

PREPARE FOR TOMORROW. FIND VULNERABILITIES TODAY.
SIMULATION AGAINST JAMMING AND SPOOFING

BEFORE WE BEGIN

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ALAN CAMERON
EDITOR & PUBLISHER
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SPEAKERS



TIM ERBES
TALEN-X



IURIE ILIE
SKYDEL SOLUTIONS



JOHN WEGER
ROCKWELL COLLINS



TIM ERBES
CHIEF TECHNOLOGY OFFICER
TALEN-X



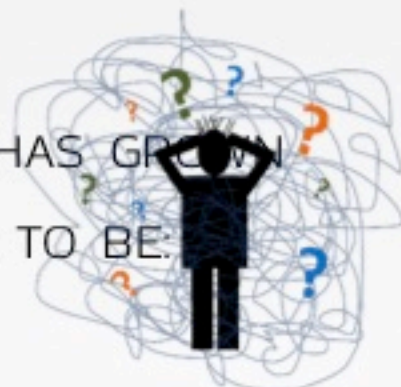
SOFTWARE-DEFINED GNSS SIMULATOR

CONTACT: TERBES@TALEN-X.COM

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GNSS SIMULATORS HAVE STAGNATED

- THE FUNDAMENTAL WAY WE USE SIMULATORS HASN'T CHANGED FOR ~10 YEARS.
 - SIMULATOR COSTS ARE HIGH - \$500,000 FOR A BASIC CONFIGURATION.
 - JAMMING IS NOT INCLUDED, YOU MUST PROVIDE THIS YOURSELF USING OTHER HARDWARE.
 - SCENARIO CREATION IS COMPLICATED AND LIMITED
- BUT THE COMPLEXITY OF THREATS AND TESTING HAS GROWN
- **PARADIGM NEEDS TO CHANGE**, SIMULATORS NEED TO BE:
 - EASY TO USE
 - AFFORDABLE
 - SUPPORT NAVWAR TESTING



SOLUTION - BROADSIM

- **GNSS SIMULATION — 1000 HZ**

- GPS C/A, L2C, P, Y, M-CODE
- GLONASS G1 AND G2
- GALILEO E1, E5A, AND E5B
- BEIDOU B1 AND B2

- **SOFTWARE-DEFINED**

- FLEXIBLE, LOW COST, SCALABLE
- RAPID DEVELOPMENT CYCLES

- **ADVANCED JAMMING**

- BPSK, AWGN, BOC, CW, PULSED, SWEPT
- 50 MHZ BANDWIDTH



POWERED BY  **SKYDEL**

- **SYNCHRONIZATION**

- LIVE SKY TIME SYNCHRONIZATION
- RTK AND MULTI-VEHICLE SIMULATION

- **EXTENSIVE API**

- FULL CONTROL THROUGH C#, C++, OR PYTHON

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KEY FEATURES

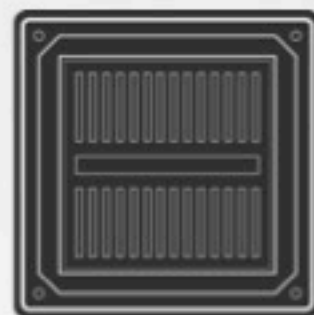
- ADVANCED JAMMING
- EXTENSIVE API
- 6DOF TRAJECTORIES WITH HIGH DYNAMICS
- RECEIVER ANTENNA PATTERN MODELLING
- SATELLITE ANTENNA PATTERN MODELLING
- SPACE BASED MOTIONS
- PSEUDORANGE ERRORS
- DOWNLINK DATA MODIFICATIONS
- MULTI PATH
- ON-THE-FLY SCENARIO RE-CONFIGURATION
- FLEXIBLE LICENSING & IN-FIELD UPGRADABILITY



A **GPS** with
real-time
simulation **WORLD** WEBINAR,
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HOW IT WORKS

- GPU GENERATES THE IQ DATA STREAM
 - 10 TRILLION FLOATING-POINT OPERATIONS PER SECOND (TFLOPS)
- SOFTWARE DEFINED RADIOS CONVERT THE IQ DATA INTO RF
 - USRPS = EXCELLENT RF FRONT END
- RESULT: COST EFFECTIVE REAL-TIME AND FULL-BAND GNSS SIMULATOR

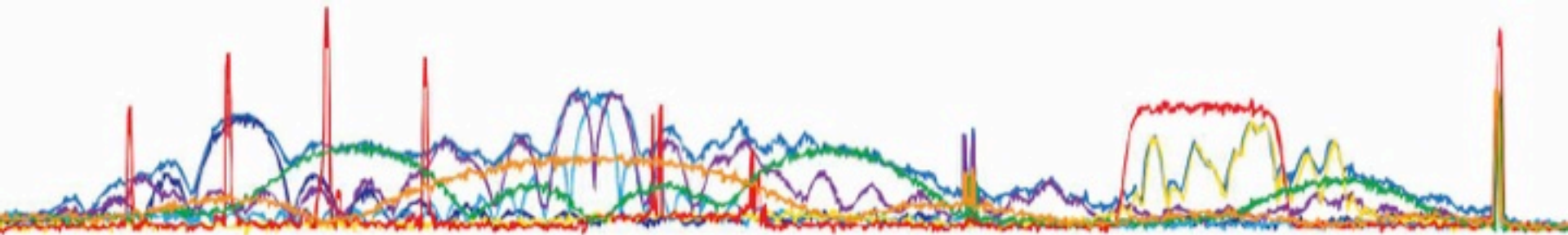


GPU

+

SDR





OLD METHOD OF JAMMING

- REQUIRES A SEPARATE SIGNAL GENERATOR (SG) FOR EACH JAMMER
- JAMMING SIGNALS ARE LIMITED BY THE NUMBER OF SG'S AVAILABLE
- SG'S NEED TO BE INTEGRATED INTO SOFTWARE TO RUN AUTONOMOUSLY
- JAMMING POWER DEFINED AT THE RECEIVERS FRONT END, NOT BASED ON THE JAMMERS TRANSMIT PARAMETERS (I.E. LOCATION, POWER)

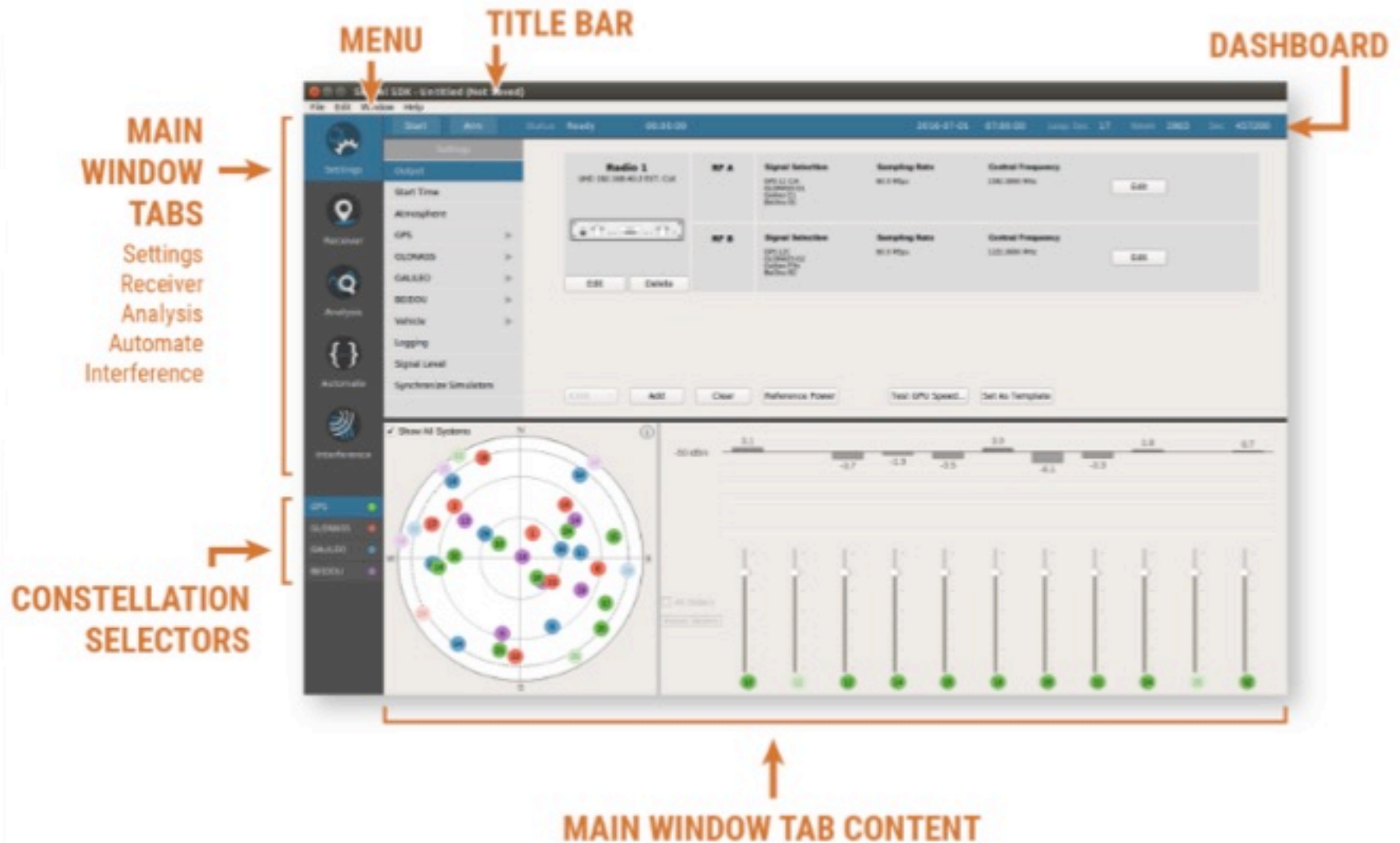


NEW METHOD OF JAMMING (WITH BROADSIM)

- JAMMING SIGNALS GENERATED WITHIN BROADSIM – SOFTWARE UPGRADE ONLY
- UNLIMITED NUMBER OF JAMMING SIGNALS GENERATED ON 1 RF OUTPUT
- EACH JAMMING SIGNAL CAN HAVE DIFFERENT POWER LEVELS, MODULATIONS, AND LOCATIONS
- COMPLETE JAMMING CONTROL THROUGH THE SDX GUI AND/OR API
- OPTION TO SPECIFY THE LOCATION AND POWER OF JAMMING TRANSMITTERS - BROADSIM CALCULATES THE JAMMING POWER AT THE RECEIVER BASED ON THE LOCATION AND JAMMING PARAMETERS
- SELECT VARIOUS PROPAGATION LOSS MODELS
- ABILITY TO MODEL BLUE FORCE ELECTRONIC ATTACK (BFEA)

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EASY TO USE



EXTENSIVE API

Skydel SDX - Untitled (Not Saved)

File Edit Window Help

Start Arm Status Ready 00:00:00 2017-01-19 11:00:00

Time	Command	Status
1	New("DiscardCurrentConfig":true)	Success
2	SetModulationTarget("Address":"192.168.40.2","ClocksExternal":true,"Id":{"d88f2020-e8b0-43f3-9a2d-0ed231dda9b6"},"Path":"","Type":"X300")	Success
3	ChangeModulationTargetSignals("Band":"UpperL","Id":{"d88f2020-e8b0-43f3-9a2d-0ed231dda9b6"},"MaxRate":6e+07,"MinRate":12500000,"Output":0,"Signal":"L1CA")	Success
4	ChangeModulationTargetSignals("Band":"UpperL","Id":{"d88f2020-e8b0-43f3-9a2d-0ed231dda9b6"},"MaxRate":6e+07,"MinRate":12500000,"Output":1,"Signal":"","")	Success
5	SetGpsTime("Start":{"Day":19,"Hour":13,"Minute":0,"Month":1,"Second":0,"Spec":"/UTC","Year":2017})	Success
6	SetModificationToGpsNavMessage("BitsMod":"66.111110","Condition":"EQUAL138.1.0x1","Id":{"8104fc5b-8032-48ad-b703-ecd88886ad"},"MsgTypeID":10,"Prio":20,"StartTime":900,"StopTime":3000)	Success
7	MessageSequenceSwap("Index":3,"Index":2,"Signal":"L2C")	Success
8	EnableLogRaw("Enabled":true)	
9	SetLogRawRate("Rate":100)	
10	SetVehicleTrajectory("Type":"Circular")	
11	SetVehicleTrajectoryCircular("Alt":0,"Clockwise":false,"Lat":0.78539816339745,"Lon":1.2740903539556635,"Radius":50,"Speed":3,"Type":"Circular")	

Settings Receiver Analysis Automate Interference



```
import skydelsdx
from skydelsdx.commands import SetModulationTarget
from skydelsdx.commands import New
from skydelsdx.commands import SetGpsTime
from skydelsdx.commands import SetGpsSatelliteDataHealth
from skydelsdx.commands import SetModificationToGpsNavMessage
from skydelsdx.commands import ChangeModulationTargetSignals

sim = skydelsdx.RemoteSimulator(True)
sim.connect()

sim.call(New(True))
sim.call(SetModulationTarget("X300", "", "1"))
sim.call(ChangeModulationTargetSignals(0, 1, "L1CA"))
sim.call(ChangeModulationTargetSignals(1, 1, ""))
sim.call(SetGpsTime(datetime(2016, 7, 5, 9, 0, 0)))
sim.call(SetModificationToGpsNavigationMessage("66.111110", "EQUAL138.1.0x1", {"8104fc5b-8032-48ad-b703-ecd88886ad"}, 10, 20, 900, 3000))
sim.call(SetGpsSatelliteDataHealth(10, 1))

sim.disconnect()
```

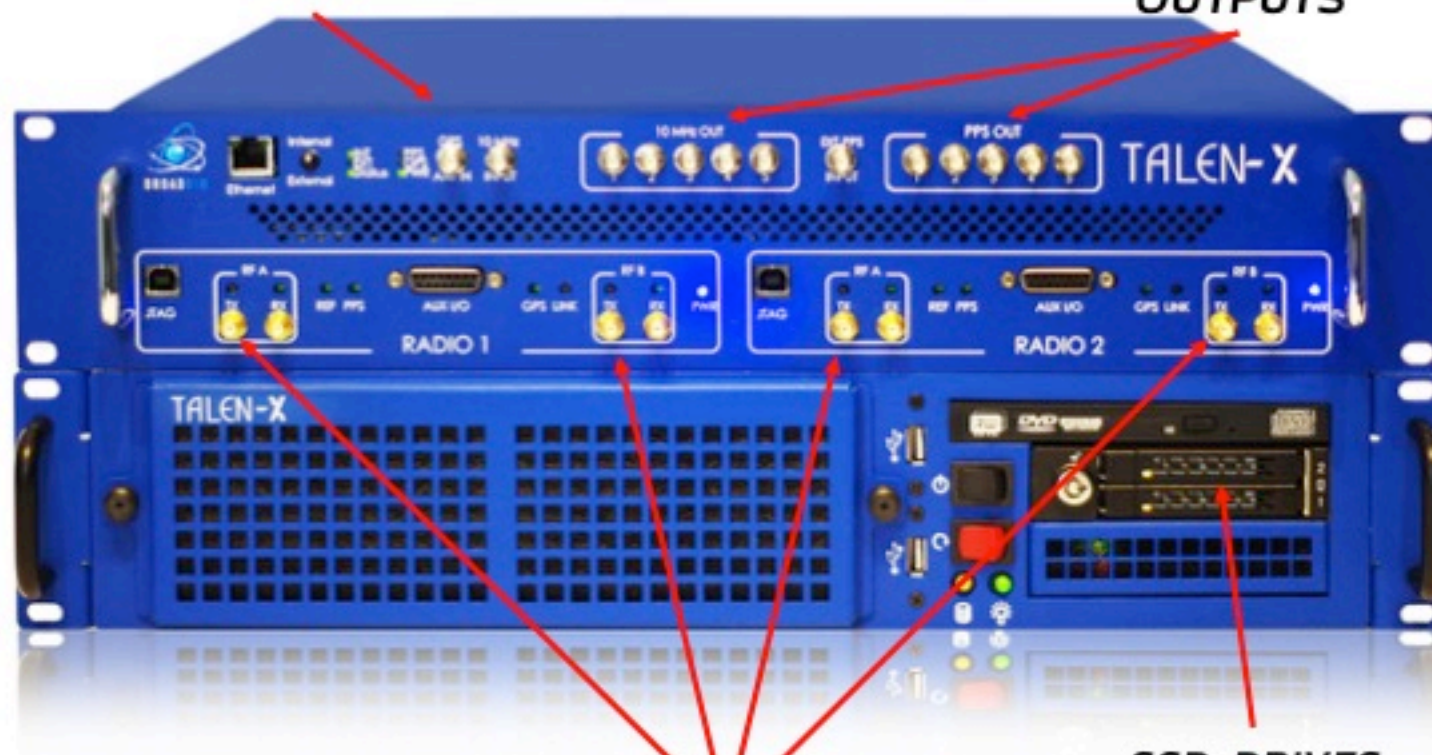
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BROADSIM HARDWARE

