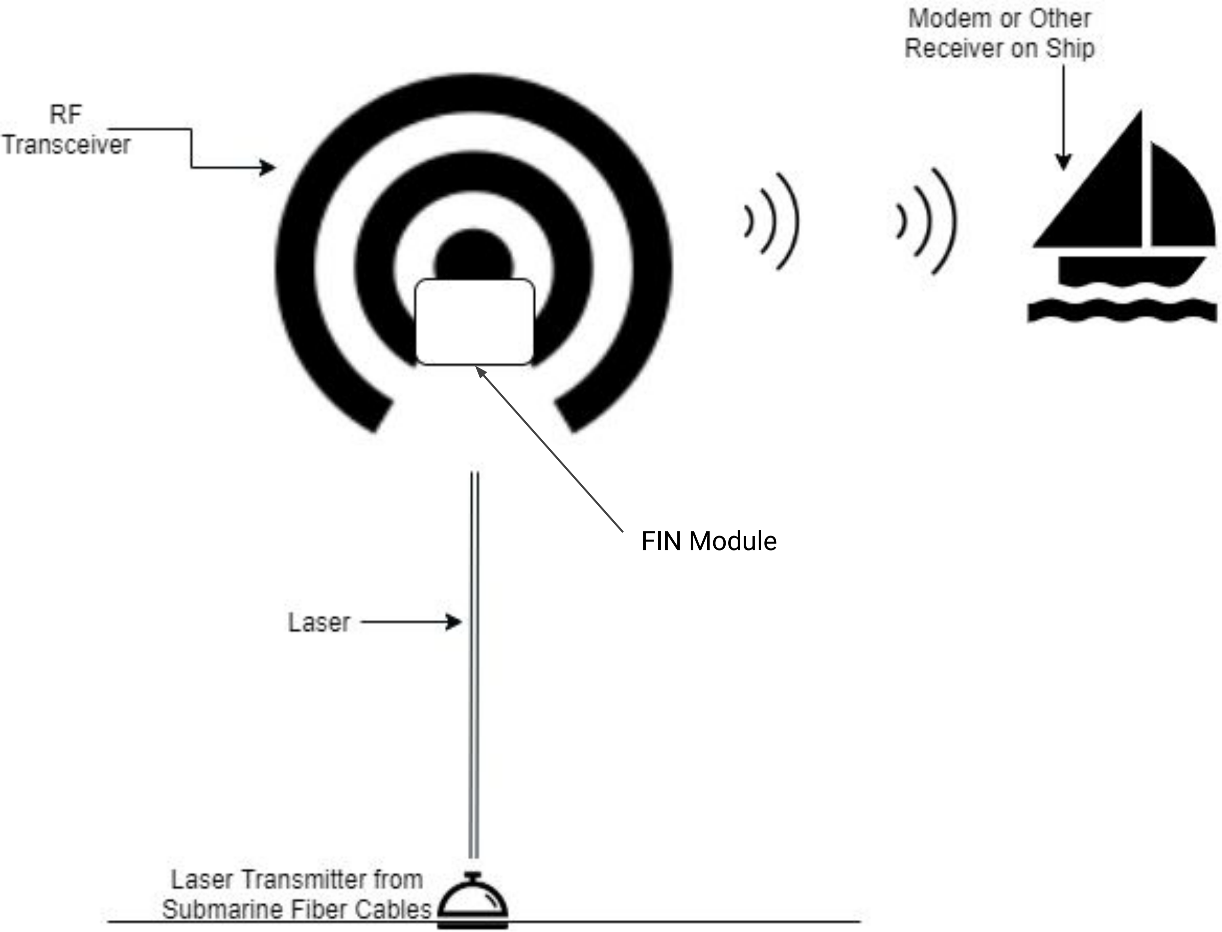
By: James Gamage, Nicholas Soule, Andrea Mitofsky,
Joshua Bowman, John Aron

