DEEPSIG

Realizing the full potential of data & learning within communications systems & wireless baseband

GTC 2019, San Jose

Dr. Tim O'Shea, CTO : tim@deepsig.io

3100 Clarendon Blvd, Suite 200 Arlington, VA 22201
www.deepsig.io

Brief DeepSig Overview / Background

Team:

Incredible team of AI, ML, SDR, DSP, & SW subject matter experts

Core team from GNU Radio, USRP, numerous other backgrounds

Growing rapidly

Seed Round:

$1.5M, March 2018
Scout Ventures (Lead), Blu Venture Investors

Actively seeking interested parties for further rapid scaling

Products:

OmniSIG and OmniPHY both shipping **Software**.

Numerous licensed software copies sold

Mature production C++11 code base for both

IP:

Several key patents on the technology allowed/issued (more pending)

Exclusive License of additional Patents from Virginia Tech

Innovation:

Top Recognized AI Wireless innovators

1100+ Citations of key early works

Software Radio Leadership (GNURadio)

Leaders IEEE / Industry Activities in ML Comms

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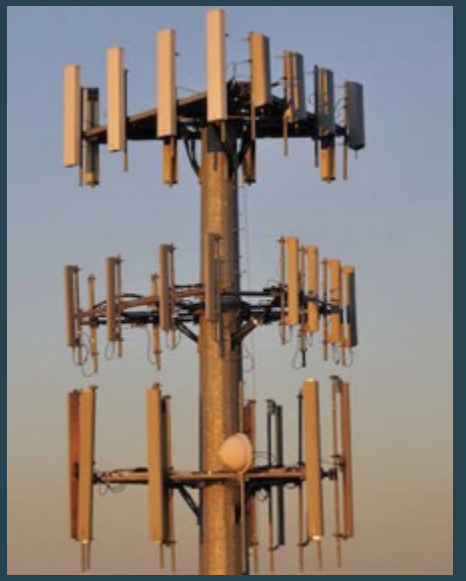
The problem of Complexity in Wireless

- The Degrees of Freedom in wireless systems are expanding.
  - Antennas, channels, bands, codes, bandwidths, beams, modes, etc.,
- The types and effects of impairments continues to grow.
  - Rising noise floor, sources of interference, hardware imperfections, etc.,
- Spectrum environments and channel models are more difficult.
  - Number of devices, dense urban environments, unlicensed operation, etc.,
- The number of vectors for optimization is steadily increasing.
  - Dynamic radio behaviors, power usage (at both the UE and BTS), throughput, latency, coherence, etc.,



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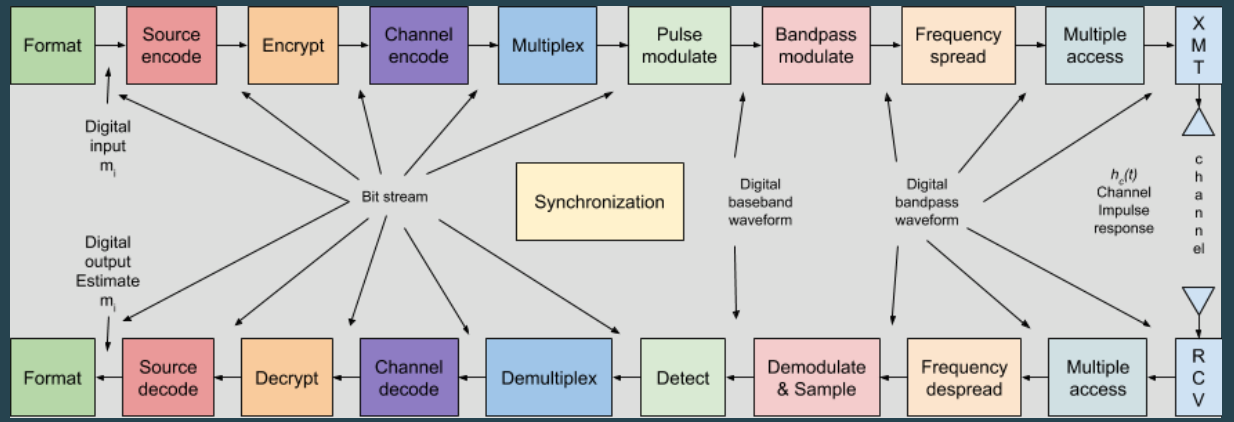
[Not] Coping with Wireless Complexity

- Complexity create an extremely difficult design, optimization problem!
- **The tools and methods for designing and optimizing wireless systems has not scaled with the problem complexity.**
- Today systems are designed & optimized in modular / piecemeal fashion and then glued together.
  - This approach precludes end-to-end optimization
  - Often requires simplified world models within each module
  - Both result in sub-optimal solutions to todays communications systems



- **<u>The right way:</u>**
  - End-to-end optimization ... Using real world measurement instead of toy models

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Challenges in Wireless Baseband

Make Wireless 5G+ and IoT Scale

Increase Device Performance and Density

Drastically reduce power consumption & device cost

Real Time Wireless Analytics

Recognize device failures & wireless cyber attacks

Learn from pattern of life, identify threats, anomalies

Minimize cost and engineering time

Optimize Radio System Deployments

Efficient planning of 5G, LTE-U & IoT

Intelligent spectrum sharing strategies

Deployable Software Capabilities:

Cloud managed infrastructure & optimization

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Forget everything else!

My number one need is 5G power reduction!!

Nick Cordero, ***Verizon***

If 5G is so important, why isn't it secure?

Dr. Tom Wheeler, frmr chair ***FCC***

Dynamic protection areas will spur spectrum sharing

Paige Atkins, ***NTIA***

What DeepSig AI Software does for Wireless

Machine Learning Communications - new era of wireless that can optimize for many factors

Improve Power Efficiency, Performance & Device Density in L1/PHY

- Energy efficient operations learned from real data sets & hardware

Reduce Wireless Device Cost – relax RF / linearity requirements

OmniPHY™ Baseband Technology

Sense and exploit wireless information in real time

- Plan/map cell performance, detect interference & malicious devices

OmniSIG™ Sensing Software

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Tensor processing and machine learning ecosystem

- Key enablers for next generation baseband

docker

OmniPHY™
OmniSIG ™
Software
Components

TensorFlow

PYTORCH

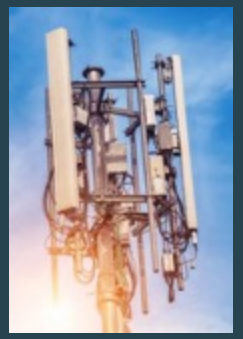
TensorRT

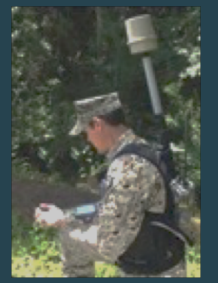
NVIDIA

Qualcomm snapdragon

NVIDIA

XILINX





5G BTS | Mobile & IOT | Satellite & Backhaul | Defense ISR & Comms

Largest Impact ← Early Opportunities

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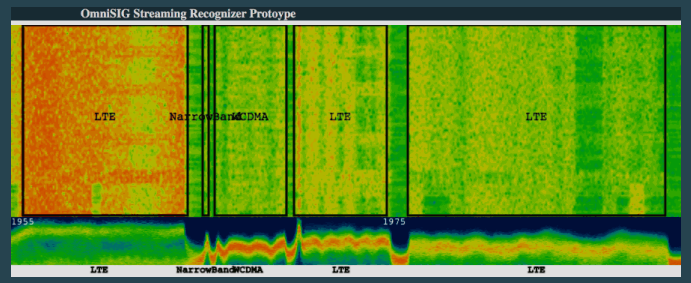
OmniSIG™ RF Sensing Software

- ~1000X faster & cheaper sensing
- Detect and map RF events and interference
- Rapid model updates and learning



