# U.S. COAST GUARD ACADEMY
# TEAM "GUARDIAN ANGEL"

# *Satellite-Based Rescue 21*

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## Search and Rescue

The USCG's foremost mission is Search and Rescue (SAR). The purpose of SAR is to minimize the loss of life, injury, and property damage by rendering aid in the maritime domain.

Fig. 1 Active SAR case

## System Overview

A mariner makes a distress call on VHF channel 16, a satellite listens and records the raw data, and the data is then downlinked to a ground station for processing.

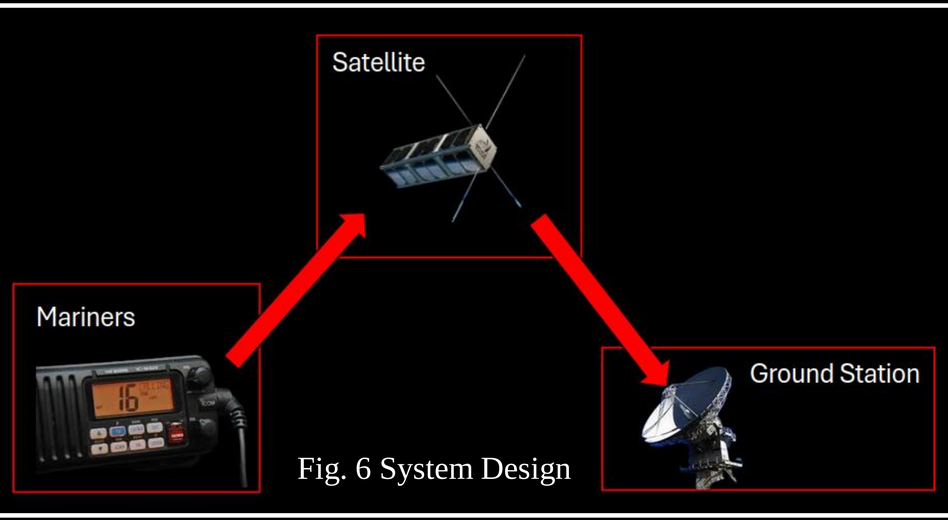


Fig. 6 System Design

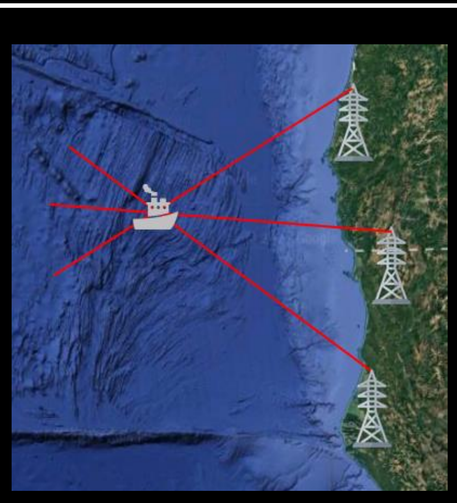

Fig. 2 CONUS Rescue 21

## Rescue 21

The USCG responds to maritime distress calls on VHF channel 16 (156.8 MHz). Rescue 21 is the communications system used to observe, demodulate, and locate these calls. Rescue 21 towers along the coast determine the direction of incoming broadcasts to provide lines of position, multiple of which can yield a fix to aid in SAR.

Fig. 3 Rescue 21 Alaska Tower

## Rescue 21 Alaska

Due to harsh climate and geographic isolation, the Rescue 21 system in Alaska has less towers and was not designed to provide estimated positions of broadcasts. Weather conditions make for outages as well, diminishing availability of the system and the capacity for the USCG to hear distress calls off Alaska's coasts.

## Aboard the Satellite

A Software Defined Radio (SDR) is used to record distress calls. The SDR uses Phase-Locked Loops (PLLs) to record the carrier frequency of broadcasts, or Doppler curves, over time. A *single* PLL can track *one* broadcast but cannot track the multiple that may exist throughout the large footprint visible to the satellite. A bank of *multiple* PLLs in parallel can track *several* broadcasts so long as each broadcast occupies a separate PLL. After a broadcast is recorded, the data is sent down to a ground station to be processed.

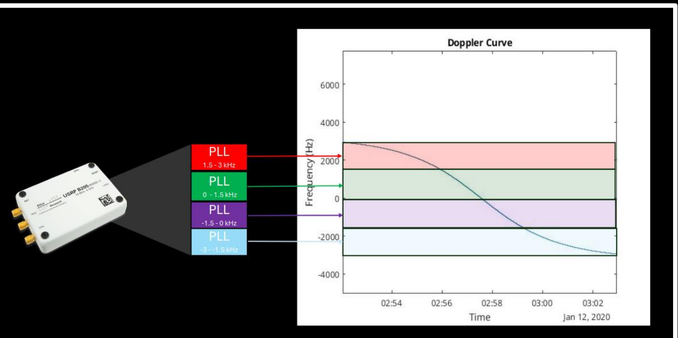


Fig. 7 PLL Bank (simplified to four PLLs)

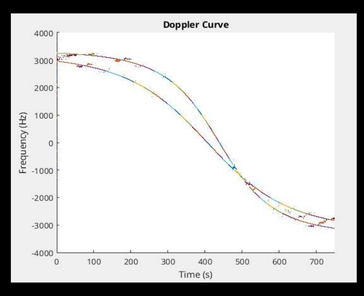


Fig. 8 PLL Bank output to be downlinked

## On the Ground

Once at the ground station, the raw data is separated by broadcast into Doppler curves. Each Doppler curve is then used to estimate the position of each broadcaster. The curves are also used in demodulation to recover broadcast messages separately.