GPS INPUT FOR TIME
SYNCHRONIZATION

(4) 10 MHZ AND PPS
OUTPUTS

4U
TALL

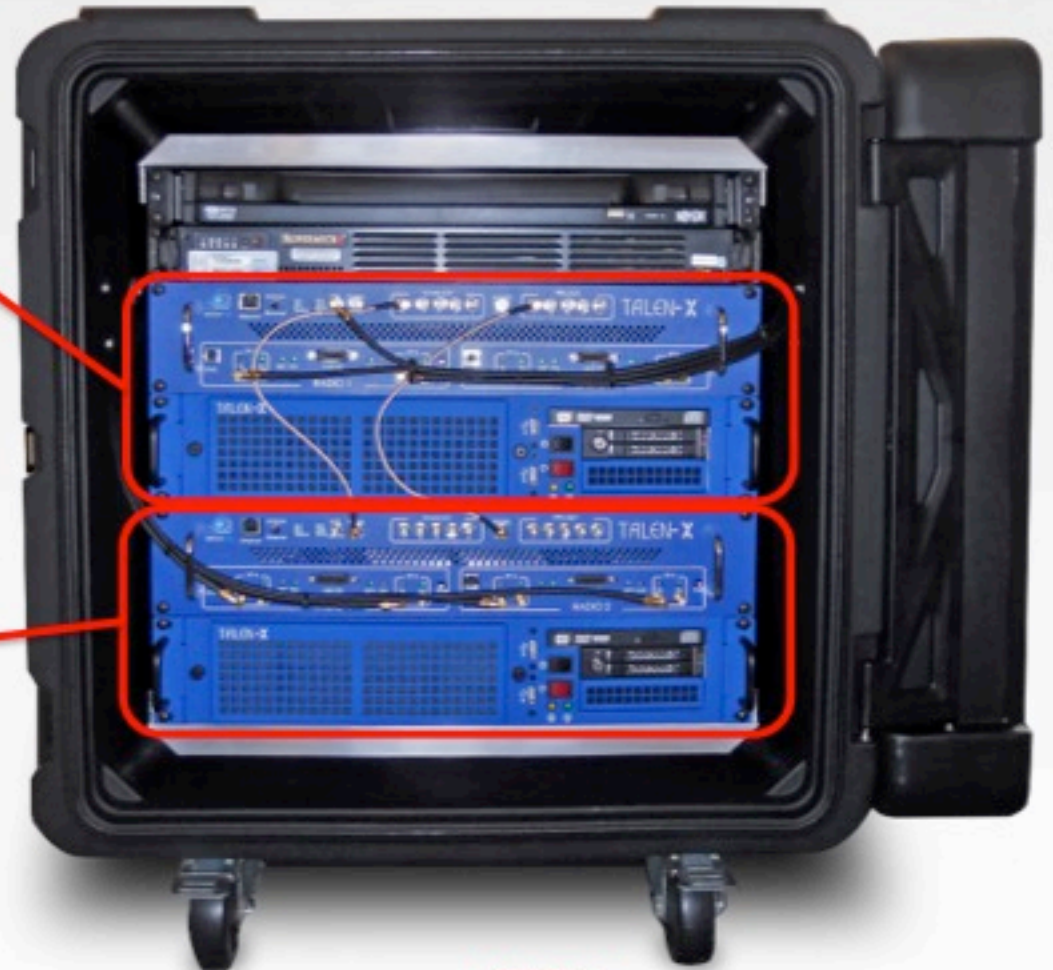


4 RF OUTPUTS

SSD DRIVES
CD/DVD BAY
I7 PROCESSOR

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SYNCHRONIZE MULTIPLE SYSTEMS



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IURIE ILIE

CHIEF TECHNICAL OFFICER AND CO-FOUNDER SKYDEL SOLUTIONS

GNSS JAMMING: TEST FOR COMPLEX ENVIRONMENT

IURIE ILIE
SKYDEL SOLUTIONS

INTRODUCTION

- **GNSS JAMMING IS A REAL THREAT**
 - JAMMING IS A CHEAPEST WAY TO DISRUPT A GNSS RECEPTION
 - GNSS SIGNALS FROM THE LIVE SKY ARE WEAK AND EASY TO JAM
 - COTS JAMMING DEVICES ARE ILLEGAL TO USE, BUT CAN BE LEGALLY BOUGHT ON THE MARKET
 - COMPLEX MULTIBAND JAMMERS CAN BE BUILD USING SOFTWARE-DEFINED RADIOS (SDR)
 - LOW COST SDR ARE READILY AVAILABLE, AND CAN BE COMBINED WITH OPEN-SOURCE SOFTWARE
- **THERE IS NEED FOR NEW TEST SOLUTIONS TO STRESS THE GNSS RECEIVERS FOR COMPLEX JAMMING ENVIRONMENT**

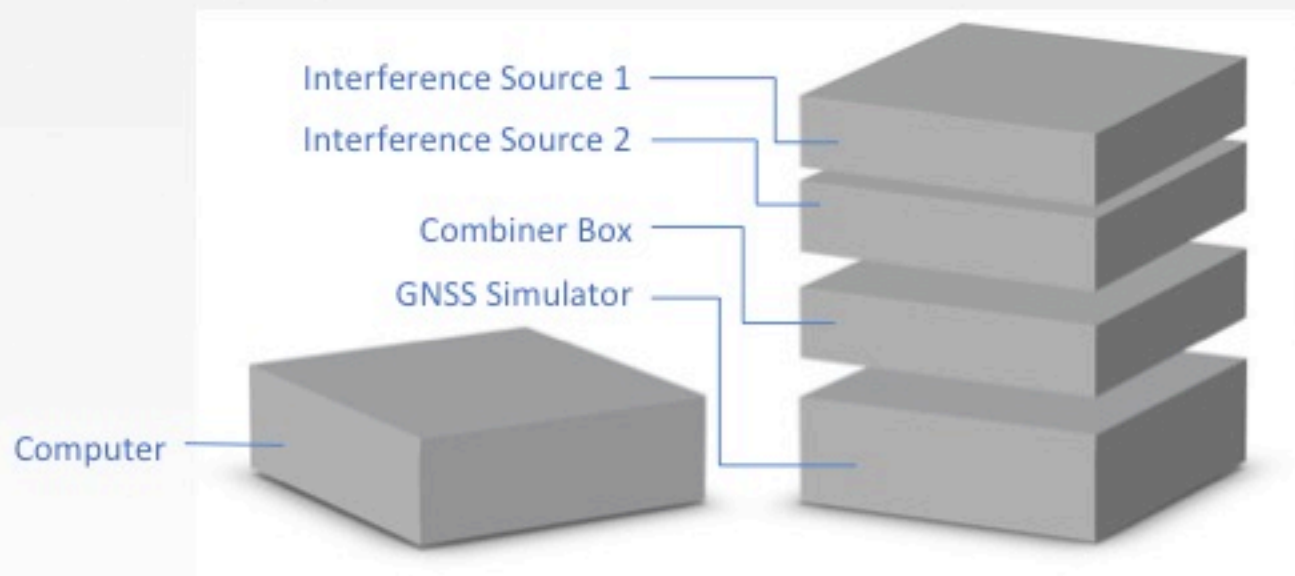
EXAMPLES OF SDRS & JAMMERS AVAILABLE TO THE PUBLIC



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CONVENTIONAL WAY OF TESTING

- THE CURRENT APPROACH TO TESTING INTERFERENCE IS USING AN EXTERNAL SIGNAL GENERATOR FOR EACH INTERFERENCE SOURCE.
- LIMITED NUMBER OF INTERFERENCE SOURCES
- USE A LOT OF RACK SPACE
- EXPENSIVE
- COMPLICATED



THE BETTER WAY

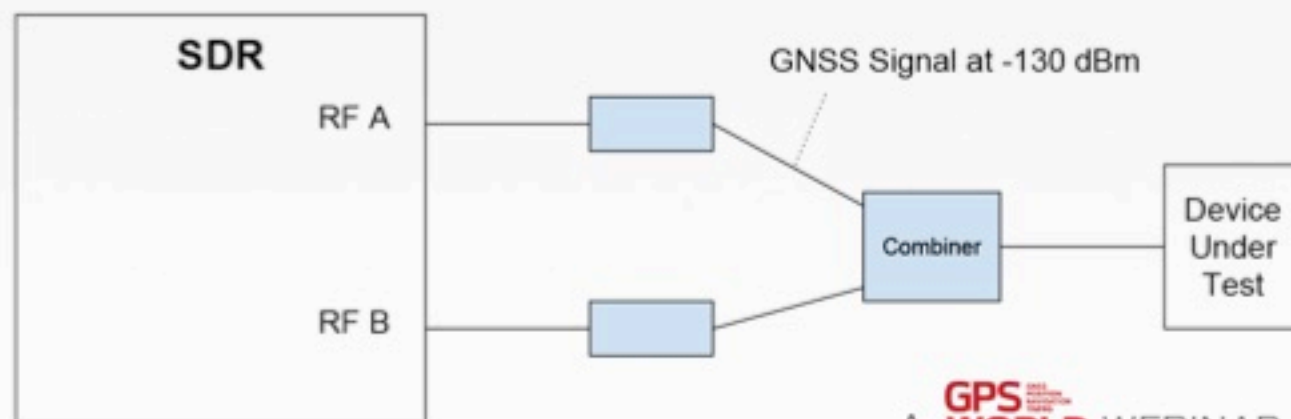
- SOFTWARE-DEFINED SIMULATOR USES THE COMBINATION OF BOTH GPU-ACCELERATED COMPUTING AND THE FLEXIBILITY OF SDR TO CREATE A COMPLETE INTERFERENCE TESTING PLATFORM.
- INTEGRATED
- EASY TO USE
- REUSE SAME HW
- **CUSTOM WAVEFORM**
- **100S OF JAMMERS**



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SOFTWARE-DEFINED RADIO FLEXIBILITY

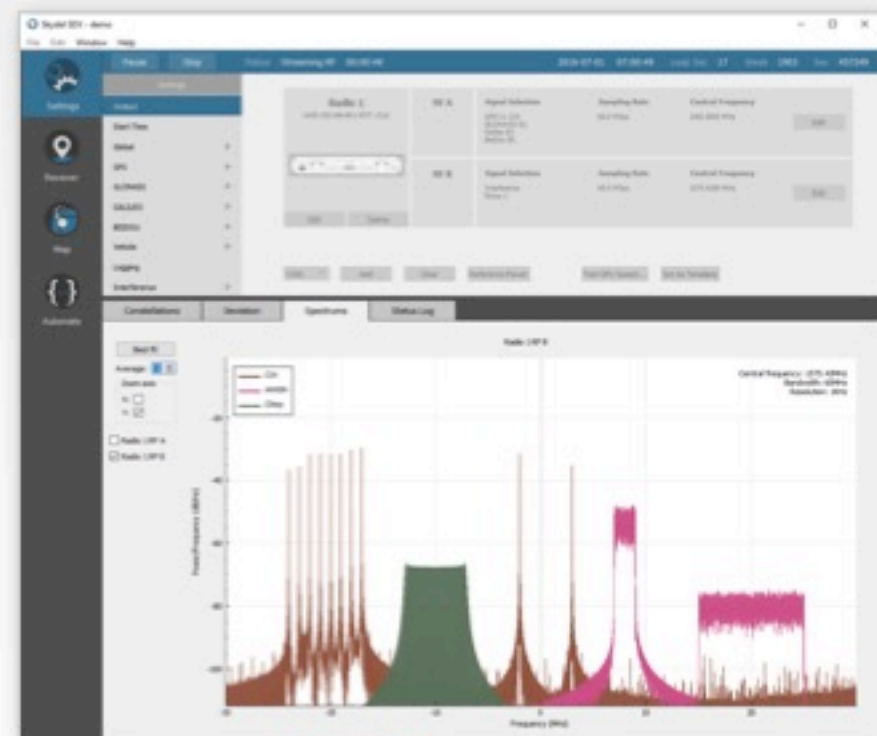
- SDR CAN BE USED TO GENERATE GNSS AS WELL AS INTERFERENCE
- NO NEED TO ADD DEDICATED OR EXPENSIVE HARDWARE JUST FOR JAMMERS
- INTERFERENCE MODULATION IS DONE IN GPU (JUST LIKE GNSS SIGNALS) WHICH ALLOWS TO SIMULATE A VAST NUMBER AND TYPE OF JAMMERS SIMULTANEOUSLY



DESIGN COMPLEX INTERFERENCE WAVEFORM

EACH TRANSMITTER CAN OUTPUT A COMPLEX WAVEFORM MADE OF MULTIPLE SIMPLER WAVEFORMS

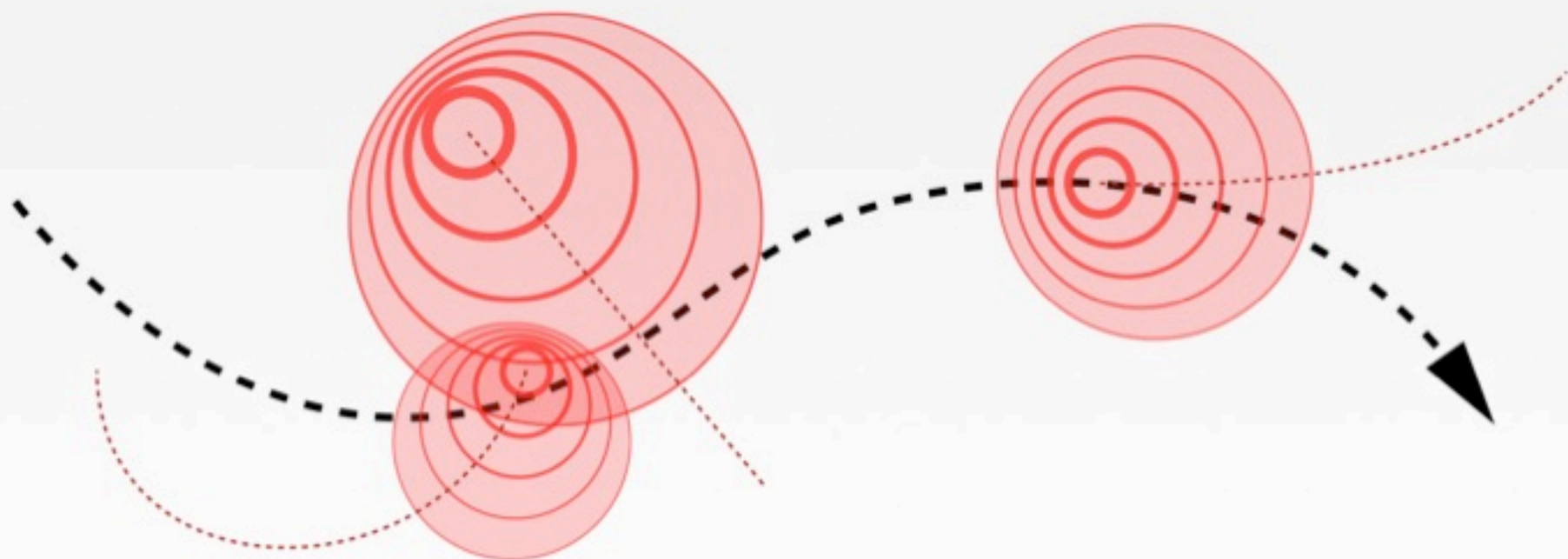
- CW
- CHIRP
- PULSE
- BPSK
- BOC
- AWGN
- CUSTOMER-DEFINED