OmniSIG Mapping Wireless Usage

Public Safety Threat Awareness

Move threat warning to Tactical Edge

5G/IoT Intrusion Detection

Network Optimization & Fault Detection

Berkeley SETI Institute

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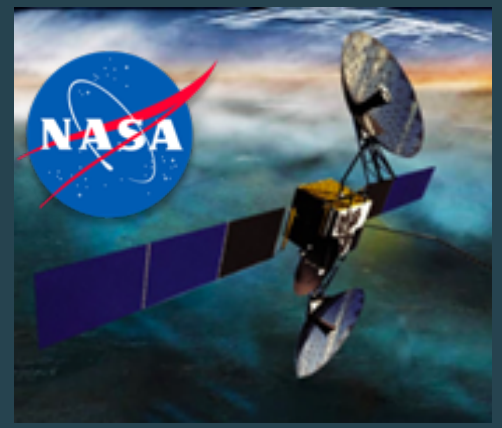
> ***Y'all are so far ahead of your competition, it's kind of laughable.***
>
> *Adam Thompson,* ***NVIDIA***

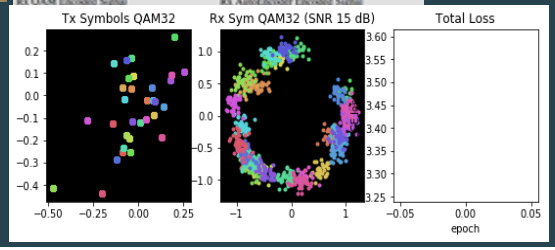
> ***OmniSIG is providing about 700x speedup.***
>
> ***Navy SPAWAR***

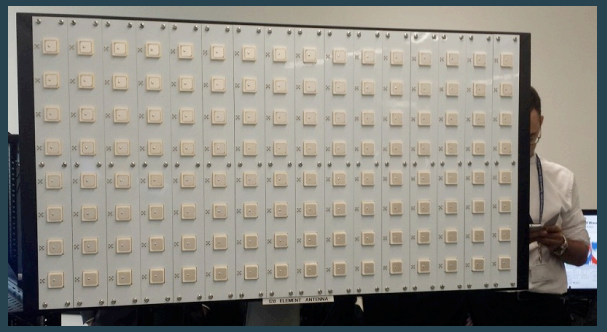
OmniPHY™ **Baseband Technology**

- Next leap of modem technology – end-to-end optimized PHY
- 10X+ Power Reduction, reduced cost, enhanced performance
- Better performance in Wireless WiFi, 4G/5G, IoT, NR-U Systems
- Fully Learned Waveforms: Satcom, Milcom, Mesh, 6G+



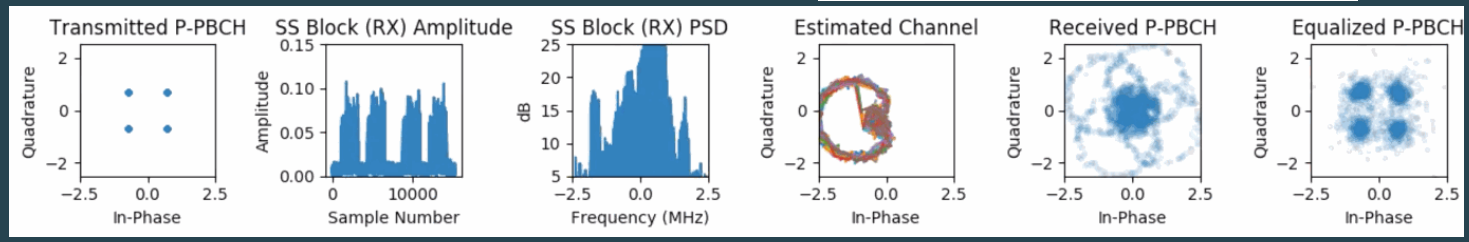
OmniPHY Secure SatCom & Drone Comm Link Learning





4G & 5G Massive MIMO & L1 enhancements
Learn Environment to Reduce Power/Cost

5G+/NR-U Performance Enhancements



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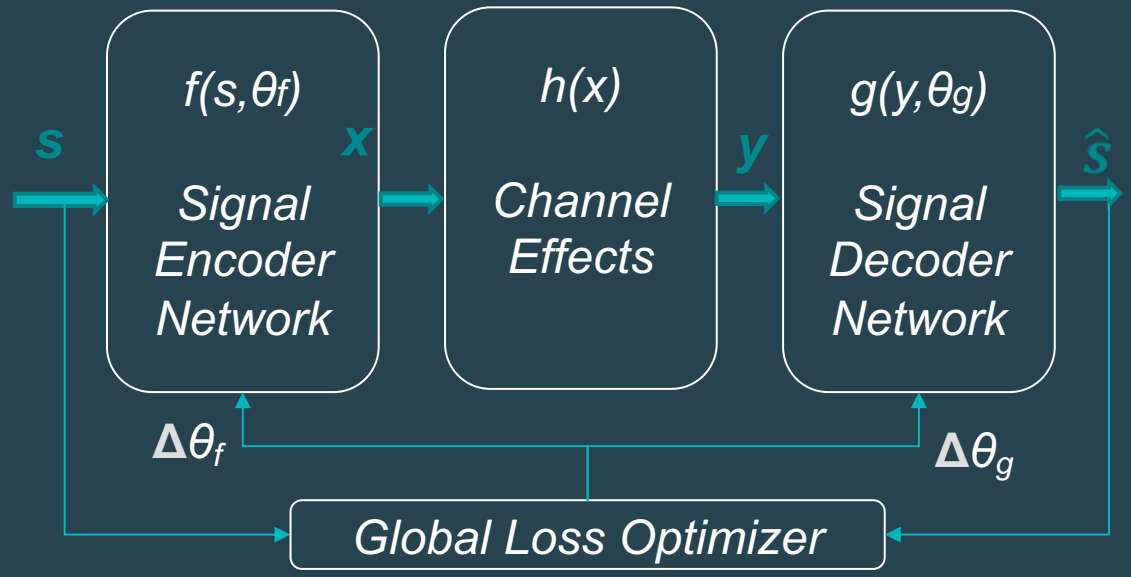
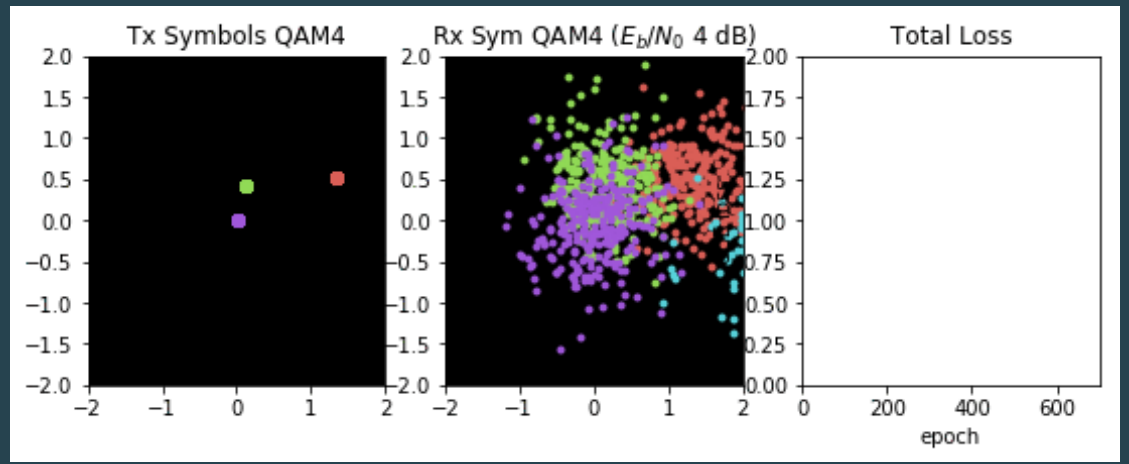
Building Communications Systems with Deep Learning

- Autoencoder approach to communications systems
- Optimal communication schemes directly from data
- Scales from simple to complex channel models