The Challenge

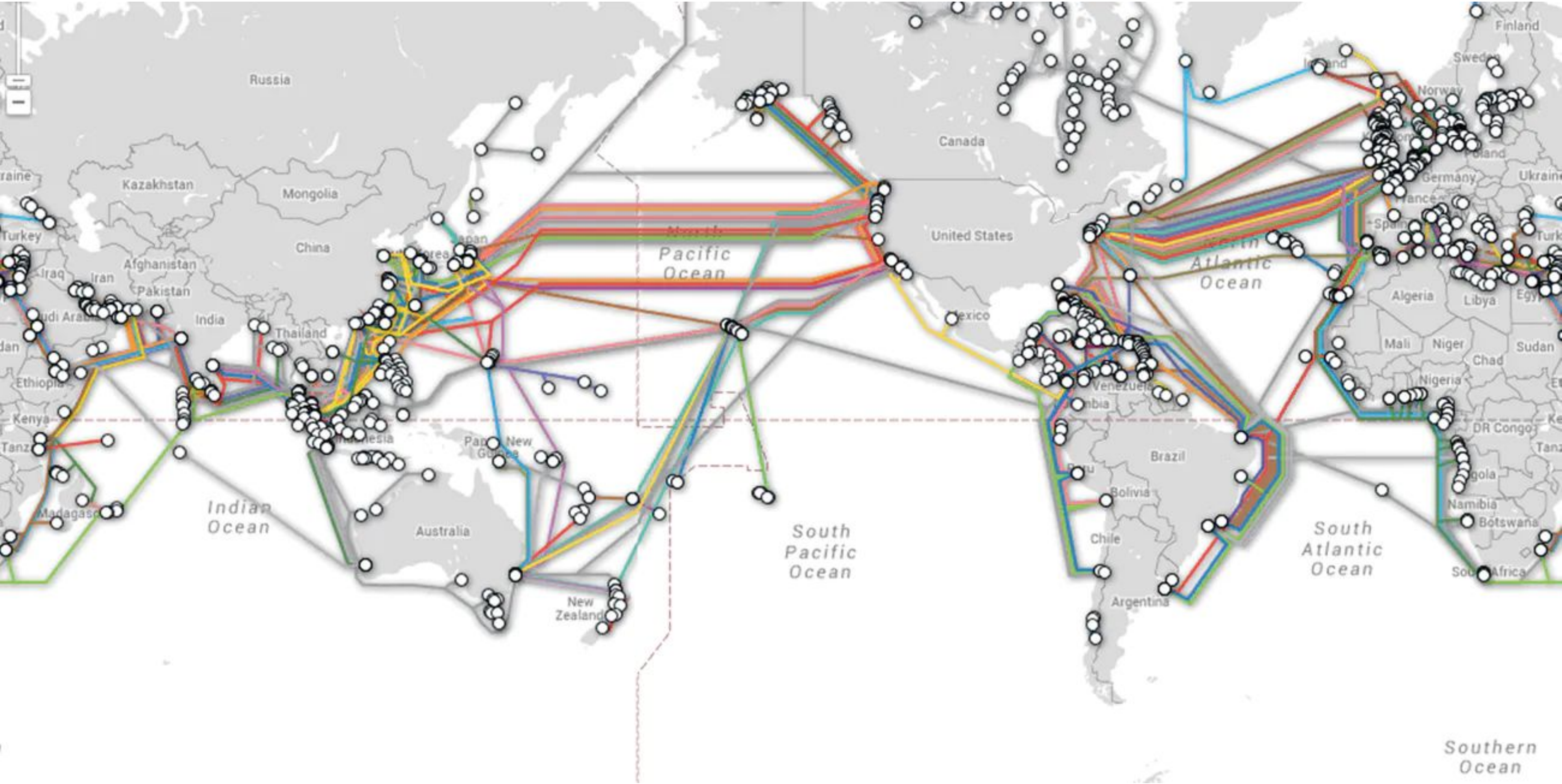
“The internet is not easily accessible in many areas of the world, like the Earth’s oceans. Fishermen, sailors, and others have limited data connection with the rest of the world. Although satellite internet is widely available, it is very expensive for a user to implement. Your challenge is to design a low-cost method of delivering internet to people located far away on the ocean.”