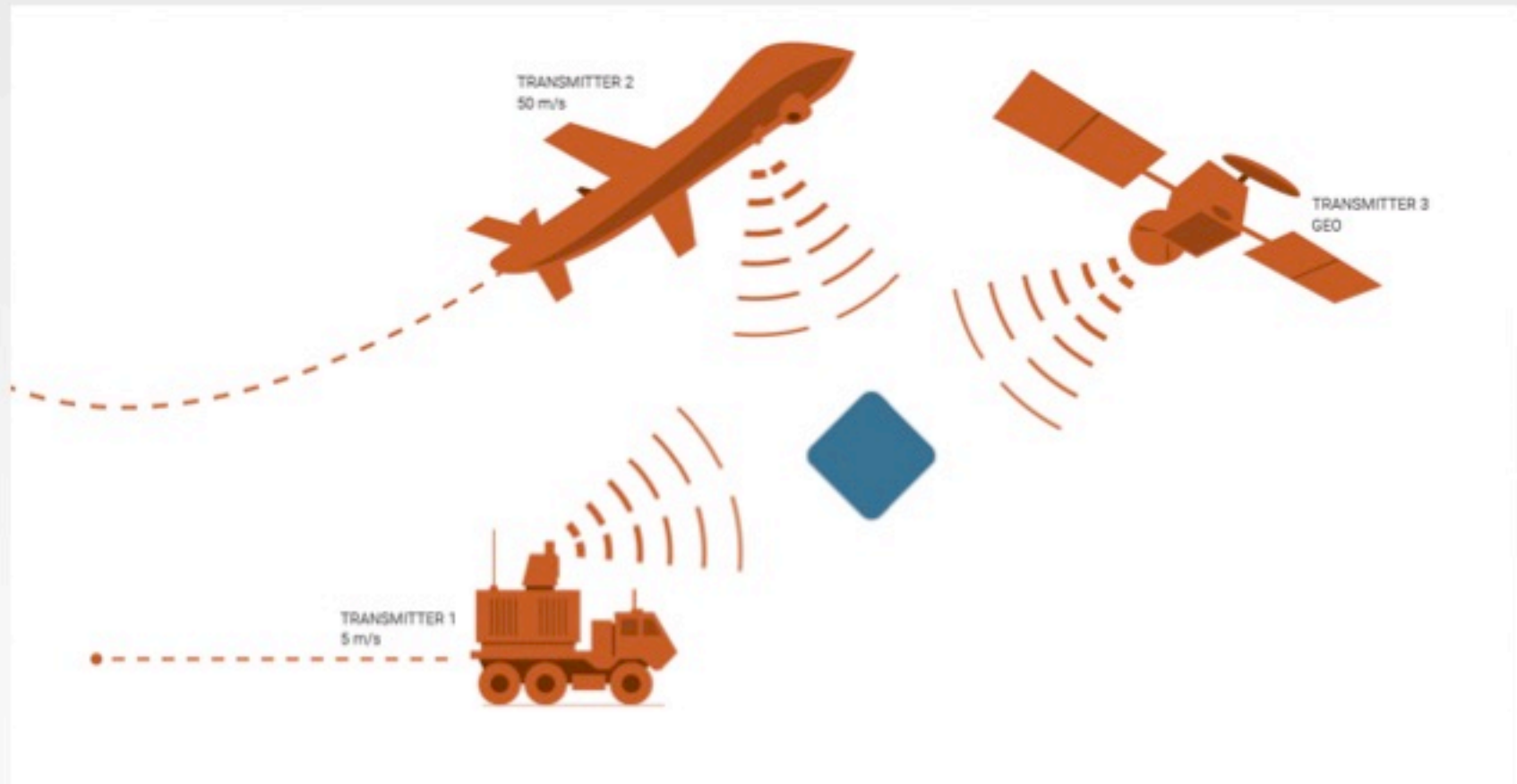
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DYNAMIC SCENARIO EXAMPLE

- A RECEIVER MOVING IN AN ENVIRONMENT WITH MULTIPLE INTERFERENCE SOURCES. EACH SOURCE CAN MOVE & TRANSMIT DIFFERENT WAVEFORMS WITH DIFFERENT POWER LEVEL.



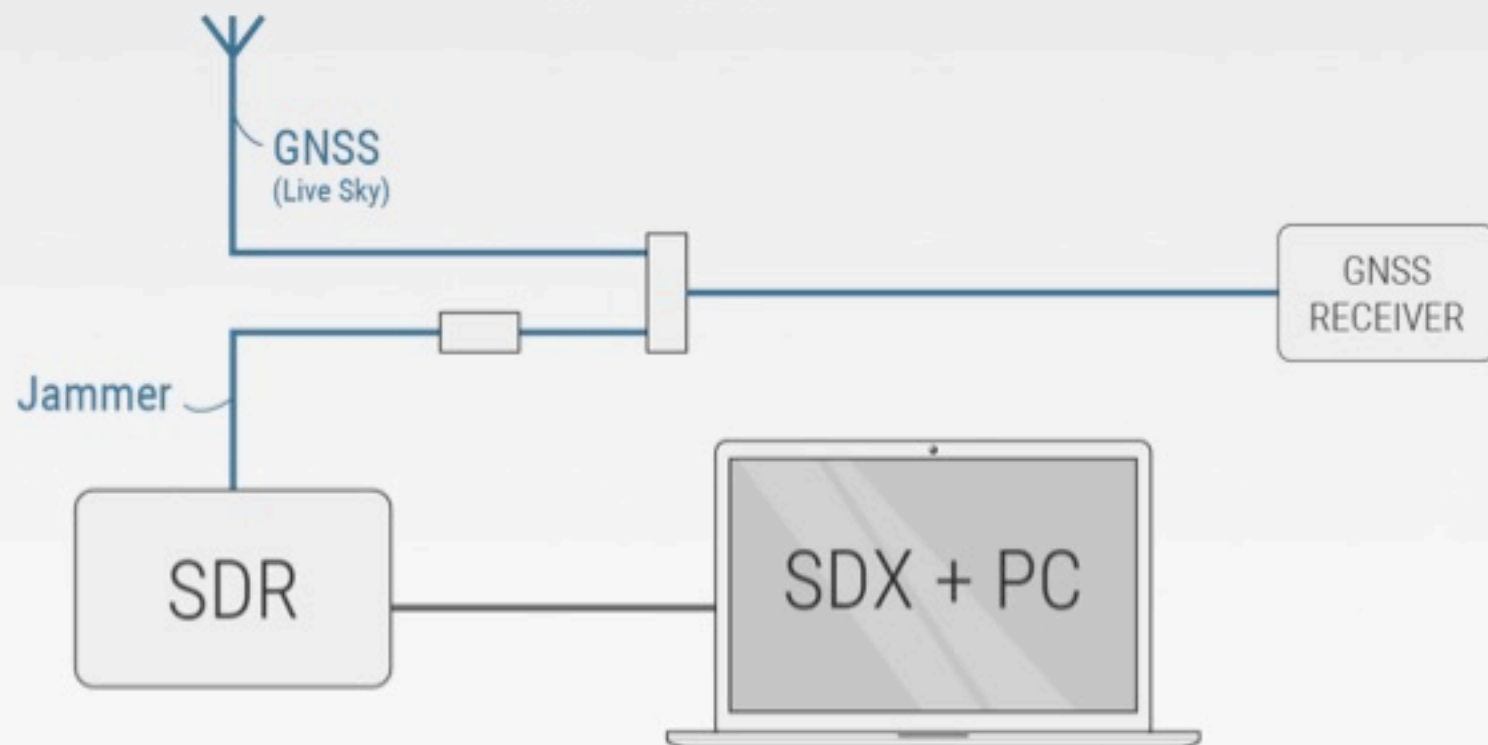
DYNAMIC SCENARIO EXAMPLE



SOURCE CAN BE AN AIRCRAFT, A SATELLITE OR A GROUND BASED TRANSMITTER. EACH TRANSMITTER FOLLOW ITS OWN TRAJECTORY. TRAJECTORIES CAN BE PREDEFINED OR DYNAMICALLY CONTROLLED.

EXAMPLE SETUP

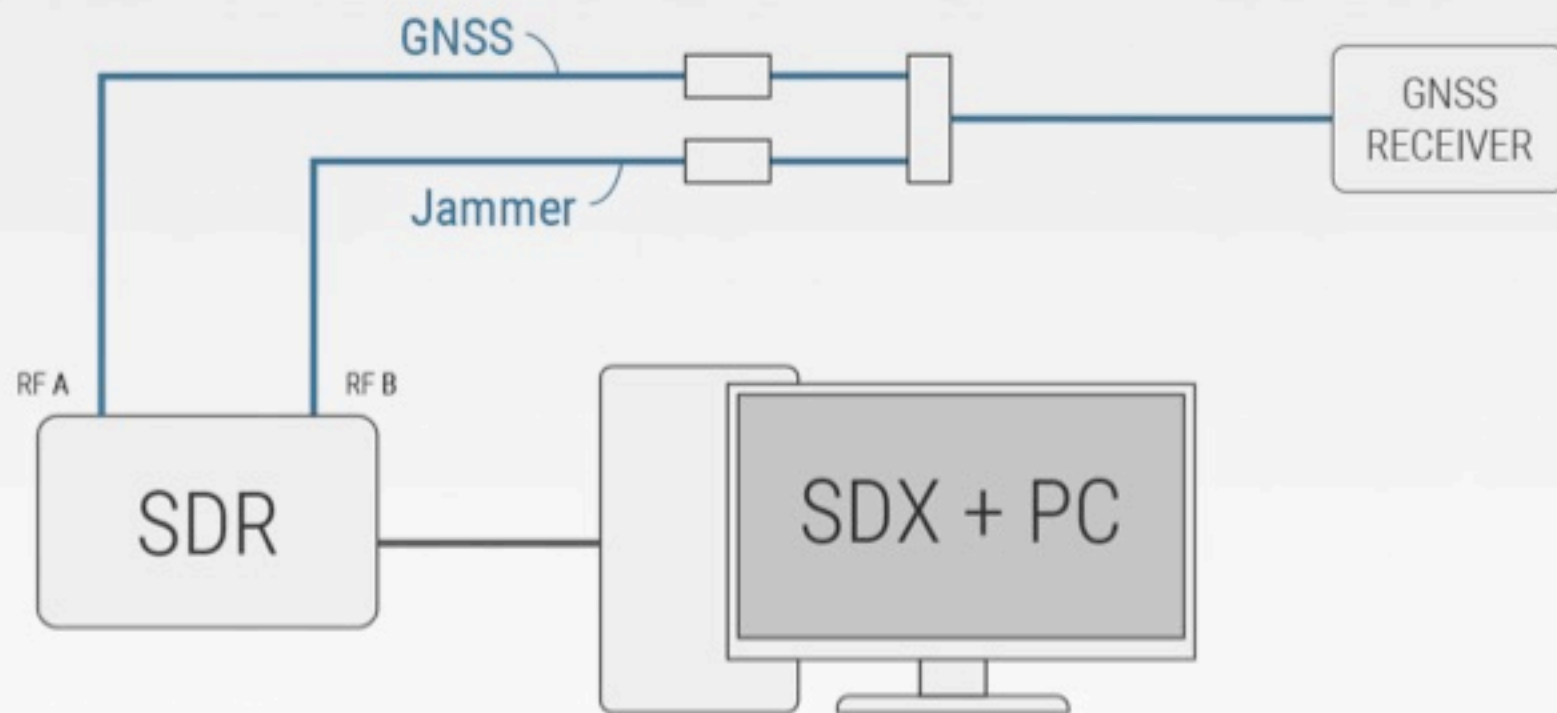
JAMMER + GNSS LIVE



- ✓ COST EFFICIENT SETUP
- ✓ TEST ROBUSTNESS WITH REAL SIGNALS IN CONTROLLED ENVIRONMENT
- ✓ HARDWARE REUSE

EXAMPLE SETUP

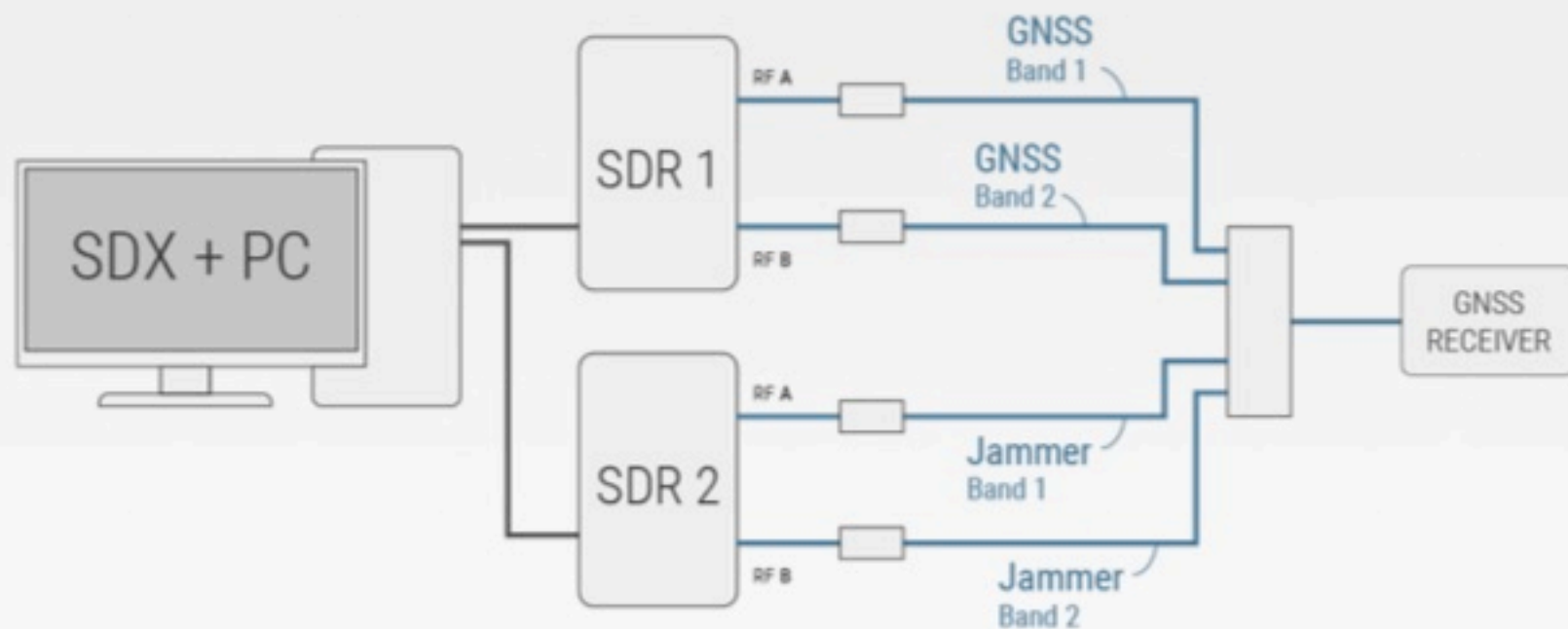
JAMMER + MULTI-CONSTELLATION



- ✓ GNSS AND JAMMERS ON THE SAME RADIO
- ✓ UP TO 120 DB OF J/S RATIO
- ✓ MULTI-CONSTELLATIONS

EXAMPLE SETUP

MULTI-BAND JAMMING



- ✓ SCALABLE TO COVER UPPER AND LOWER GNSS BAND
- ✓ UP TO 100MHZ OF BANDWIDTH FOR JAMMING SIGNALS
- ✓ EXTEND TO MULTIPLE RADIOS

CONCLUSION

TESTING JAMMING – BEFORE & AFTER

THE CURRENT WAY

- NEED TO ATTACH A SIGNAL GENERATOR (H/W) PER INTERFERENCE
- NUMBER OF INTERFERENCE SOURCES LIMITED BY # OF SIGNAL GENERATORS
- SIGNAL GENERATORS REQUIRE INTEGRATION OR OPERATION IN REAL TIME
- POWER LEVELS ARE STATIC; SIGNAL LEVEL IS SET ONCE AND TRANSMITTED AT RECEIVER FRONT-END, W/O SIMULATION CONTEXT.