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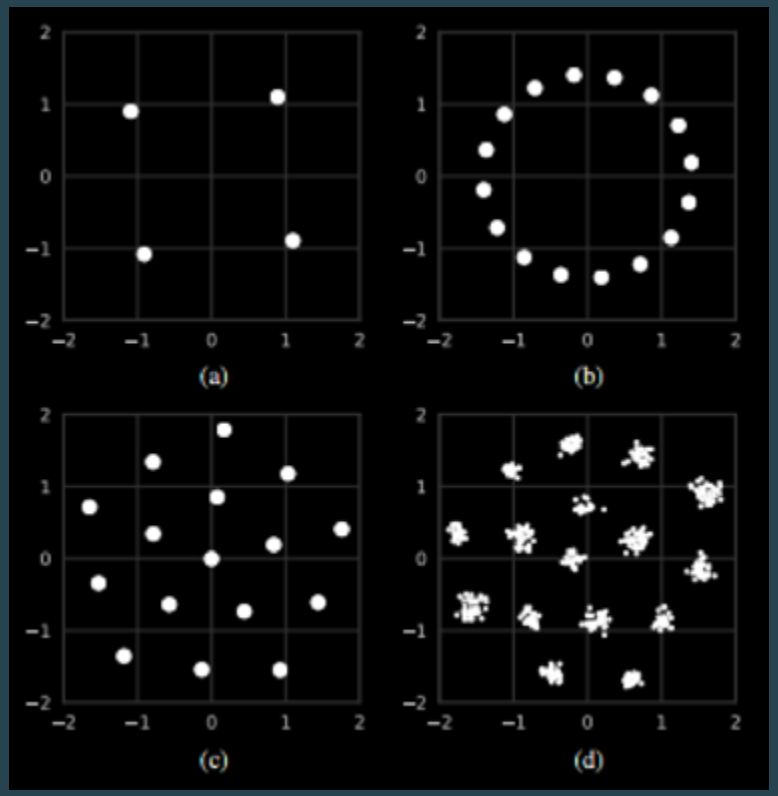
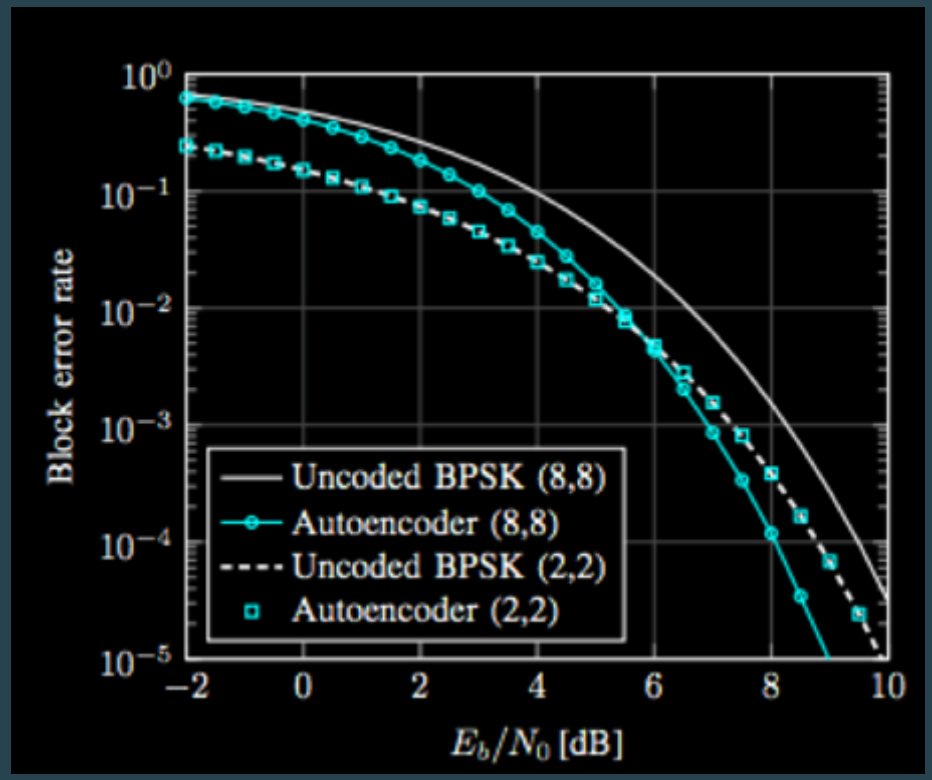
Building Communications Systems with Deep Learning

- Performance converges rapidly to traditional ML bounds
  - Larger block sizes inherently learn error correction coding/gain





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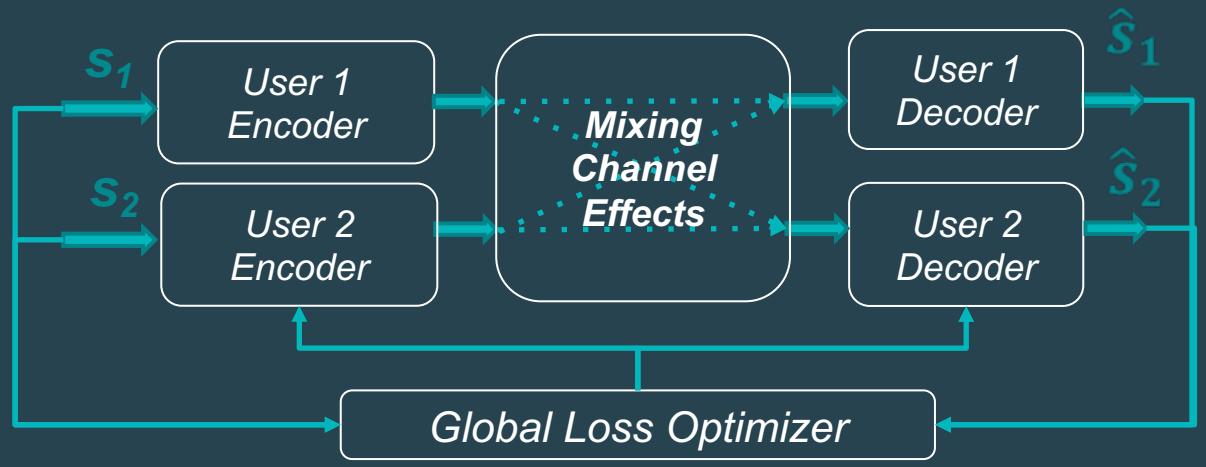
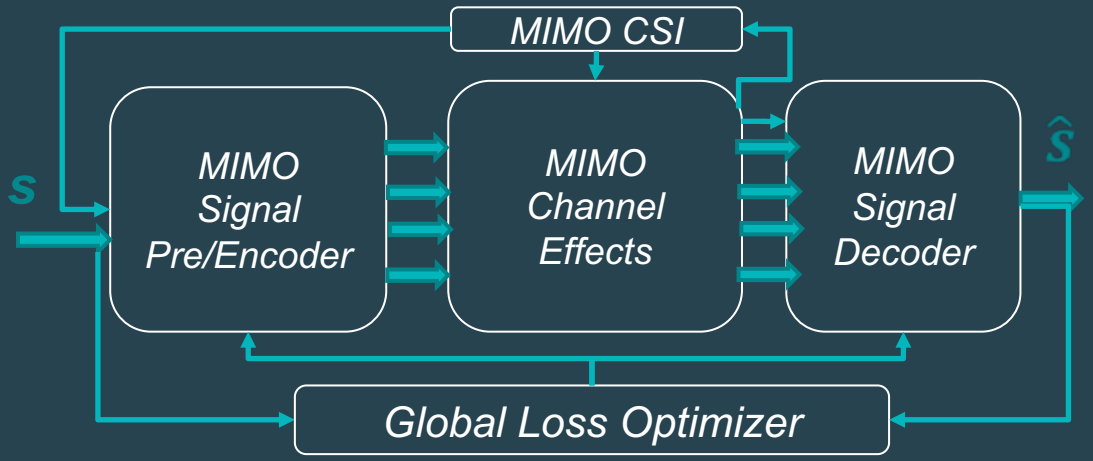
Building Communications Systems with Deep Learning