Why FIN?

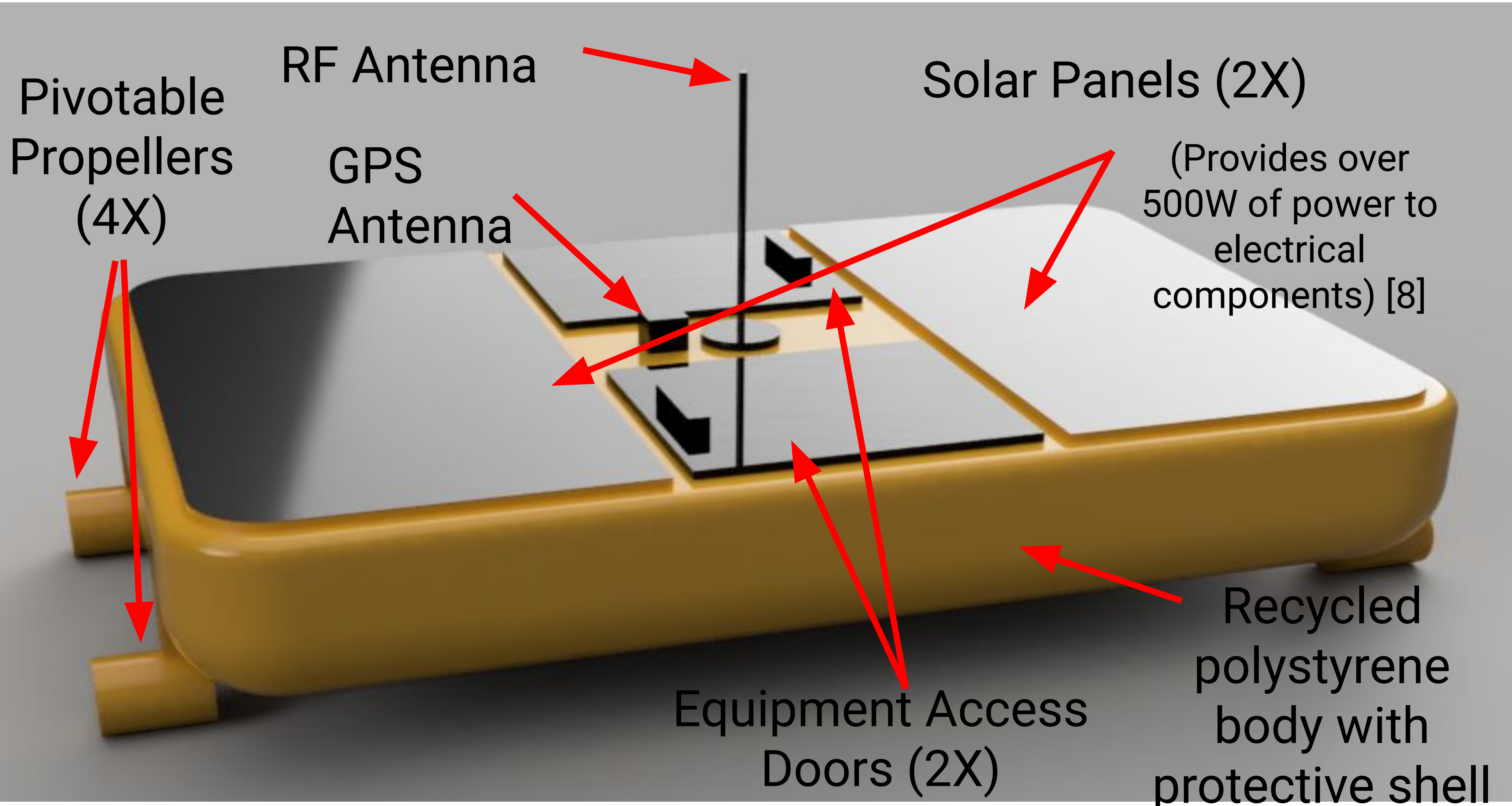
- Significantly cheaper
- More dependable connection, no cloud interference
- Reduces amount of space clutter
- Emergency distress communication available
- Sensors on the FIN monitor ocean health