NEW APPROACH USING SKYDEL SDX

- UNLIMITED NUMBER OF INTERFERENCE SIGNALS AND MULTIBANDS WITH A SINGLE SDR
- SAME SDR CAN BE A GNSS SIMULATOR OR JAMMERS SIMULATOR
- GRANULAR CONTROL OVER EACH INTERFERENCE POWER, MODULATION, AND DYNAMICS
- JAMMING CAN BE TURNED AT WILL, ON-THE-FLY, WITH THE GUI OR API
- POWER LEVEL IS CALCULATED BASED ON DYNAMICS OF THE INTERFERENCE (LOCATION, SPEED, DISTANCE): FULL INTEGRATION WITH GNSS SIMULATION.



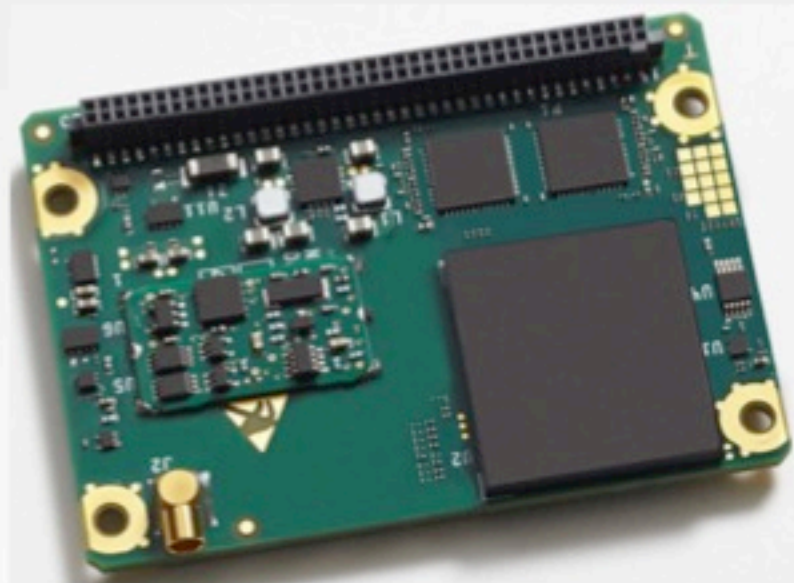
TIM ERBES
CHIEF TECHNOLOGY OFFICER
TALEN-X

SPOOFING TESTING – WHAT IS THE OBJECTIVE?

QUANTIFY THE PERFORMANCE OF GPS RECEIVERS IN THREAT ENVIRONMENTS.

DOMAINS THAT REQUIRE SPOOFING TESTING:

- RESILIENCY
- ASSURED PNT
- ANTI-SPOOFING



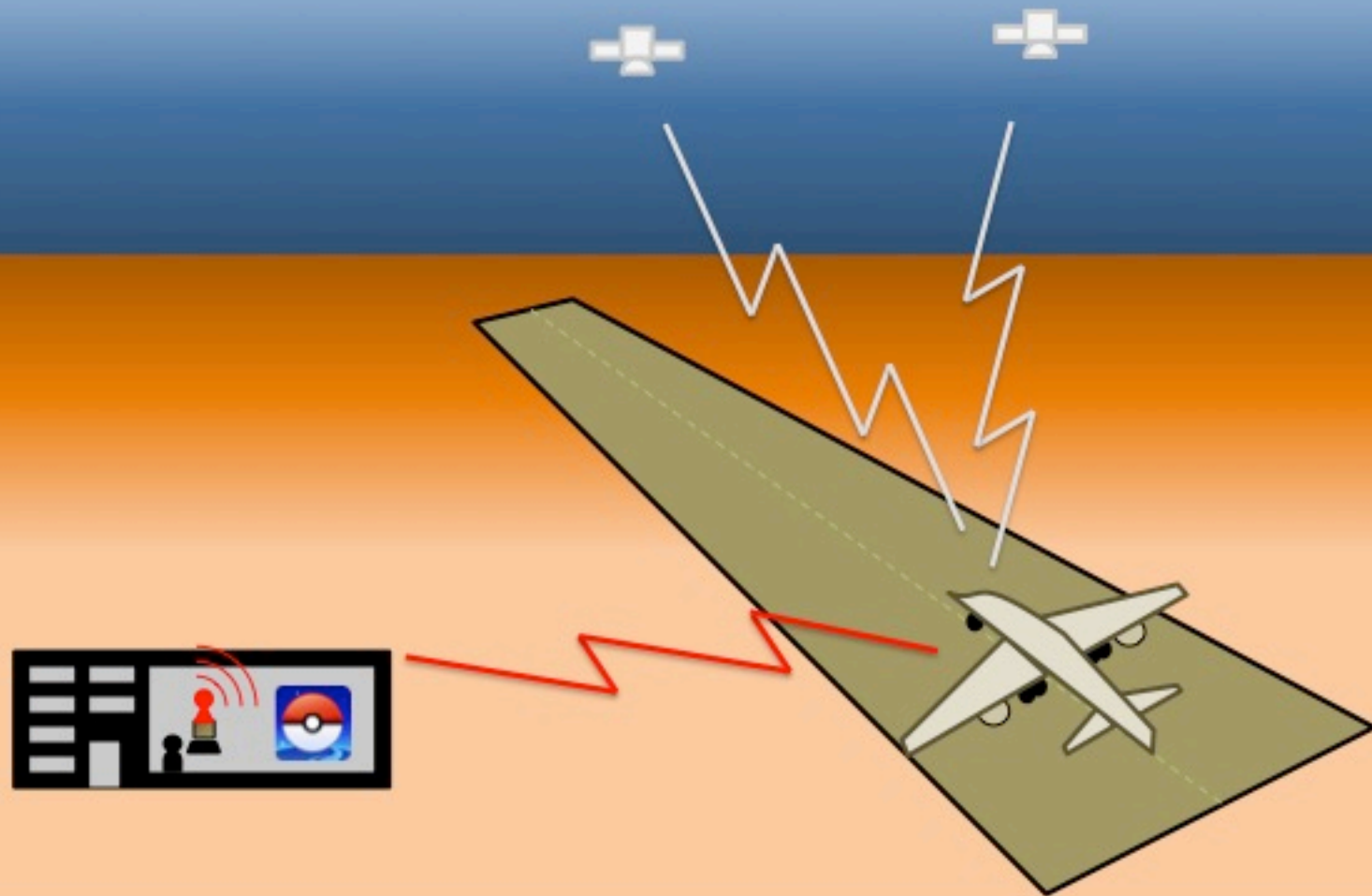
REAL WORLD SCENARIO – CHEATING AT POKÉMON GO



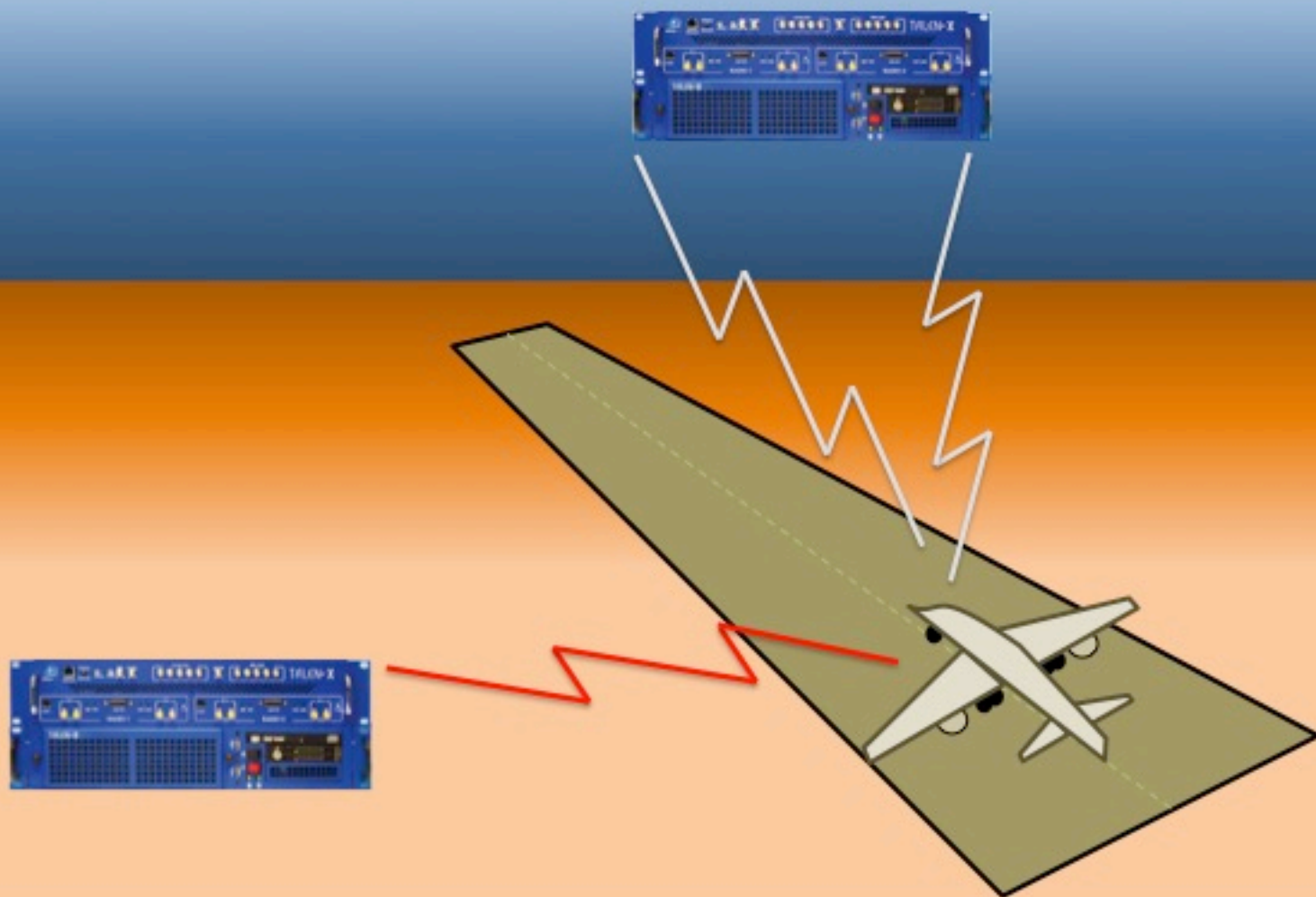
[HTTP://WWW.RTL-SDR.COM/CHEATING-AT-POKEMON-GO-WITH-A-HACKRF-AND-GPS-SPOOFING/](http://www.rtl-sdr.com/cheating-at-pokemon-go-with-a-hackrf-and-gps-spoofing/)

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REAL WORLD SCENARIO – CHEATING AT POKÉMON GO



SIMULATION MIMICS REALITY



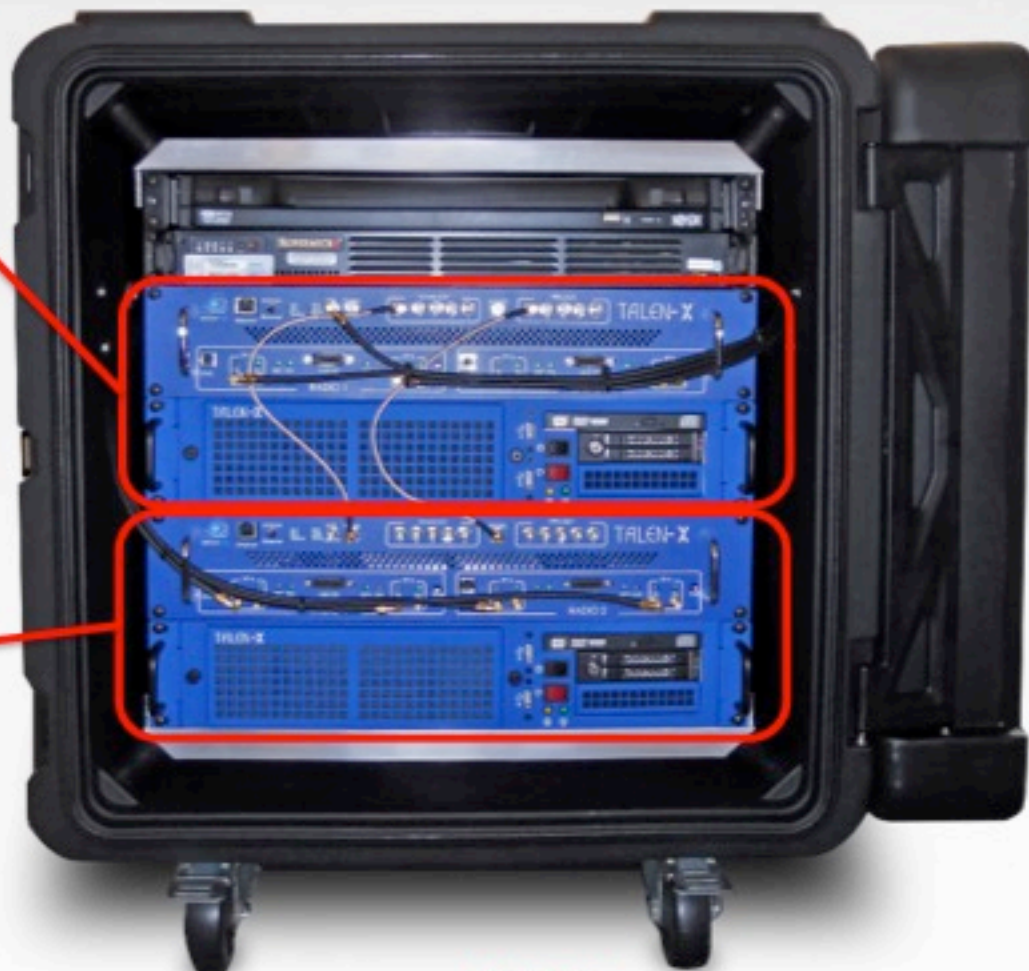
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SIMULATION