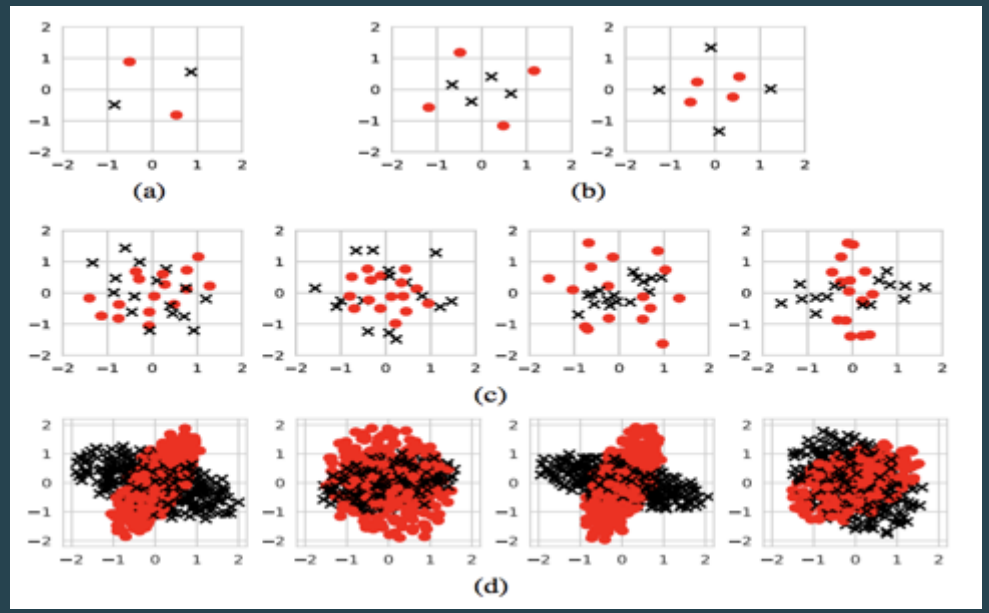
- Extending the approach to MIMO & Multi-User
- Major implications for massive densification



Multi-User NOMA Scheme Learning

Single User MIMO Learning





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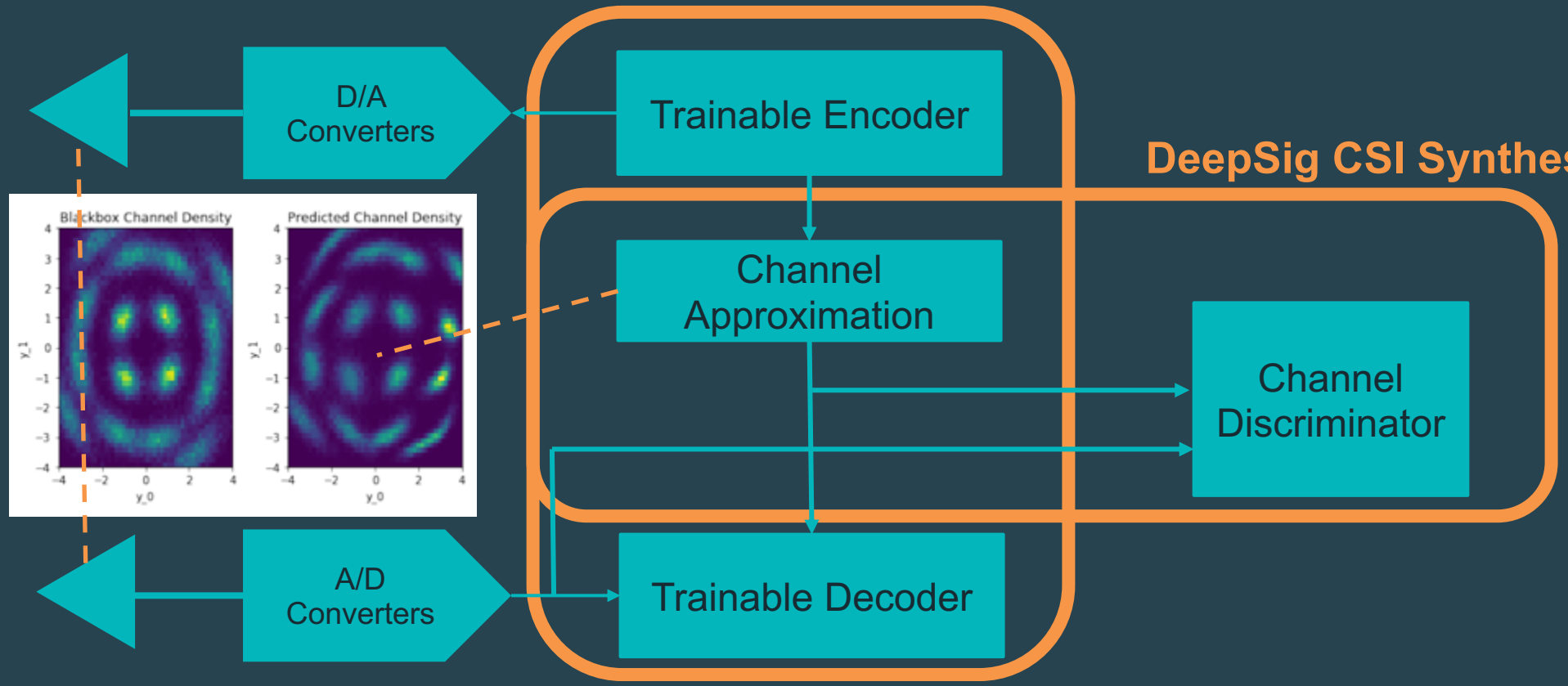
Building Communications Systems with Deep Learning

- Training for channels in the real world
  - Conditional-Comm-VGAN approach to stochastic channel response approximation



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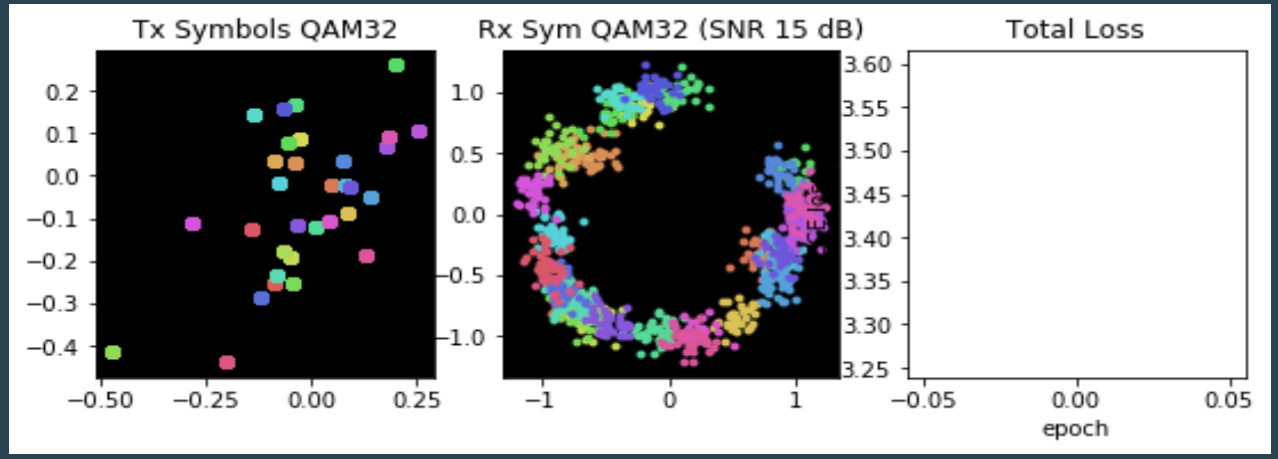
Building Communications Systems with Deep Learning

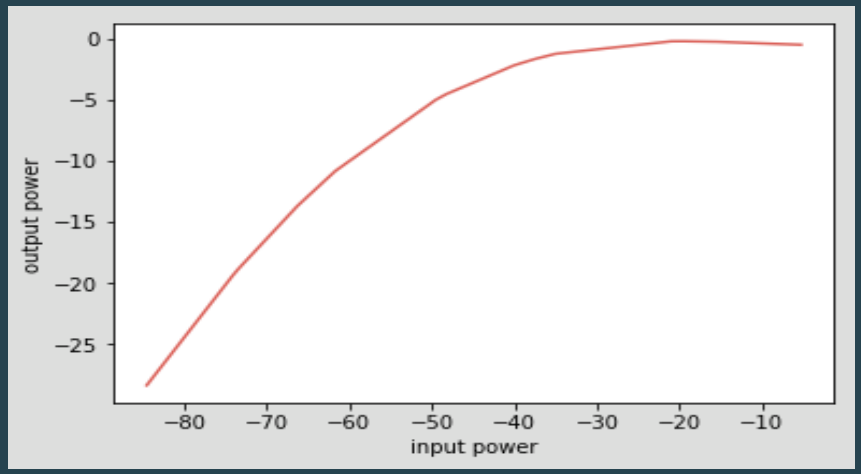
- Learning optimal communications for non-linear hardware effects
- Encoding for amplifier non-linearities!
- Enormous source of computational and power efficiency many systems