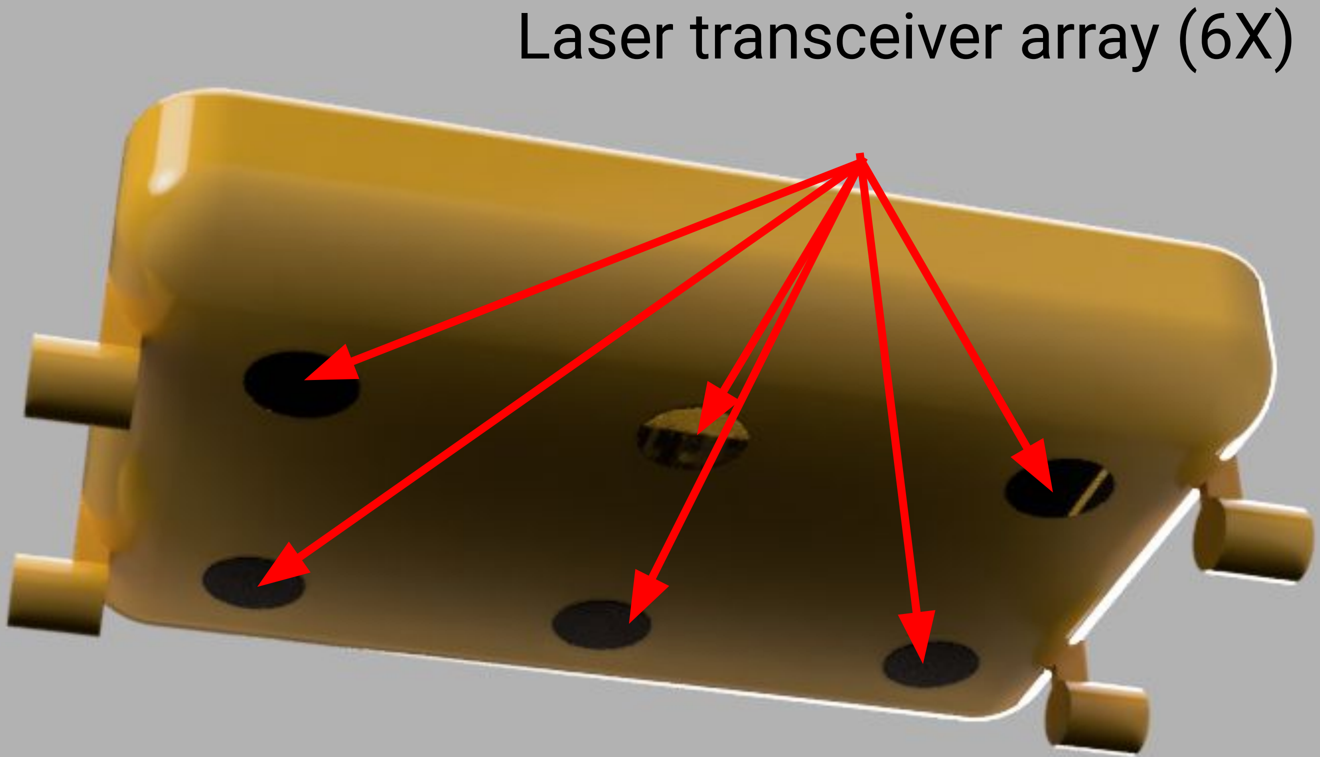


- Lay new undersea fiber cable with laser transceivers at the location of optical repeaters, every 100 km
- Build Floating InterNet (FIN) Modules which translate laser data into a radio signals for internet
- Users access internet through off the shelf radio modems