TRUTH

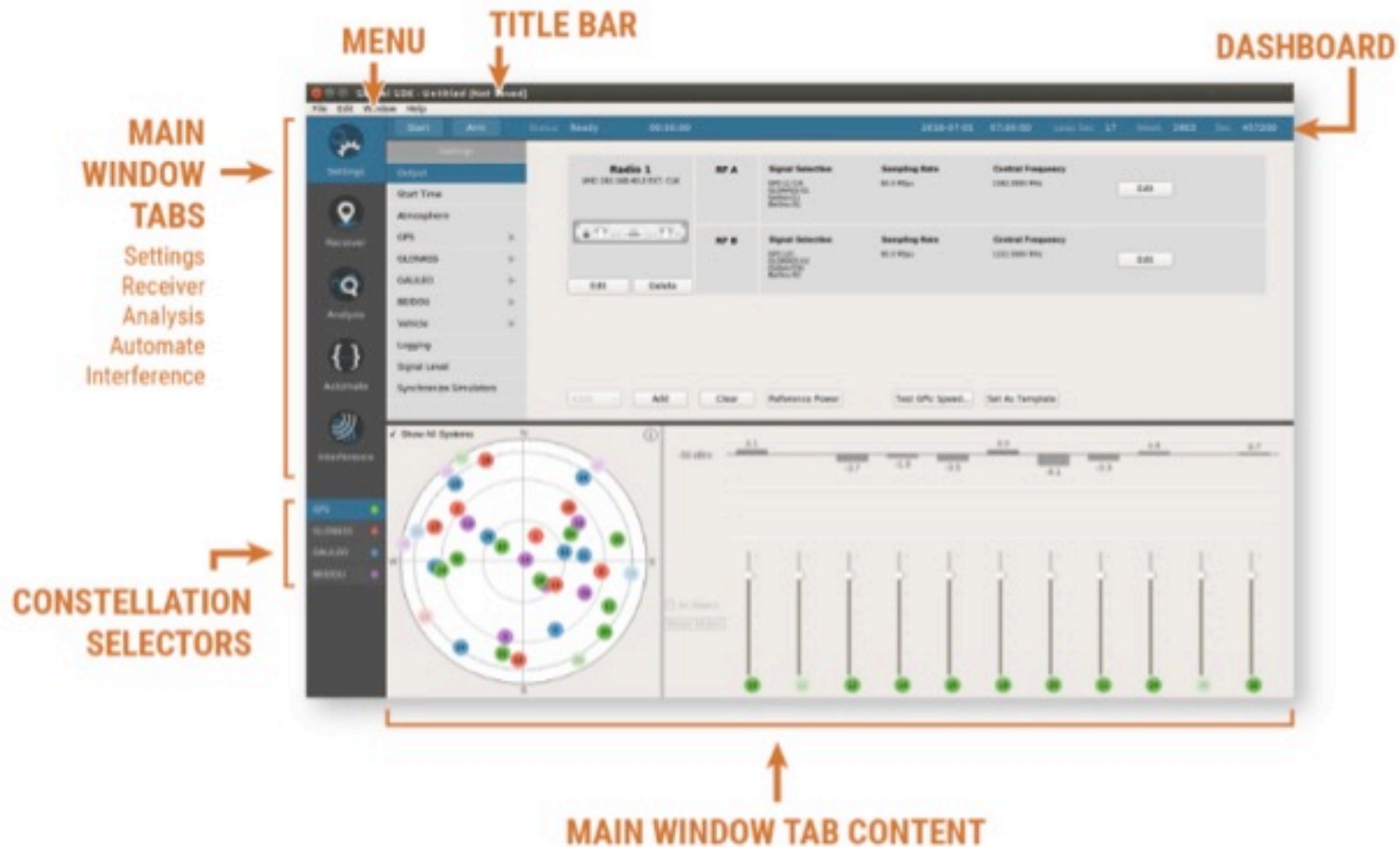


SPOOFER



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WE COULD USE THE GUI



API CAN BE FASTER

skydel SDX - Untitled (Not Saved)

File Edit Window Help

Start Arm Status Ready 00:00:00 2017-01-19 13:00:00

Time	Command	Status
1	New("DiscardCurrentConfig":true)	Success
2	SetModulationTarget("Address":"192.168.40.2","ClocksExternal":true,"M"="(d88f2020-e8b0-43f3-9a2d-0ed231d5a9b4)","Path":"","Type":"X300")	Success
3	ChangeModulationTargetSignals("Band":"","UpperL","M"="(d88f2020-e8b0-43f3-9a2d-0ed231d5a9b4)","MaxRate":6e+07,"MinRate":1250000,"Output":0,"Signal":"/L1CA")	Success
4	ChangeModulationTargetSignals("Band":"","UpperL","M"="(d88f2020-e8b0-43f3-9a2d-0ed231d5a9b4)","MaxRate":6e+07,"MinRate":1250000,"Output":1,"Signal":"/")	Success
5	SetGpsTime("Start":{"Day":19,"Hour":13,"Minute":0,"Month":1,"Second":0,"Spec":"/UTC","Year":2017})	Success
6	SetModificationToGpsCNavMessage("BitsMod":"66-11110","Condition":"EQUAL","M"="(8104f5b-8032-48ad-b703-ecd5ad8886ad)","MsgType":10,"Prn":1)	
7	MessageSequenceSwap("Index":3,"Index":2,"Signal":"/L2C")	
8	EnableLogRaw("Enabled":true)	
9	SetLogRawRate("Rate":100)	
10	SetVehicleTrajectory("Type":"Circular")	
11	SetVehicleTrajectoryCircular("Alt":0,"Clockwise":false,"Lat":0.78539816339745,"Lon":1.2740903539558635,"Radius":50,"Speed":3,"Type":1)	

```
import skydelsdx
from skydelsdx.commands import SetModulationTarget
from skydelsdx.commands import New
from skydelsdx.commands import SetGpsTime
from skydelsdx.commands import SetGpsSatelliteDataHealth
from skydelsdx.commands import SetModificationToGpsNavigationMessageSequenceSwap
from skydelsdx.commands import ChangeModulationTargetSignals
```

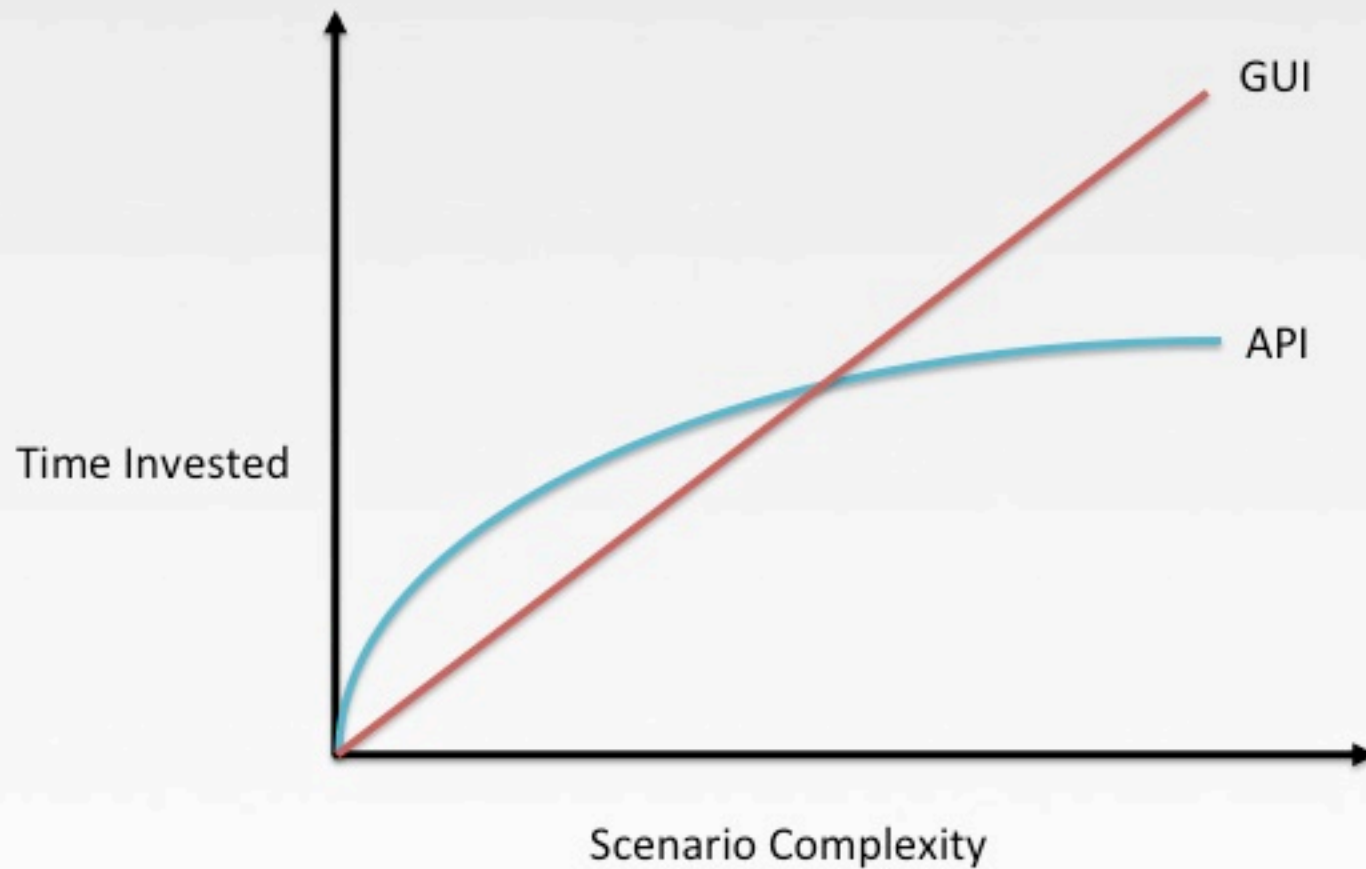
```
sim = skydelsdx.RemoteSimulator(True)
sim.connect()
```

```
sim.call(New(True))
sim.call(SetModulationTarget("X300", "", "1"))
sim.call(ChangeModulationTargetSignals(0, 1, "/L1CA"))
sim.call(ChangeModulationTargetSignals(1, 1, "/"))
sim.call(SetGpsTime(datetime(2016, 7, 5, 9, 0, 0)))
sim.call(SetModificationToGpsNavigationMessageSequenceSwap(3, 2, "/L2C"))
sim.call(SetGpsSatelliteDataHealth(10, 1))

sim.disconnect()
```



GUI VS API



CODE - WHOLE CLASS

```
1  using System;
2  using Sdx;
3  using Sdx.Cmd;
4
5  namespace BroadSimSpoofingExample
6  {
7      class BroadSimInterface
8      {
9
10         public void Run()...
11
12         public void SetupTruth(RemoteSimulator sim, Lla truthLla)...
13
14         public void SetupSpoofers(RemoteSimulator sim, Lla spooferLla)...
15
16         public void SetupJammer(RemoteSimulator sim, Lla spooferLla)...
17
18         private void Connect(RemoteSimulator sim, string host, int instance)...
19
20         private void SetupOutput(RemoteSimulator sim, string radioIpAddress)...
21
22         static double ToRadian(double degree)...
23
24     }
25 }
```


CODE — RUN()

```
public void Run()
{
    Lla truthLla = new Lla(ToRadian(43.8791), ToRadian(-103.4591), 1750);
    Enu offset = new Enu(1000, 0, 0);
    Lla spooferLla = truthLla.AddEnu(offset);

    RemoteSimulator sim1 = new RemoteSimulator();
    RemoteSimulator sim2 = new RemoteSimulator();

    Connect(sim1, "192.168.10.1", 0);
    Connect(sim2, "192.168.10.1", 1);

    SetupOutput(sim1, "192.168.101.2");
    SetupOutput(sim2, "192.168.102.2");

    SetupTruth(sim1, truthLla);
    SetupSpoofer(sim2, spooferLla);
    SetupJammer(sim2, spooferLla);

    Console.WriteLine("Starting");
    sim1.Start();

    Console.WriteLine("Sending Post Commands");
    sim2.Post(new EnableIntTx(true, "Jammer"), 120); // spoofer turns on @ 2 mins
    sim2.Post(new EnableSignal(0, "L1CA", true), 120);
    sim2.Post(new SetIntTxRefPower(-20 /*dbm*/, "Jammer"), 122);
}
```

CODE — HELPER FUNCTIONS

```
private void Connect(RemoteSimulator sim, string host, int instance)
{
    Console.WriteLine("Connecting to BroadSim");
    sim.IsVerbose = false;
    sim.Connect(host, instance);
    sim.Stop();

    Console.WriteLine("Create New Configuration");
    sim.Call(new New(true));
}

private void SetupOutput(RemoteSimulator sim, string radioIpAddress)
{
    Console.WriteLine("Output Settings");
    sim.Call(new SetModulationTarget("X300", "", radioIpAddress, true, "Radio1"));
    sim.Call(new ChangeModulationTargetSignals(0, 50000000, 50000000, "UpperL", "L1CA", "Radio1"));
    sim.Call(new ChangeModulationTargetInterference(, 50000000, 50000000, 1, 1575420000, "Radio1"));
}

static double ToRadian(double degree)
{
    return (Math.PI / 180) * degree;
}
```

CODE – SETUPTRUTH()

```
public void SetupTruth(RemoteSimulator sim, Lla truthLla)
{
    Console.WriteLine("Setting up truth");

    sim.Call(new EnableMasterPps(true));

    sim.Call(new SetGpsTime(new DateTime(2017, /*year*/ 7, /*month*/ 2, /*day*/
        0, /*hour*/ 0, /*min*/ 0 /*sec*/)));

    sim.Call(new ImportRinex("/opt/broadsim/rinex/2017-182.txt"));

    sim.Call(new SetVehicleTrajectoryFix("Fix",
        truthLla.Lat, truthLla.Lon, truthLla.Alt, 0, 0, 0));
}
```

CODE - SETUPSPOOFER

```
public void SetupSpoofers(RemoteSimulator sim, Lla spoofersLla)
{
    Console.WriteLine("Setting up spoofers");

    sim.Call(new EnableSlavePps(true));

    sim.Call(new SetGpsTime(new DateTime(2017, /*year*/ 7, /*month*/ 2, /*day*/
        0, /*hour*/ 0, /*min*/ 2 /*sec*/)));

    sim.Call(new ImportRinex("/opt/broadsim/rinex/2017-182.txt"));

    sim.Call(new SetVehicleTrajectoryFix("Fix",
        spoofersLla.Lat, spoofersLla.Lon, spoofersLla.Alt, 0, 0, 0));

    // spoofers are off at start, signals are 20db stronger than truth
    sim.Call(new SetPowerGlobalOffset(10 /*db*/));
    sim.Call(new SetPowerGpsCaOffset(10 /*db*/));
    sim.Call(new EnableSignal(0, "L1CA", false));

    sim.Call(new SetPseudorangeRamp("GPS",
        0, // prn (0=all)
        1000.0, // offset (meters)
        0, // time of ramp up
        0, // time of ramp up complete
        640800, // time of ramp down
        640800, // time of ramp down complete
        "Geometric Delay"));
}
```