Constellation Learning



Cellular Remote Radio Head / Amplifier

Amplifier AM/AM Response



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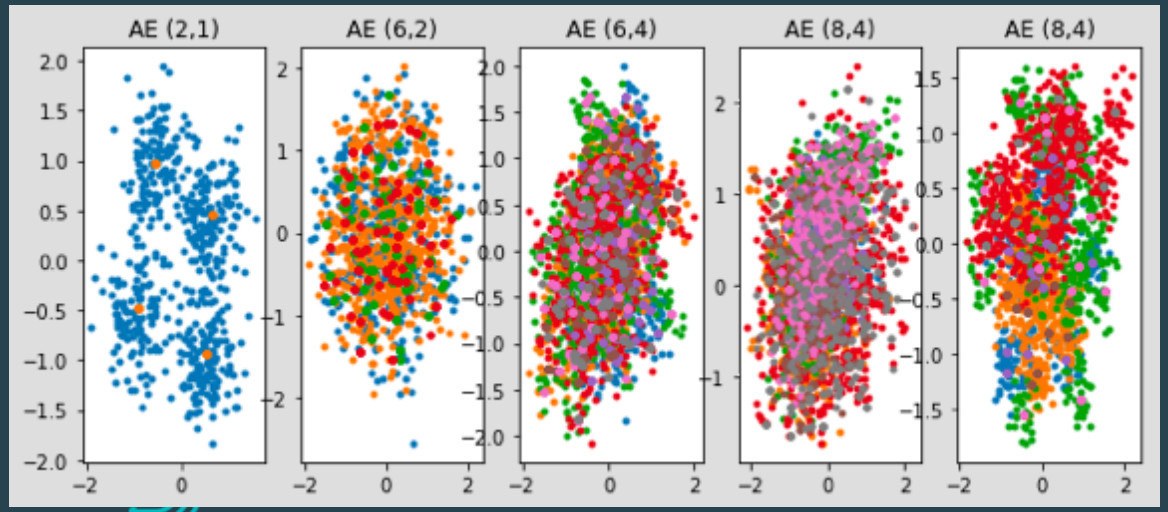
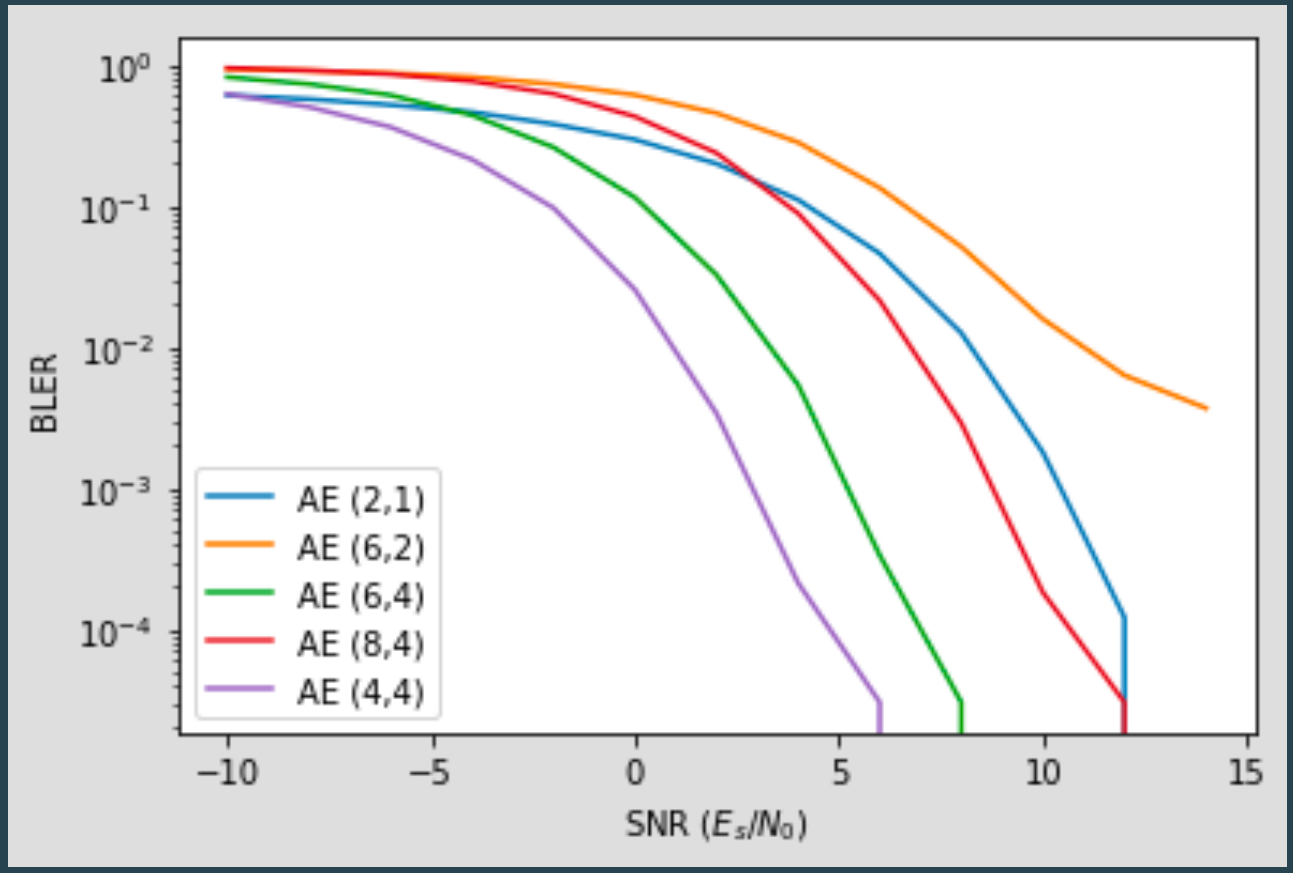
Building Communications Systems with Deep Learning

- Rapidly learn codes for a wide range of information rates
  - Built in error correction
  - Low complexity
  - A Number of modes which can be used in OmniPHY shown here
- Can also cascade traditional error correction