Russia
Kazakhstan
Mongolia
China
Afghanistan
Iran
Iraq
Pakistan
India
Thailand
Turkey
Ethiopia
Kenya
Indian
Ocean
Australia
New
Zealand
Pacific
Ocean
South
Pacific
Ocean
Canada
United States
Venezuela
Brazil
Bolivia
Chile
Argentina
Atlantic
Ocean
South
Atlantic
Ocean
Finland
Sweden
Norway
Poland
Germany
Ukraine
Algeria
Libya
Mali
Niger
Chad
Sudan
Nigeria
DR Congo
Namibia
Botswana
Southern
Ocean


RF Antenna
Pivotable Propellers (4X)
GPS Antenna
Solar Panels (2X)
(Provides over 500W of power to electrical components) [8]
Recycled polystyrene body with protective shell
Equipment Access Doors (2X)



According to Archimedes principle, a volume of 3m x 2m x 3cm is buoyant enough to support 500 lb force.

FIN Module - Electrical Components

- 12V 50Ah lithium battery (1X)
- 1x2m 300W 24V solar panel (2X)
- RF Antenna (1X)
- Laser Transceivers (6X)
- GPS module (1X)
- Processor (1X)
- Pivotable Propellers (4X)
- Environmental sensors (1X)

FIN Module - Transceivers

- Above water, signal sent by Radio Waves
  - Frequency near 400 MHz, in ITU band allocated for land/mobile communication
  - Transmitting power of 500W for 55 km radius
- Below water, signal sent by blue laser
  - Wavelength near 400 nm at absorption minimum
  - Lower latency and higher capacity
- Possibly use sonar instead of blue laser
  - Technology more proven
  - Higher latency and lower capacity

Latency Calculation compared to Satellite

- Laser signal through ocean depth:
  d = 3339 km (Average depth of Atlantic Ocean) [10]
  v = $2*10^8$ m/s [9]
  latency = $1.5*10^{-5}$s
- Sonar Signal through ocean depth
  d = 3339 km
  v = 1500 m/s [3]
  latency = 2.23s
- Roundtrip electromagnetic signal to satellite
  d = $1.57*10^6$ m [4]
  v = $3*10^8$ m/s
  latency = 0.0052s
- Roundtrip electromagnetic signal to geosynchronous satellite
  d = $7.2*10^7$ m [4]
  v = $3*10^8$
  latency = 0.24s

$$\boxed{Latency = distance/velocity}$$

Capacity Calculations

Use of blue lasers for undersea communication is discussed in the literature. However, the best experimental results show data rates of 11.5 Gbps over only 10m [10].

Blue light has very low absorption in sea water $\boldsymbol{\alpha}_{abs}$=0.01 1/m [12]
Scattering coeff. is small compared to absorption coeff. $\boldsymbol{\alpha}_{scatter} \lesssim \boldsymbol{\alpha}_{abs}$=0.01 1/m [11]
Overall, this is a loss of 20dB/km

Shannon Hartley Theorem

$$C = B \log_2 \left(1 + \frac{S}{N}\right)$$

Assuming a bandwidth of 10MBps and S/N=10,
approximate capacity is 35MBps

Cost Considerations

- The world needs more bandwidth and we can expand with it
- FIN coverage is only within 55 km of undersea fiber lines, but most boats and planes are also there
- 28M Cruise ship passengers per day willing to pay $5/day to $.75/minute [16]
- Cost to lay new undersea cable $300M [14]
- FIN maintenance costs are $1.1M/year (Assuming 55 units, one per 100km to cross the Atlantic ocean, we replace ⅕ of the units each year, and each FIN module costs $100K.)