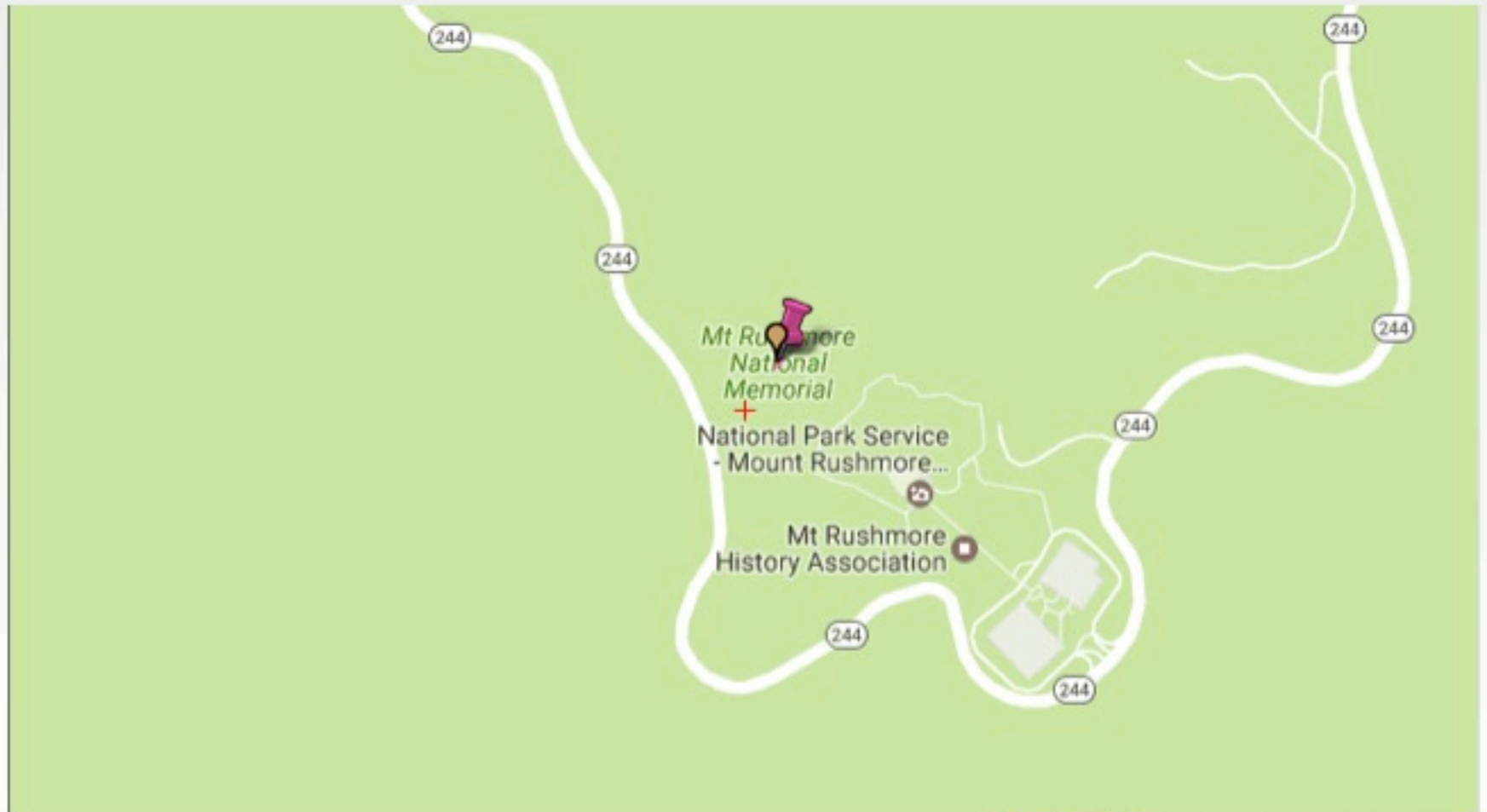

CODE – SETUPJAMMER()

```
public void SetupJammer(RemoteSimulator sim, Lla spooferLla)
{
    Console.WriteLine("Setting up jamming");

    //dynamic jammer for spoofer
    sim.Call(new AddIntTx("Jammer", false, 1, "Jammer"));
    sim.Call(new EnableIntTxDynamicMode(true, "Jammer"));
    sim.Call(new SetIntTxRefPower(0 /*dbm*/, "Jammer"));
    sim.Call(new SetIntTxFix(spoofersLla.Lat, spoofersLla.Lon, spoofersLla.Alt, 0, 0, 0, "Jammer"));
    sim.Call(new SetAWGNTToIntTx(
        true, // enabled
        1575420000, // center freq (hz),
        0, // relative power (db),
        20000000, // bandwidth (hz)
        "Jammer", // jammer name
        "AWGN_2mhz")); // waveform name

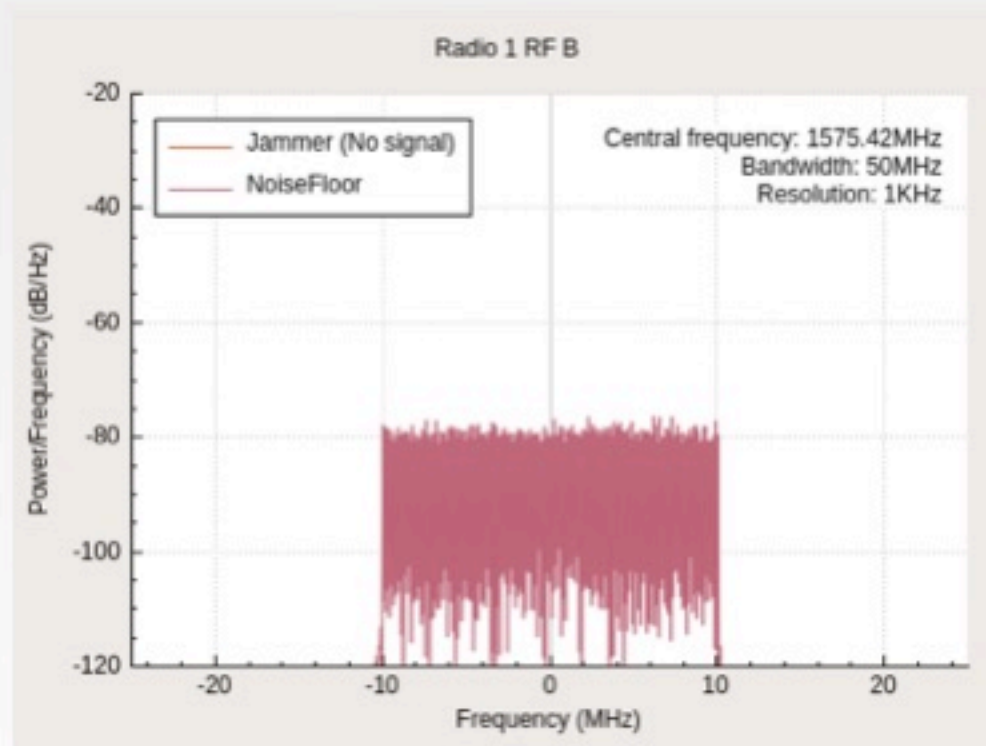
    //simple jammer for noise floor
    sim.Call(new AddIntTx("NoiseFloor", true, 1, "NoiseFloor"));
    sim.Call(new EnableIntTxDynamicMode(false, "NoiseFloor"));
    sim.Call(new SetIntTxRefPower(-50 /*dbm*/, "NoiseFloor"));
    sim.Call(new SetAWGNTToIntTx(
        true, // enabled
        1575420000, // center freq (hz),
        0, // relative power (db),
        20000000, // bandwidth (hz)
        "NoiseFloor", // jammer name
        "AWGN_20mhz")); // waveform name
}
```

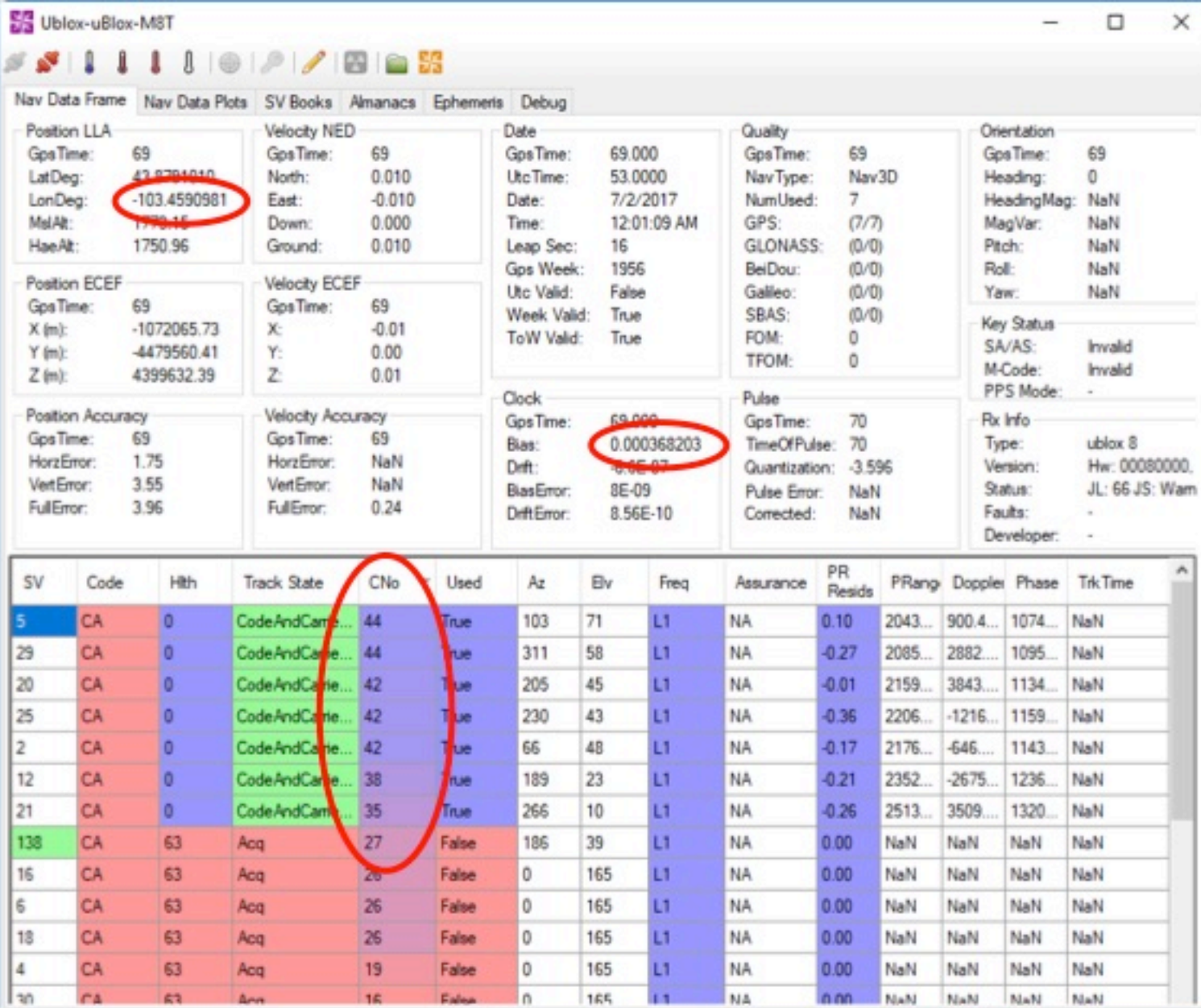

MAP - BEFORE



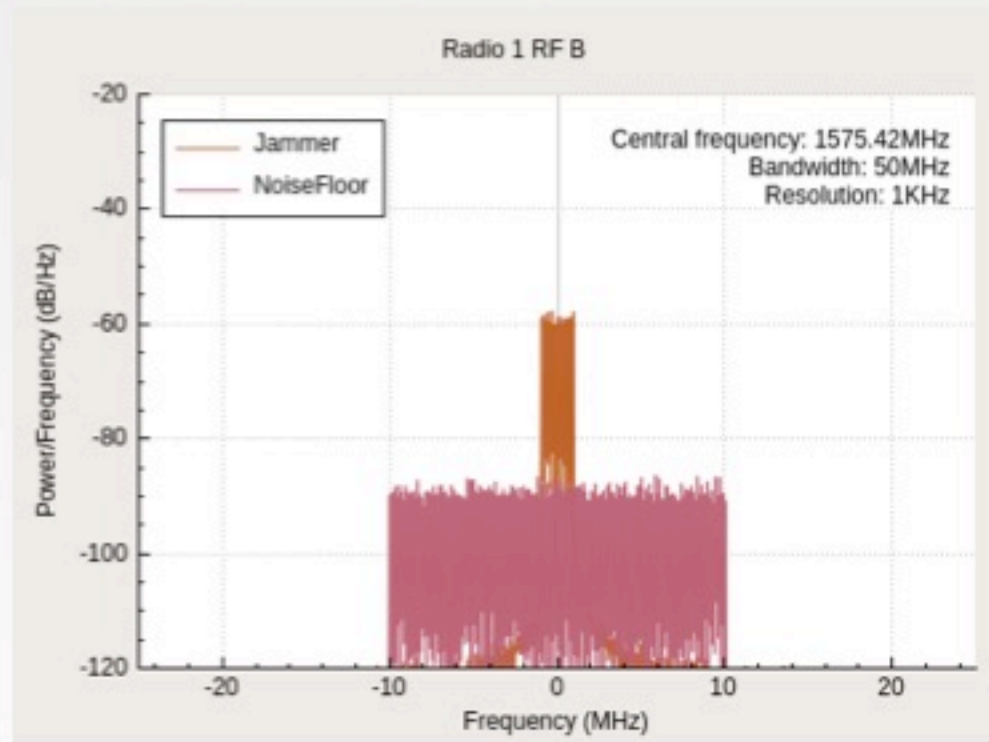
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NOISE





NOISE + JAMMER



Ublox-uBlox-M8T

Nav Data Frame Nav Data Plots SV Books Almanacs Ephemeris Debug

Position LLA

GpsTime: 122
 LatDeg: 43.8791021
 LonDeg: -103.4590996
 MslAlt: 1773.24
 HaeAlt: 1751.05

Velocity NED

GpsTime: 122
 North: -0.010
 East: 0.000
 Down: -0.010
 Ground: 0.010

Date

GpsTime: 122.000
 UtcTime: 106.0000
 Date: 7/2/2017
 Time: 12:02:02 AM
 Leap Sec: 16
 Gps Week: 1956
 Utc Valid: False
 Week Valid: True
 ToW Valid: True

Quality

GpsTime: 122
 NavType: NoNav
 NumUsed: 0
 GPS: (0/2)
 GLONASS: (0/0)
 BeiDou: (0/0)
 Galileo: (0/0)
 SBAS: (0/0)
 FOM: 0
 TFOM: 0

Orientation

GpsTime: 122
 Heading: 0
 HeadingMag: NaN
 MagVar: NaN
 Pitch: NaN
 Roll: NaN
 Yaw: NaN

Position ECEF

GpsTime: 122
 X (m): -1072065.84
 Y (m): -4479560.37
 Z (m): 4399632.53

Velocity ECEF

GpsTime: 122
 X: 0.00
 Y: -0.01
 Z: 0.00

Clock

GpsTime: 122.000
 Bias: 0.000333181
 Drift: -6.61E-07
 BiasError: 8E-09
 DriftError: 1.364E-09

Pulse

GpsTime: NaN
 TimeOfPulse: NaN
 Quantization: NaN
 Pulse Error: NaN
 Corrected: NaN

Key Status

SA/AS: Invalid
 M-Code: Invalid
 PPS Mode: -

Rx Info

Type: ublox 8
 Version: 00080000
 Status: JL: 30 JS: Critical
 Faults: -
 Developer: -

Position Accuracy

GpsTime: 122
 HorzError: 7.12
 VertError: 3.47
 FullError: 7.92

Velocity Accuracy

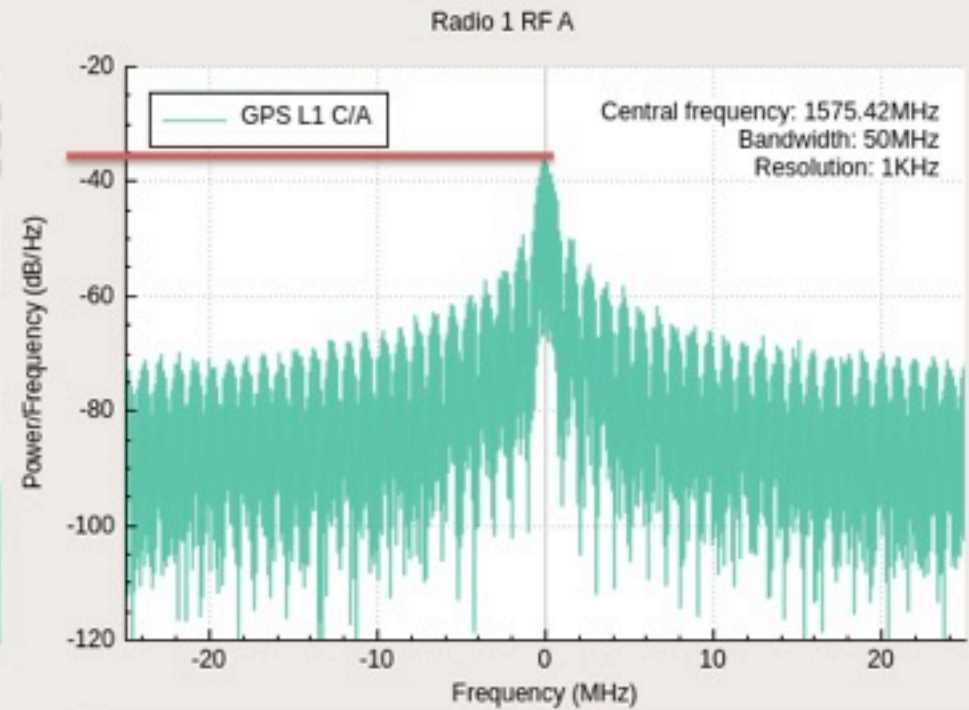
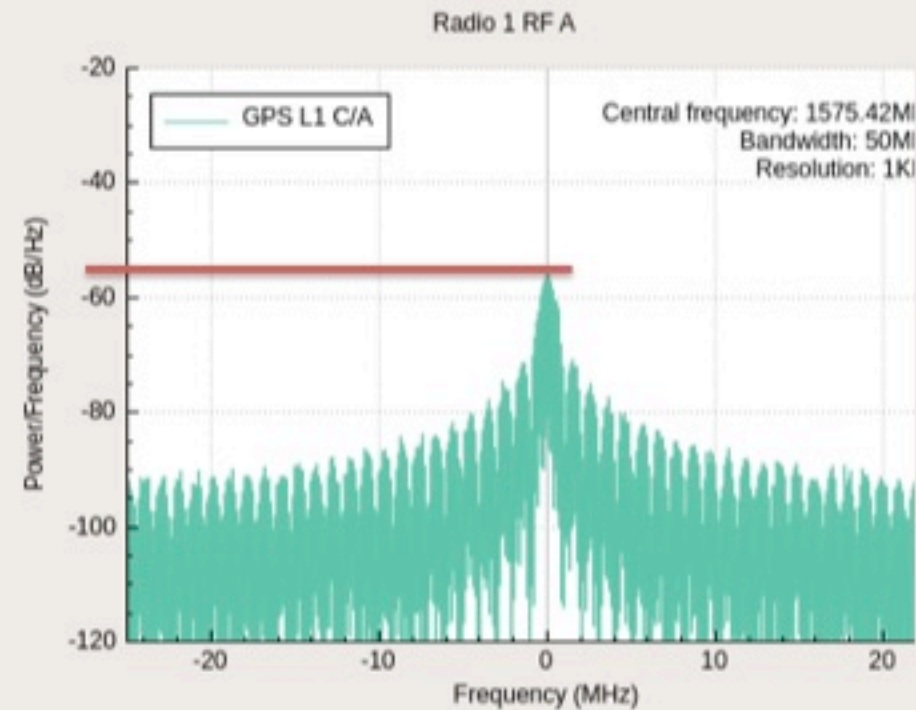
GpsTime: 122
 HorzError: NaN
 VertError: NaN
 FullError: 2.44