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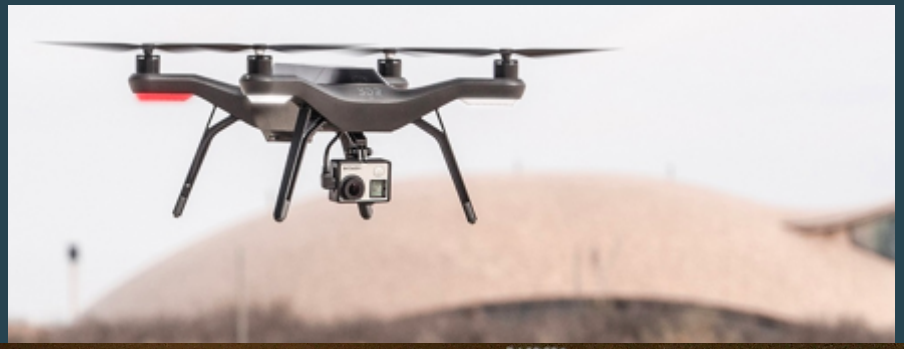
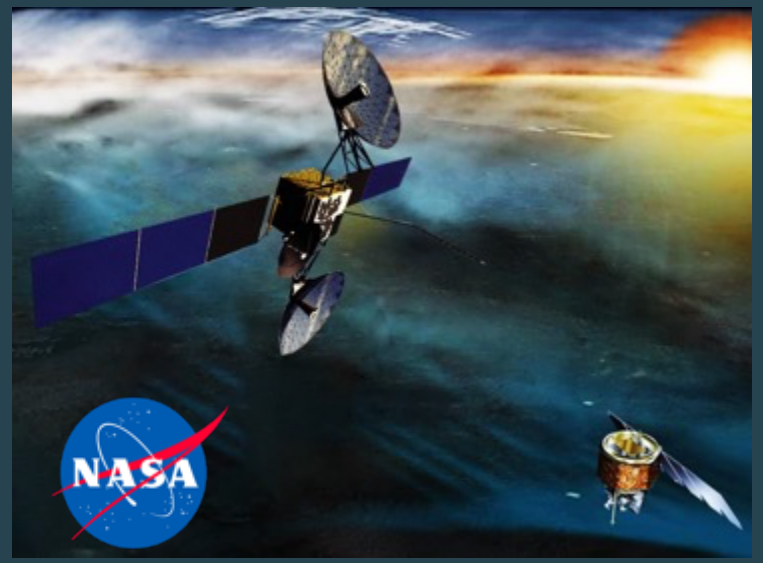
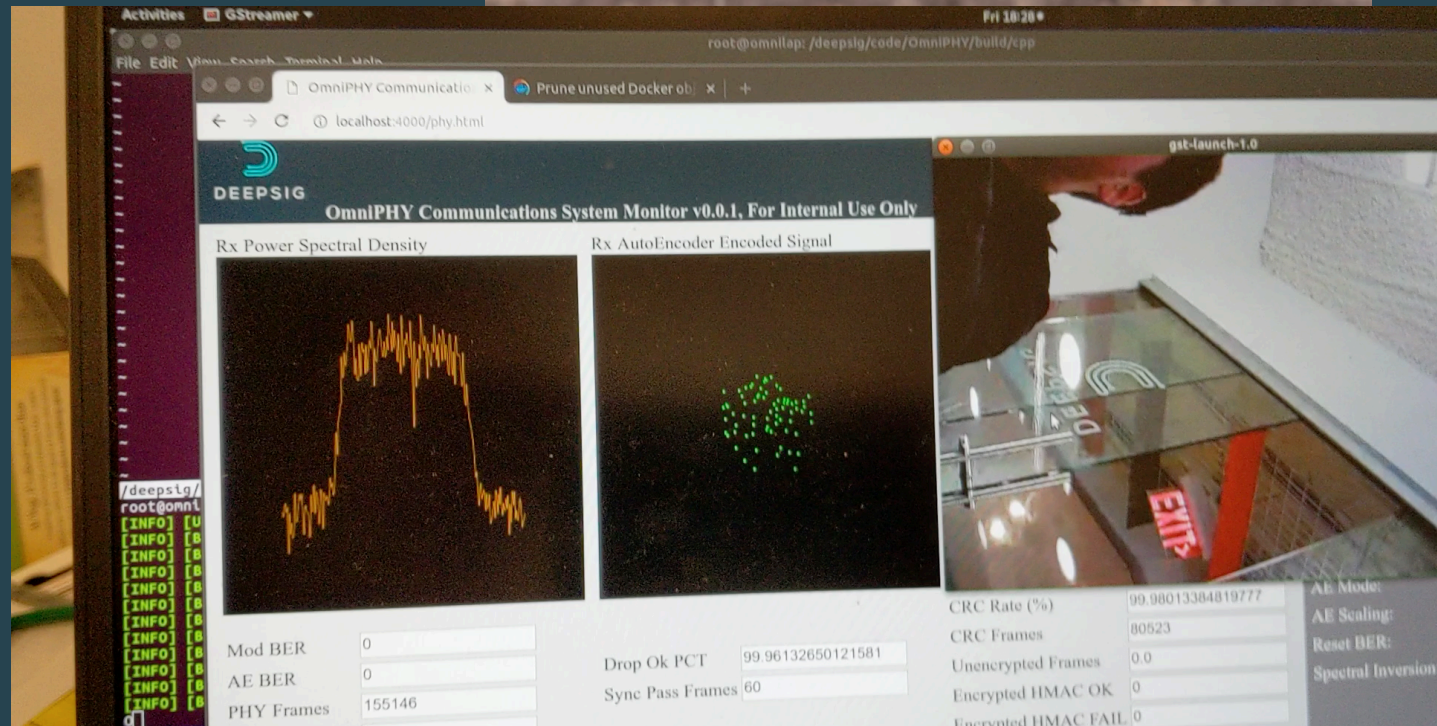
Building Communications Systems with Deep Learning

- Real world deployments of OmniPHY
  - Optimized satellite communications link /w NASA
    - Adaptation to reduce power, improve performance
    - Achieved lower BER than traditional system
  - Secure resilient drone communications & sensing (Tx2)
    - Adaptation avoid interference & attack
    - Live video streaming & telemetry
    - AES-256-GCM (FIPS 140-2 approved link crypto)
- Software shipping / available







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Building Communications Systems with Deep Learning

- Speed benchmarking on OmniPHY decoder
  - Relatively compact networks --
    - Partial optimization –
    - Optimized C++ implementation
    - Still float32 inference on desktop GPU
  - GTX 1080
    - > 140 Mbps throughput
    - 57 ns/bit inference speed
    - ~109uS per inference round trip latency
  - Bottlenecks typically on the CPU …
- Numerous additional performance improvements remain
  - Tensor core /DLA performance additional gains
- Larger sensing networks (~100+ layers deep)
  - < 5ms per inference latency
  - 200+ full spectrum characterizations per second

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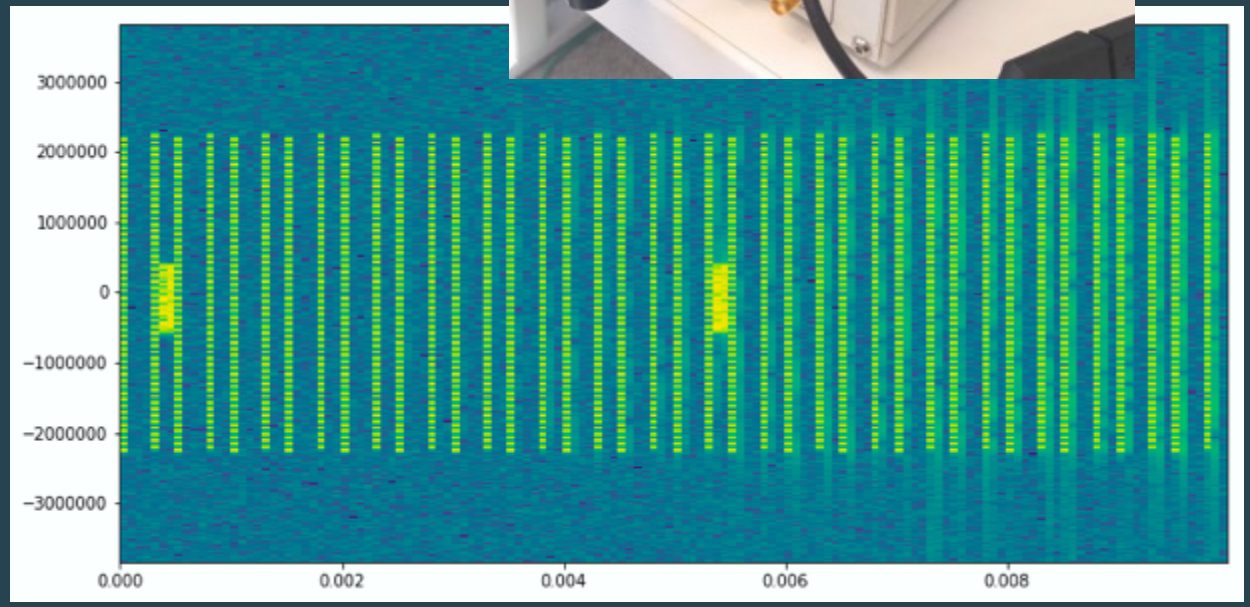
Building Communications Systems with Deep Learning

- Tensor processing and machine learning go hand-in-hand
  - Energy efficient partial 4G & 5G basebands using tensor ops
  - Easily insert ML enhancements throughout the physical layer
- Key enabler for DeepSig cellular enhancements
  - Drastically reduce power consumption and cost in BTS
  - Widely applicable for deployment of numerous wireless systems
  - Enable rapid development and iteration of algorithms and performance in real world environments