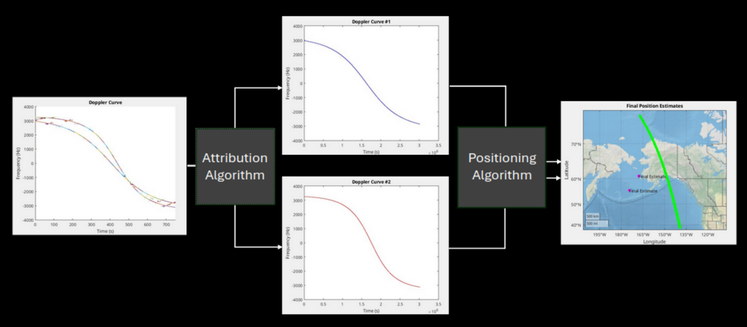


Fig. 9 Ground Station/Post Processing

## Space-Based Augmentation

A constellation of Low Earth Orbit (LEO) satellites could be used to observe and locate distress calls. The purpose of this project is to create a payload for a singular prototype satellite to launch within the year to validate viability of such a constellation.

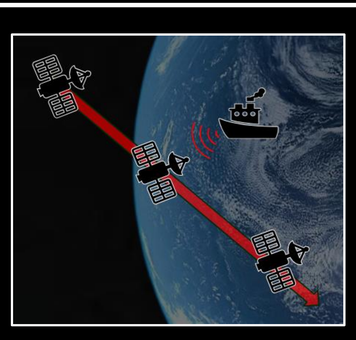

Fig. 4 Satellite observing broadcast

## Tests via Simulation

A separate SDR was programmed to simulate Doppler shifted NBFM broadcasts as they would be received by a satellite. This was configured to represent any number of broadcasts, location(s) on Earth, and satellite orbit. This "pseudotransmitter" was used to test the system without a live satellite.

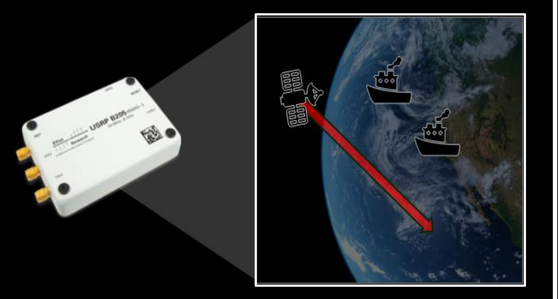

Fig. 10 Pseudotransmitter

## The Doppler Effect

The frequency of a signal will be shifted proportionally to the relative velocity of its transmitter and receiver. If the frequency of a mariner's VHF broadcast can be tracked over time by a satellite, this Doppler curve can be used to find an estimated position of the broadcaster: the relative velocity over time between this satellite and any place on Earth forms a curve unique to the location.

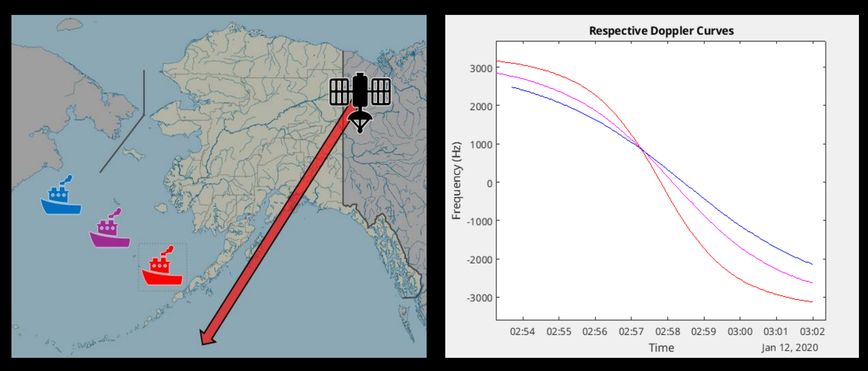


Fig. 5 Doppler curves of respective marine broadcasters

## Results

System successfully estimated position of two concurrent simulated NBFM voice broadcasts within 3.8 km and 8.6 km, respectively. Capable of demodulating single broadcasts with great fidelity and multiple broadcasts with minimal interference, depending on proximity and quantity of broadcasters.

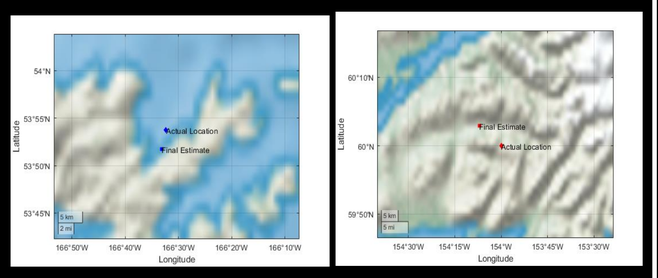


Fig. 11 Estimated positions with error of 3.8 km (left) and 8.6 km (right)

## Conclusions

A LEO constellation has promise in augmenting Rescue 21, surpassing vulnerability in Alaska while providing global coverage: in-orbit field tests with single satellite proof of concept will confirm. Though designed to locate mariners seeking to be found, its function can be extended to locate adversaries jamming critical RF channels in both maritime and terrestrial environments.