SV	Code	Hlth	Track State	CN0	Used	Az	Elv	Freq	Assurance	PR Resids	PRang	Doppler	Phase	Ttk Time
138	CA	63	Acq	28	False	186	39	L1	NA	0.00	NaN	NaN	NaN	NaN
135	CA	63	Acq	27	False	219	31	L1	NA	0.00	NaN	NaN	NaN	NaN
133	CA	63	Acq	27	False	172	39	L1	NA	0.00	NaN	NaN	NaN	NaN
14	CA	63	Acq	27	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN
196	CA	63	Acq	25	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN
28	CA	63	Acq	21	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN
5	CA	0	Acq	21	False	102	71	L1	NA	0.00	NaN	NaN	NaN	NaN
20	CA	0	Acq	19	False	205	45	L1	NA	0.00	NaN	NaN	NaN	NaN
23	CA	63	Acq	19	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN
25	CA	0	CodeTrack	19	False	229	43	L1	NA	0.00	2208...	-1271...	1160...	NaN
16	CA	63	Acq	19	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN
12	CA	0	Acq	18	False	189	23	L1	NA	0.00	NaN	NaN	NaN	NaN
11	CA	63	Acq	18	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN

C/A CODE POWER

TRUTH

SPOOFER



Ublox-uBlox-M8T

Nav Data Frame Nav Data Plots SV Books Almanaca Ephemeris Debug

Position LLA

GpsTime: 154
 LatDeg: 43.8794481
 LonDeg: -103.4466170
 MslAlt: 1788.57
 HaeAlt: 1744.37

Velocity NED

GpsTime: 154
 North: -0.010
 East: 0.000
 Down: -0.080
 Ground: 0.010

Date

GpsTime: 154.000
 UtcTime: 138.0000
 Date: 7/2/2017
 Time: 12:02:34 AM
 Leap Sec: 16
 Gps Week: 1956
 Utc Valid: False
 Week Valid: True
 ToW Valid: True

Quality

GpsTime: 154
 NavType: Nav3D
 NumUsed: 5
 GPS: (5/6)
 GLONASS: (0/0)
 BeiDou: (0/0)
 Galileo: (0/0)
 SBAS: (0/0)
 FOM: 0
 TFOM: 0

Orientation

GpsTime: 154
 Heading: 0
 HeadingMag: NaN
 MagVar: NaN
 Pitch: NaN
 Roll: NaN
 Yaw: NaN

Position ECEF

GpsTime: 154
 X (m): -1071088.48
 Y (m): -4479787.94
 Z (m): 4399629.19

Velocity ECEF

GpsTime: 154
 X: -0.02
 Y: -0.07
 Z: 0.05

Clock

GpsTime: 154.000
 Bias: -0.000632647
 Drift: -3.26E-07
 BiasError: 1.27E-07
 DriftError: 2.935E-09

Pulse

GpsTime: NaN
 TimeOfPulse: NaN
 Quantization: NaN
 Pulse Error: NaN
 Corrected: NaN

Key Status

SA/AS: Invalid
 M-Code: Invalid
 PPS Mode: -

Rx Info

Type: ublox 8
 Version: Hw: 00080000
 Status: JL: 30 JS: Ok A
 Faults: -
 Developer: -

Position Accuracy

GpsTime: 154
 HorzError: 30.04
 VertError: 53.02
 FullError: 60.93

Velocity Accuracy

GpsTime: 154
 HorzError: NaN
 VertError: NaN
 FullError: 1.03

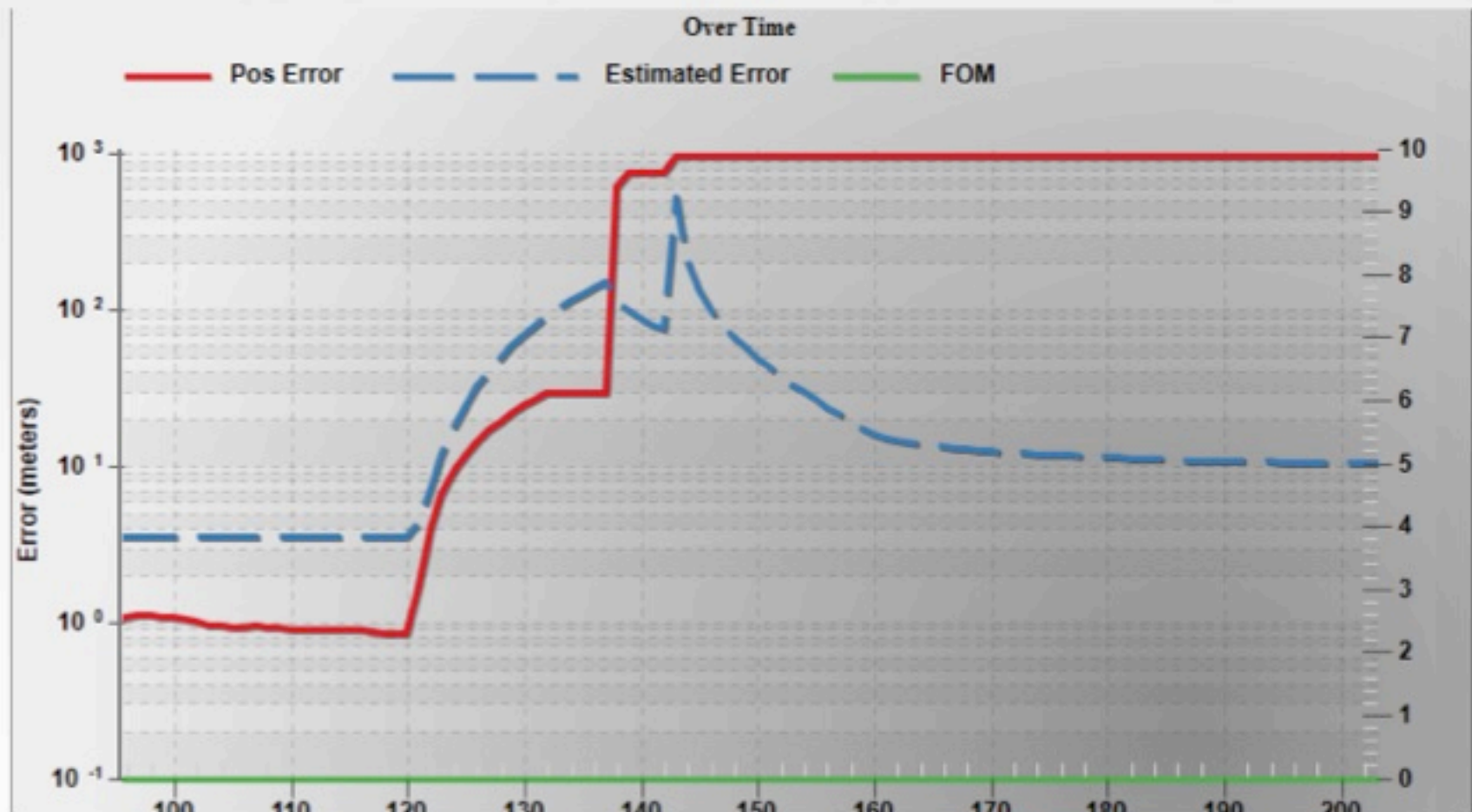
SV	Code	Hlth	Track State	CNo	Used	Az	Elv	Freq	Assurance	PR Resids	PRang	Dopple	Phase	TrkTime
29	CA	0	CodeAndCarrie...	34	True	311	59	L1	NA	-0.25	2052...	2327....	1078...	NaN
5	CA	0	CodeAndCarrie...	34	True	101	71	L1	NA	0.06	2014...	322.0...	1058...	NaN
20	CA	0	CodeAndCarrie...	32	True	205	46	L1	NA	0.57	2125...	3284....	1116...	NaN
25	CA	0	CodeAndCarrie...	32	True	229	43	L1	NA	0.32	2180...	-1783...	1145...	NaN
138	CA	63	Acq	30	False	186	39	L1	NA	0.00	NaN	NaN	NaN	NaN
12	CA	0	CodeAndCarrie...	28	True	189	23	L1	NA	-1.26	2328...	-3211...	1223...	NaN
135	CA	63	Acq	28	False	219	31	L1	NA	0.00	NaN	NaN	NaN	NaN
255	CA	0	Acq	25	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN
255	CA	0	Acq	25	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN
26	CA	0	CodeTrack	22	False	328	6	L1	NA	0.00	6246...	4043....	3282...	NaN
193	CA	63	Acq	20	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN
17	CA	63	Acq	20	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN
8	CA	63	Acq	19	False	0	165	L1	NA	0.00	NaN	NaN	NaN	NaN

MAP - AFTER

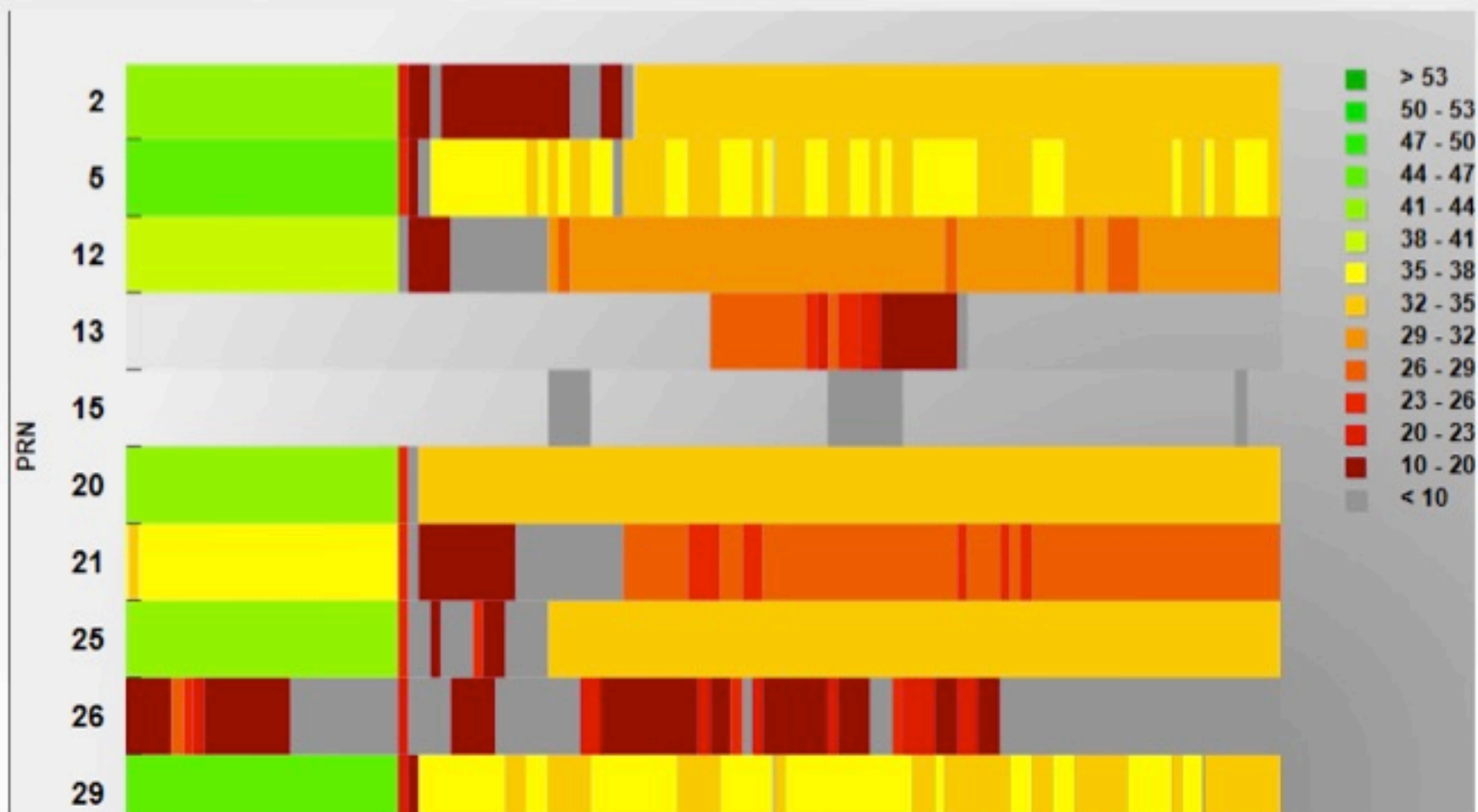


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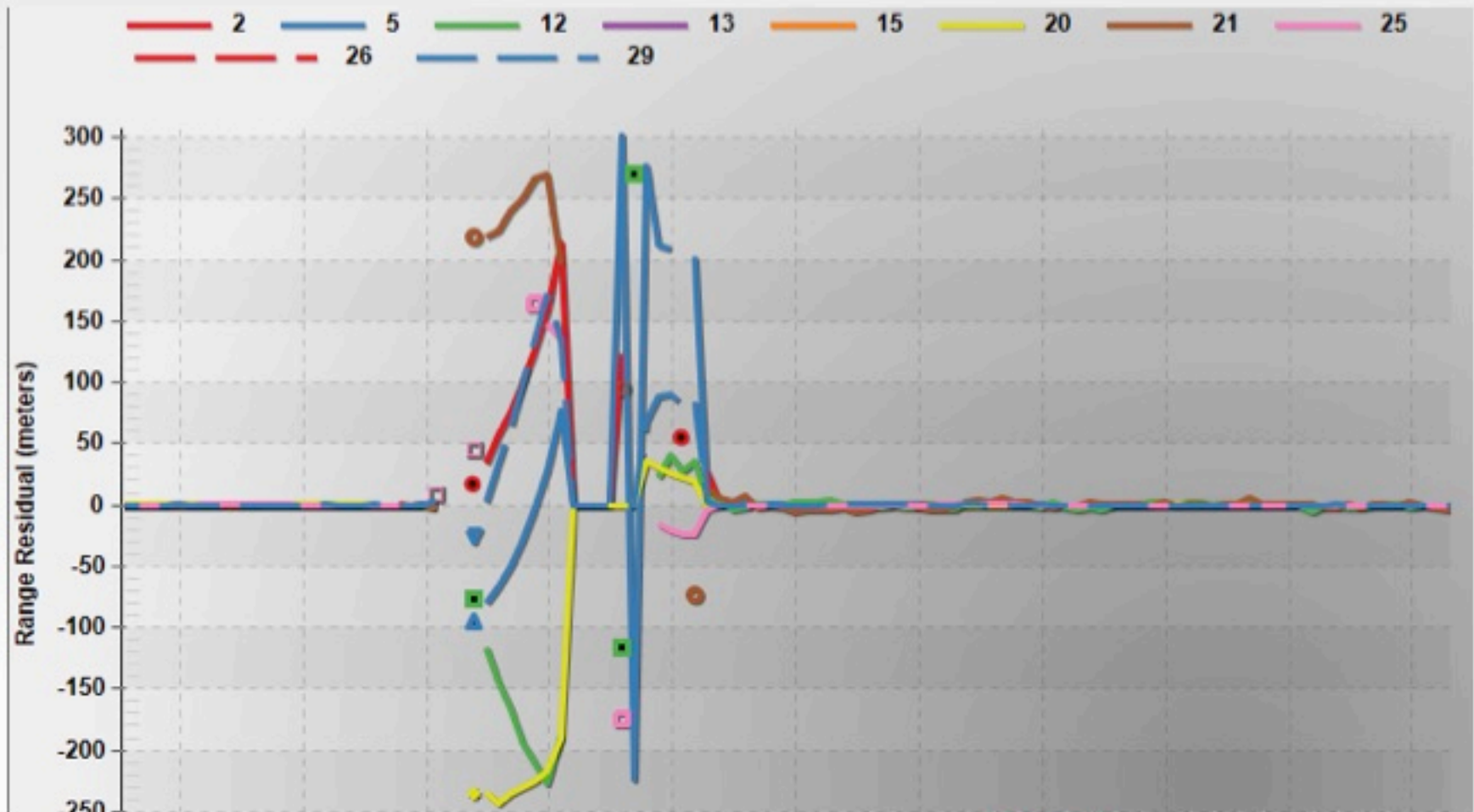
UBLOX RESULTS – POSITION ERROR W/ ESTIMATE