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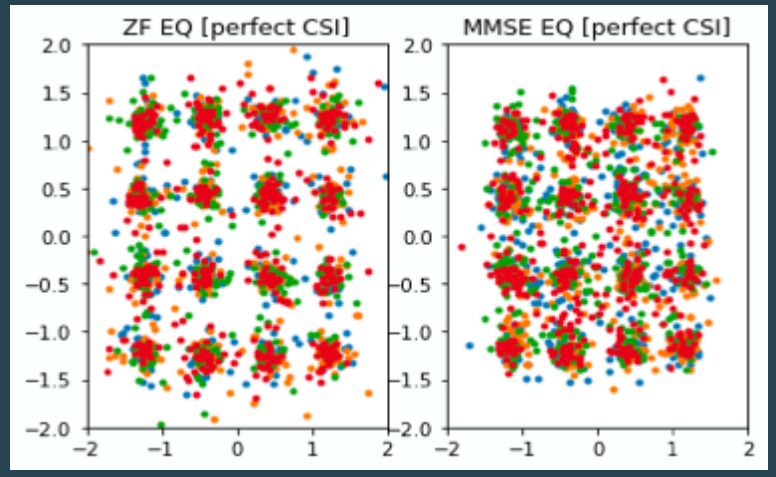
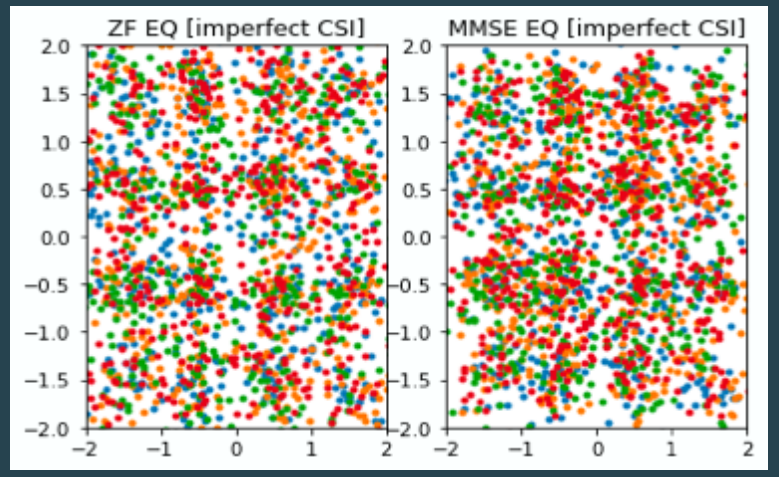
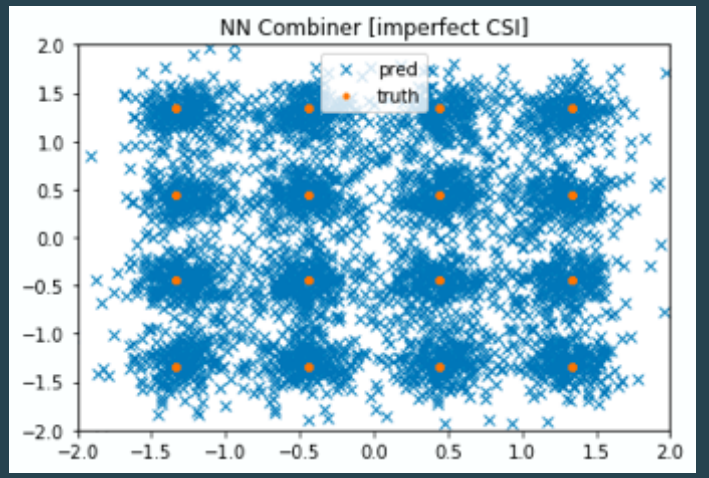
Building Communications Systems with Deep Learning

- Enhancing 5G Systems with Machine Learning
  - *Same approaches can be used to significantly reduce the power consumption in commercial standards*
  - *Adapt performance on real hardware & adapt algorithms in end-to-end optimization manner*

50% Reduction in EVM under Imperfect CSI ! (4x4 MIMO case) – Resilient to PA compression!
- Single pass deep learning approach – no iteration required (e.g. convex solver)







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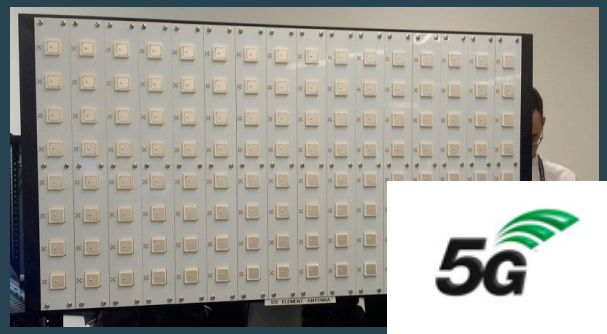
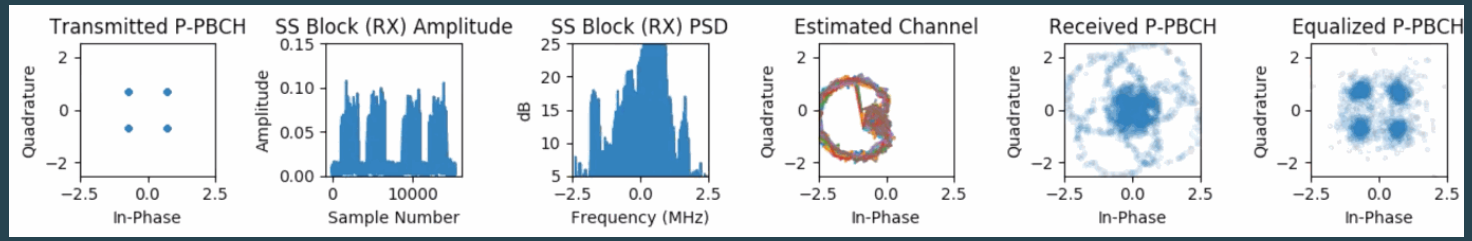
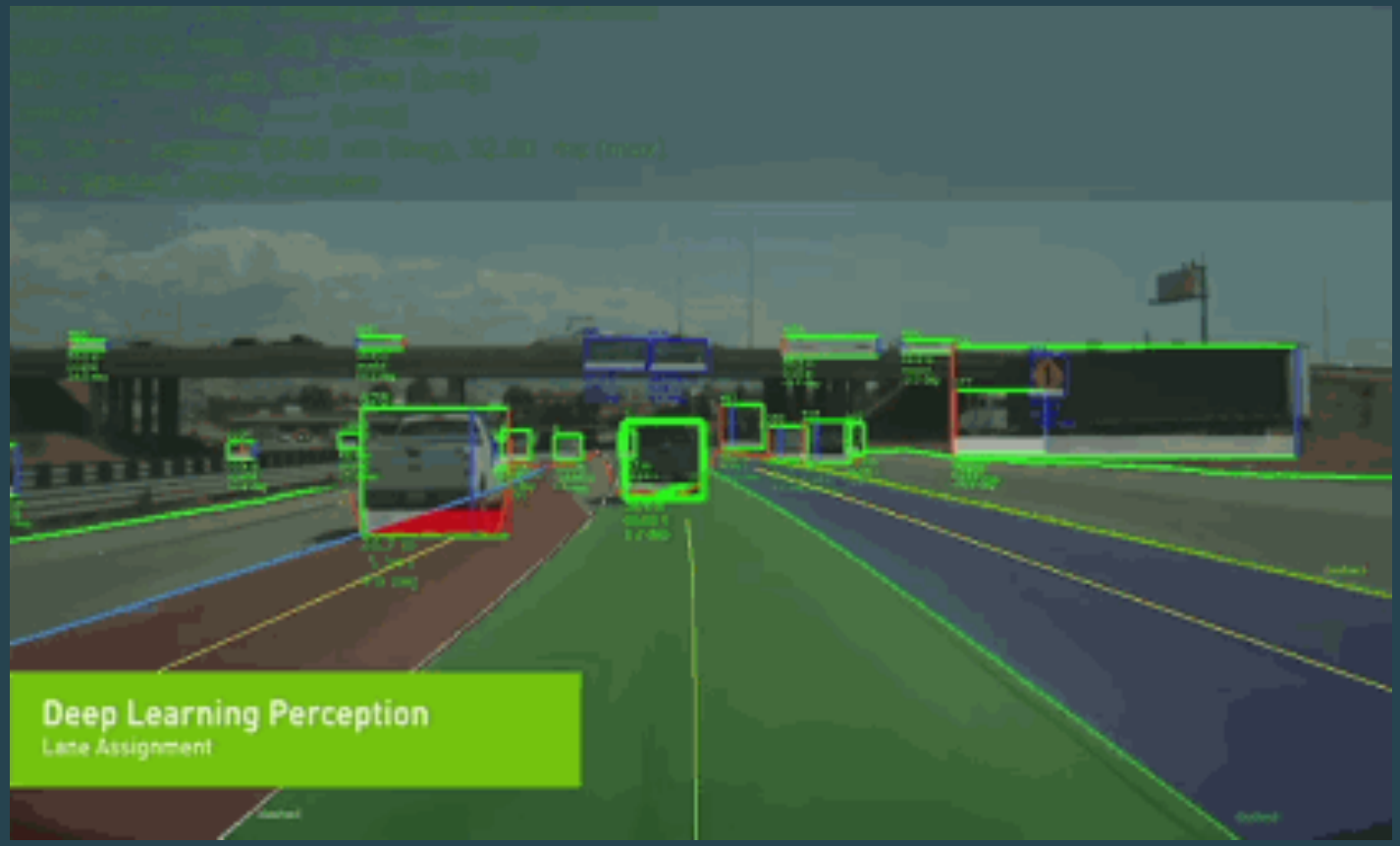