Comparison Summary

	Satellite	FIN	Ref	Best?	Comment
Latency in seconds	0.2	$1.5*10^{-5}$		FIN	Compared to geosynchronous sat.
Installation Cost	$60B	$300M	[1]	FIN	Compared to Starlink
Repair Cost/Yr	$12B	$1.1M	[1]	FIN	Compared to Starlink
Coverage	All earth	Within 50km of fiber	[18]	Satellite	Most boats and lanes are along fiber routes
Realtime water, envir., boat, and plane	😊	😊		FIN	FIN includes water monitoring sensors
Capacity in Mbits/s	506Mbps	35Mbps	[17]	Satellite	
Radio Astronomers	😟	😊	[2]	FIN	

References

[1] https://www.businessinsider.com/spacex-starlink-internet-satellites-starship-rocket-launch-costs-morgan-stanley-2019-10

[2] https://spacenews.com/little-legal-recourse-for-astronomers-concerned-about-starlink/

[3] Here's how we calculate sonar time… According to https://www.worldatlas.com/aatlas/infopage/oceans/atlanticocean.htm, the average depth of Atlantic Ocean is 3339m. According to https://www.asu.edu/courses/art345/pike_b/terrainmapping/sonar.htm, Sonar under water can travel at 1500m/s. Using these values, we calculated it takes 2.26 seconds for the sonar signal to travel 3339m.

[4] Here's how we calculate electromagnetic signal time to satellite ...Geosynchronous orbit is 3.6*10^7m above earth https://science.howstuffworks.com/satellite7.htm. Multiply this distance by 2 for round trip and divide by the speed of light to get 0.24 seconds.

[5] Wireless communication breaks through water-air barrier http://news.mit.edu/2018/wireless-communication-through-water-air-0822

[6] Ref using blue lasers for undersea communication https://www.nature.com/articles/srep40480

[7] https://manoa.hawaii.edu/kaunana/u-n-task-force-says-new-ocean-telecom-cables-should-be-green/

[8] Solar panel area for given power from https://www.homedepot.com/p/Renogy-300-Watt-24-Volt-Monocrystalline-Solar-Panel-for-Residential-Commercial-Rooftop-Back-Up-System-Off-Grid-Application-RNG-300D/307983596?mtc=Shopping-B-F_D27E-G-D27E-27_31_CONTROL-Generic-NA-Feed-PLA-NA-NA-CONTROL_Nondoorbells&cm_mmc=Shopping-B-F_D27E-G-D27E-27_31_CONTROL-Generic-NA-Feed-PLA-NA-NA-CONTROL_Nondoorbells-71700000052998923-58700005105045162-92700048675636141&gclid=EAIaIQobChMI8PS3idGo5QIVjpOzCh1hnwwwEAkYCSABEgJ20fD_BwE&gclsrc=aw.ds

[9] https://www.rpi.edu/dept/phys/Dept2/APPhys1/optics/optics/node4.html

[10 Average depth of Atlantic Ocean from https://www.worldatlas.com/aatlas/infopage/oceans/atlanticocean.htm

[11] Nature article on data com using blue laser under water https://www.nature.com/articles/srep40480

12] Info on absorption coefficient light in water http://www1.lsbu.ac.uk/water/water_vibrational_spectrum.html

[13] Info on scattering coefficient light in sea water, page 17
https://repository.lib.ncsu.edu/bitstream/handle/1840.16/1696/etd.pdf?sequence\u003d1\u0026isAllowed\u003dy

[14] Cost of laying a new underground fiber line
https://www.computerworld.com/article/2939316/googles-60tbps-pacific-cable-welcomed-in-japan.html

[15]Cost of Over Ocean satellite system with speed expected
https://www.reviews.org/internet-service/satellite-internet-for-boats/

[16] Price cruise passengers are willing to pay for internet https://www.cruisecritic.com/articles.cfm?ID=1419

[17] https://en.wikipedia.org/wiki/Satellite_Internet_access

[18] https://www.groundcontrol.com/Iridium_Extreme_PTT_Coverage_Map.htm

Questions?