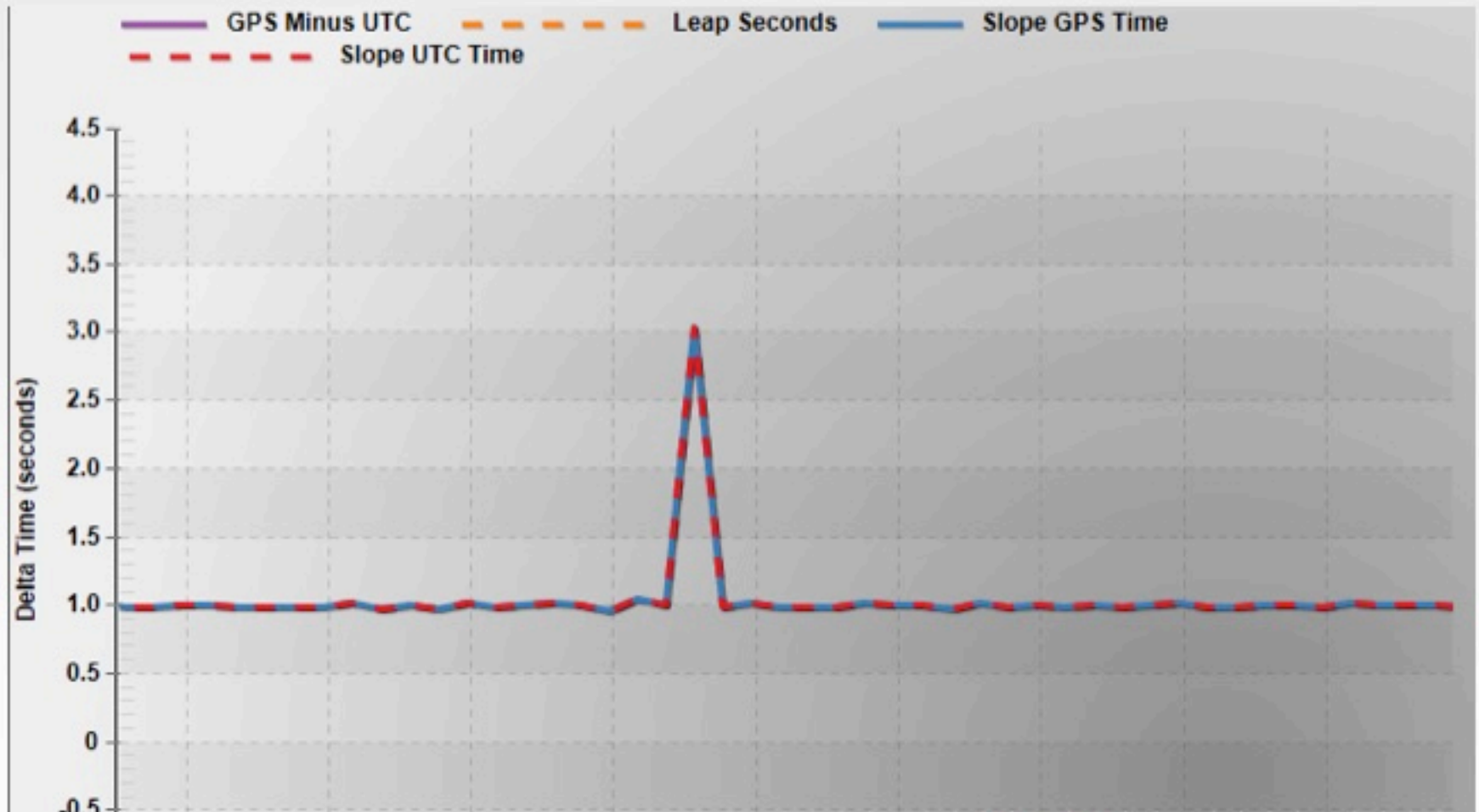
UBLOX RESULTS – C/NO



UBLOX RESULTS – RANGE RESIDUALS

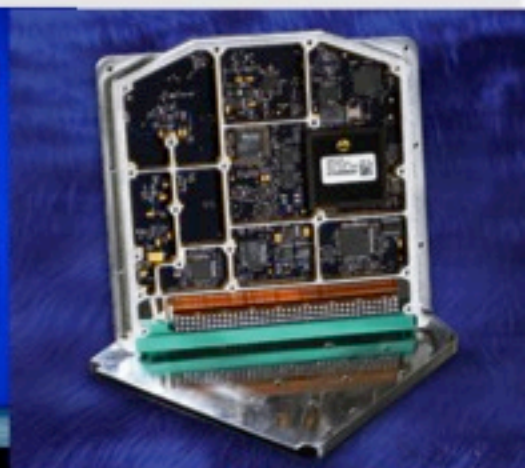
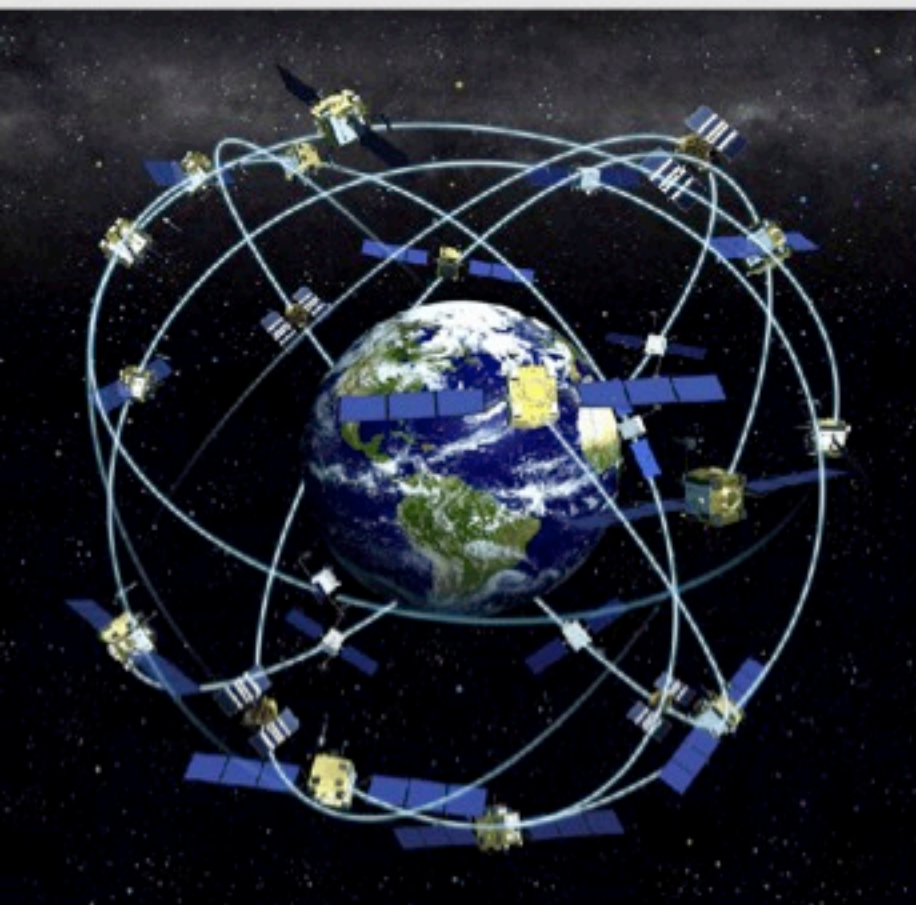


UBLOX RESULTS – TIME JUMP





JOHN WEGER
ENGINEER
ROCKWELL COLLINS



PREPARE FOR TOMORROW, FIND VULNERABILITIES TODAY ***SIMULATION AGAINST JAMMING AND SPOOFING***

DATE 20 JULY, 2017

PRESENTED BY JOHN WEGER

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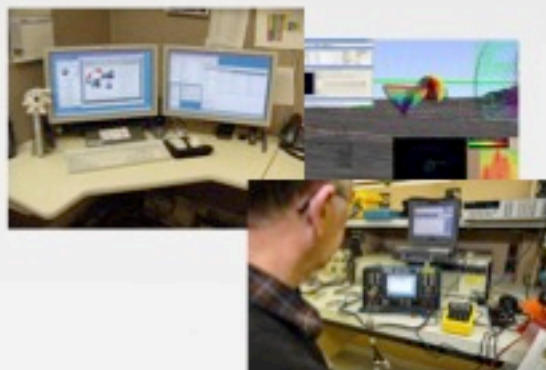
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DRIVERS FOR SYSTEM TEST COMPLEXITY

- THREATS
 - THREAT TYPES: COMPLEXITY, AGILITY, POWER
 - LAYDOWNS: LOCATIONS, COMBINATIONS
 - TACTICS: ACTIONS AND EFFECTS
- SYSTEM PERFORMANCE
 - TACTICAL SYSTEMS PROVIDING STATE OF THE ART PERFORMANCE
 - DIFFICULT FOR TEST, EVALUATION, AND TRAINING SYSTEMS TO KEEP PACE
- SYSTEM COMPLEXITY
 - COMPLEMENTARY NAVIGATION SENSORS
 - NAVIGATION FUSION ALGORITHMS
 - DIFFICULTY IN TRACING LOW-LEVEL EFFECTS TO SYSTEM-LEVEL IMPACTS

TEST AND EVALUATION

COMPONENT



- CODE
- COMPONENTS
- MODULES
- SUBASSEMBLIES
- TEST SOCKET
- OFFLINE SIMULATION

UNIT/SUBSYSTEM



- TARGET-BASED SOFTWARE CHECKS
- EMI / ENVIRONMENTAL
- RF SIMULATORS
- ANECHOIC CHAMBER
- LIVE SKY / SURROGATE VEHICLES

SYSTEM



- INTEGRATED SYSTEMS
- REALISTIC ENVIRONMENTS
- COOPERATIVE OPERATIONS
- REALISTIC THREATS

INCREASING COST

THREAT COMPLEXITY

- TRADITIONALLY SIMULATED IN SIMPLE FASHION AS RF INTERFERENCE POWER COUPLED INTO THE RECEIVER FRPA FEED
- SYSTEMS SUCH AS THE WRIGHT PATTERSON WAVEFRONT SIMULATOR ALLOW CONSIDERABLY GREATER FIDELITY FOR GPS/INS SYSTEMS
 - MULTIPLE INDEPENDENT THREATS & TYPES
 - PROPAGATION AND ANTENNA MANIFOLD EFFECTS
- HIGHER-LEVEL SYSTEMS (AIRCRAFT, VEHICLES) RELY ON LIVE-SKY THREAT TESTING
 - LOGISTICS
 - BROADCAST CLEARANCE
- SOME CASES ARE SIMPLY UN-TESTABLE IN THE REAL WORLD
 - SATELLITE FAULTS & OUTAGES
 - SYSTEM-WIDE FAILURES (MONITOR & CONTROL)
 - INTERDEPENDENT SYSTEMS

SYSTEM PERFORMANCE

- NEW CAPABILITIES ARE DEPLOYED INTO OPERATIONAL SYSTEMS AT THE SAME SPEED AT WHICH TEST CAPABILITIES ARE DEVELOPED
 - REAL-TIME KINEMATIC / PRECISION CARRIER PHASE DIFFERENTIAL
 - GLOBAL DIFFERENTIAL GPS
 - CRPA ELECTRONICS
- THE ABILITY TO MAINTAIN AN INDEPENDENT “GOLD STANDARD” FOR RESULTS COMPARISON IS BECOMING INCREASINGLY DIFFICULT
 - SYSTEMS UNDER TEST OFTEN EXCEED OUR ABILITY TO MEASURE THEM IN A LABORATORY ENVIRONMENT
 - COMMERCIAL TECHNOLOGY PACING THE ABILITY TO MAINTAIN 10X MEASUREMENT
 - RF SYNTHESIS PROVIDES TRUTH (FOR NOW) FOR PERFORMANCE ANALYSIS
- NEXT GENERATION SYSTEMS WILL LIKELY RIVAL WHAT CAN BE ACHIEVED WITH METROLOGY, CREATING AMBIGUITY IN “TRUTH” VS MEASURED PERFORMANCE

AS THE ART OF THE POSSIBLE BECOMES AN AFFORDABLE REALITY,
WE NEED TO CHANGE OUR APPROACH TO TESTING

SYSTEM COMPLEXITY



- STANDALONE RECEIVERS ACTING AS ONE OF SEVERAL NAVIGATION AIDS.
- OPERATOR ACTION TO SELECT / DE-SELECT.
- MINIMAL CONNECTION TO AUTOMATED SYSTEMS.
- REQUIRE RELATIVELY SIMPLE RF SIMULATION CAPABILITIES.



- COUPLED GPS NAVIGATION SENSORS: INERTIAL, DOPPLER, VISION, MAG, WHEEL SPEED, CRPA
- REQUIRE HIGH LEVELS OF TEST EQUIPMENT SYNCHRONIZATION AND EXQUISITE SIMULATION CAPABILITIES
- OPERATIONAL SYSTEMS OFTEN EXCEED LIMITS OF TEST EQUIPMENT



- ASSURED PNT: REAL-TIME INTEGRATION OF ALL-SOURCE NAVIGATION INFORMATION
- SOLUTION-SEPARATION AND REAL-TIME INTEGRITY
- THREAT SENSE AND REJECT/DEFEAT
- ATTRITABLE NAVIGATION AIDS (PSEDUOLITE, STOIC)

APPROACH TO NEXT-GENERATION TEST CAPABILITIES

- THE APPROACH FOR SIMULATION AND TEST OF NEXT-GENERATION SYSTEMS WILL ULTIMATELY FOLLOW THE SAME HIGH-LEVEL PRINCIPLES BEING APPLIED TO SYSTEM-UNDER-TEST DEVELOPMENT
 - MODULARITY
 - OPEN STANDARDS
 - SOFTWARE-DEFINED TEST ENVIRONMENTS
 - HIGHLY AUTOMATED
- CHALLENGES
 - PRECISION: THE STANDARDS AND INTEGRATION METHODS MUST SUPPORT SYNCHRONIZATION OF SIMULATION HARDWARE COMPONENTS TO SATISFY MULTI-SOURCE PNT TEST NEEDS
 - INTELLECTUAL PROPERTY: THE ABILITY TO OPENLY SHARE AND BUILD ON CURRENT STATE-OF-THE-ART IN A BUSINESS OF CONSIDERABLE WORTH AND COMPETITION
 - PACE: STAYING CURRENT WITH MULTI-SOURCE NAVIGATION, FREQUENCY AGILITY, ADVANCED WAVEFORMS, AND IMPROVED COUPLING METHODS

QUESTIONS?

CONTACT US

TIM ERBES: terbes@talen-x.com

JOHN WEGER: john.weger@rockwellcollins.com

IURIE ILIE: Iurie.Ilie@skydelsolutions.com

ALAN CAMERON: acameron@northcoastmedia.net