5G



Building RF Sensing Systems with Deep Learning

- Object detection has shown incredible results in computer vision
- Detecting and classifying objects in a real 3D scene
- Critical in self driving cars, surveillance, and numerous applications
- Networks like YOLOv3 have made this very efficient



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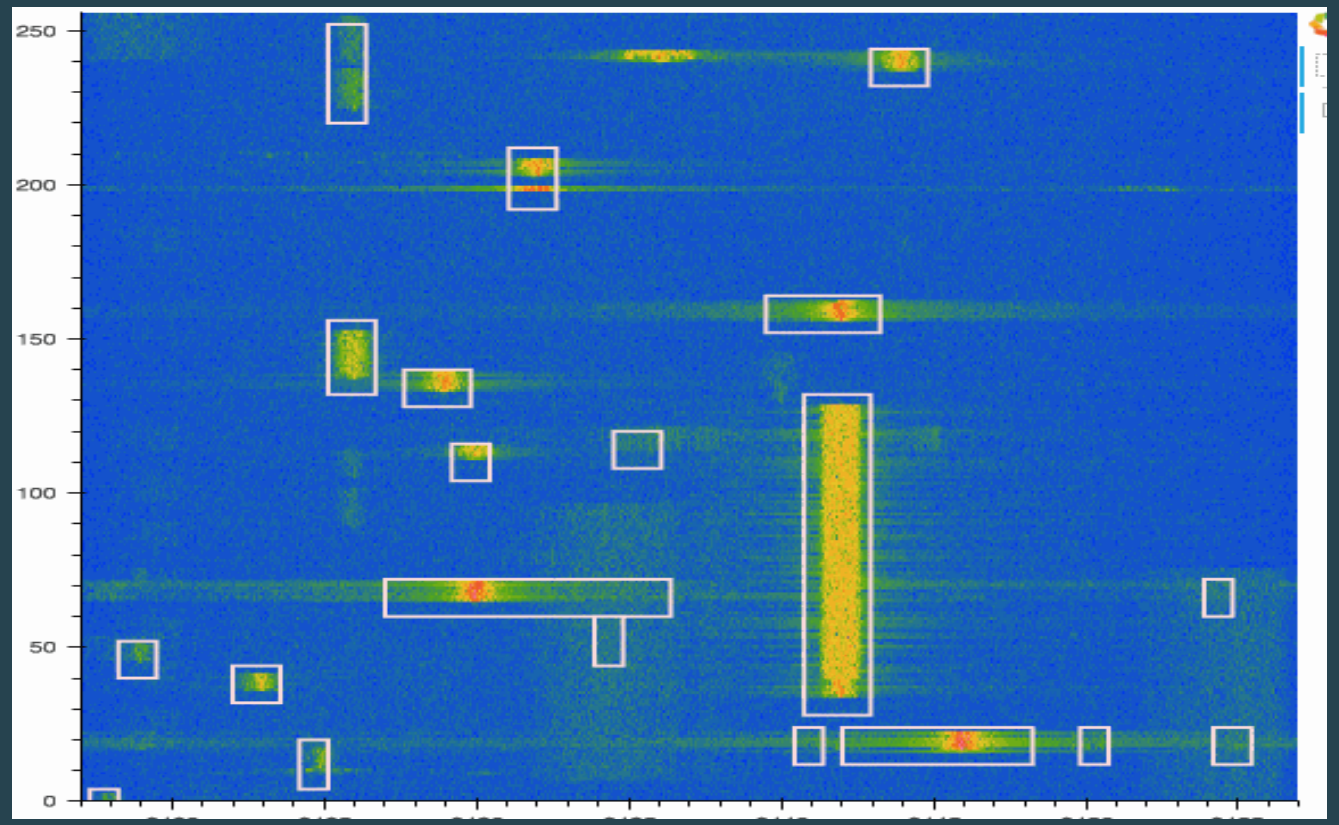
Building RF Sensing Systems with Deep Learning

- Object detection in the RF spectrum is a critical enabler to awareness
  - Malicious activity detection
  - Device interference detection
  - Dynamic spectrum access and ISM band coordination
  - Surveillance and monitoring
- Has never really been feasible are practical before at wide bandwidths across many signal types



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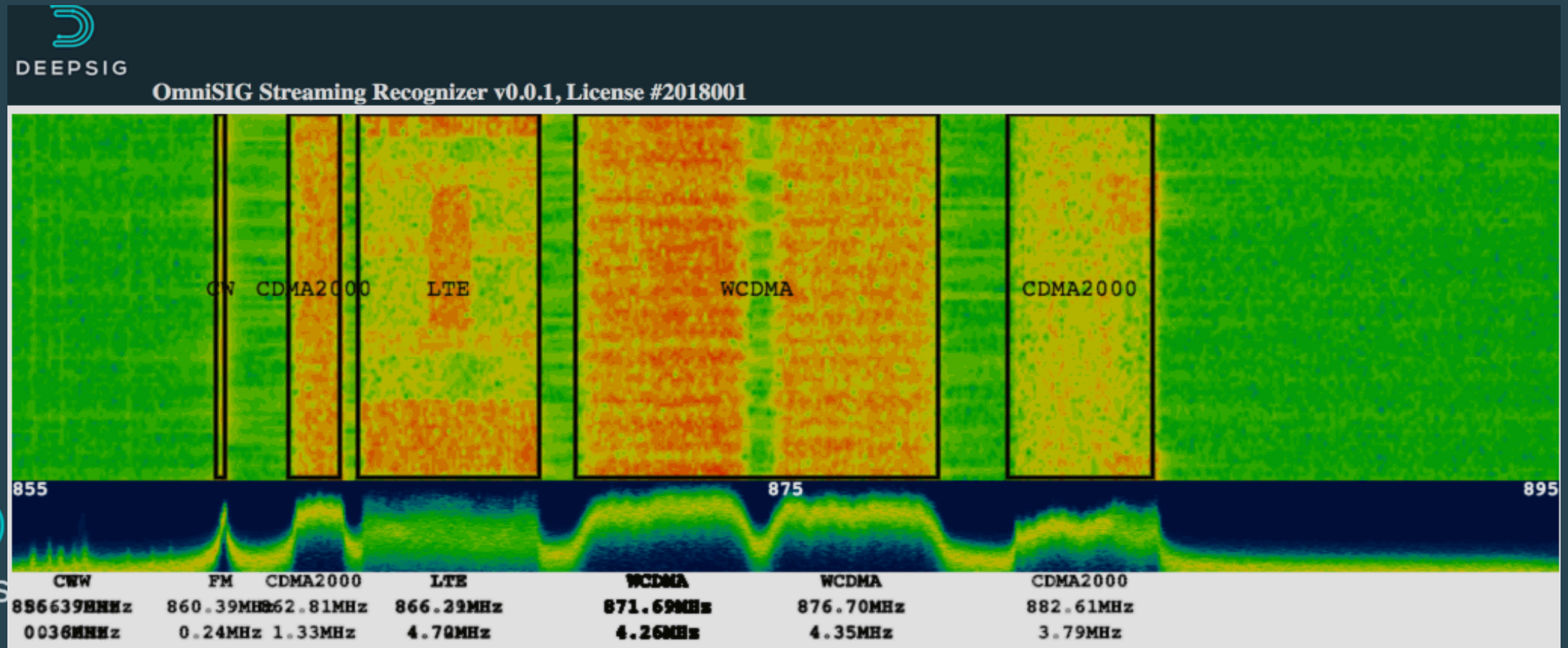
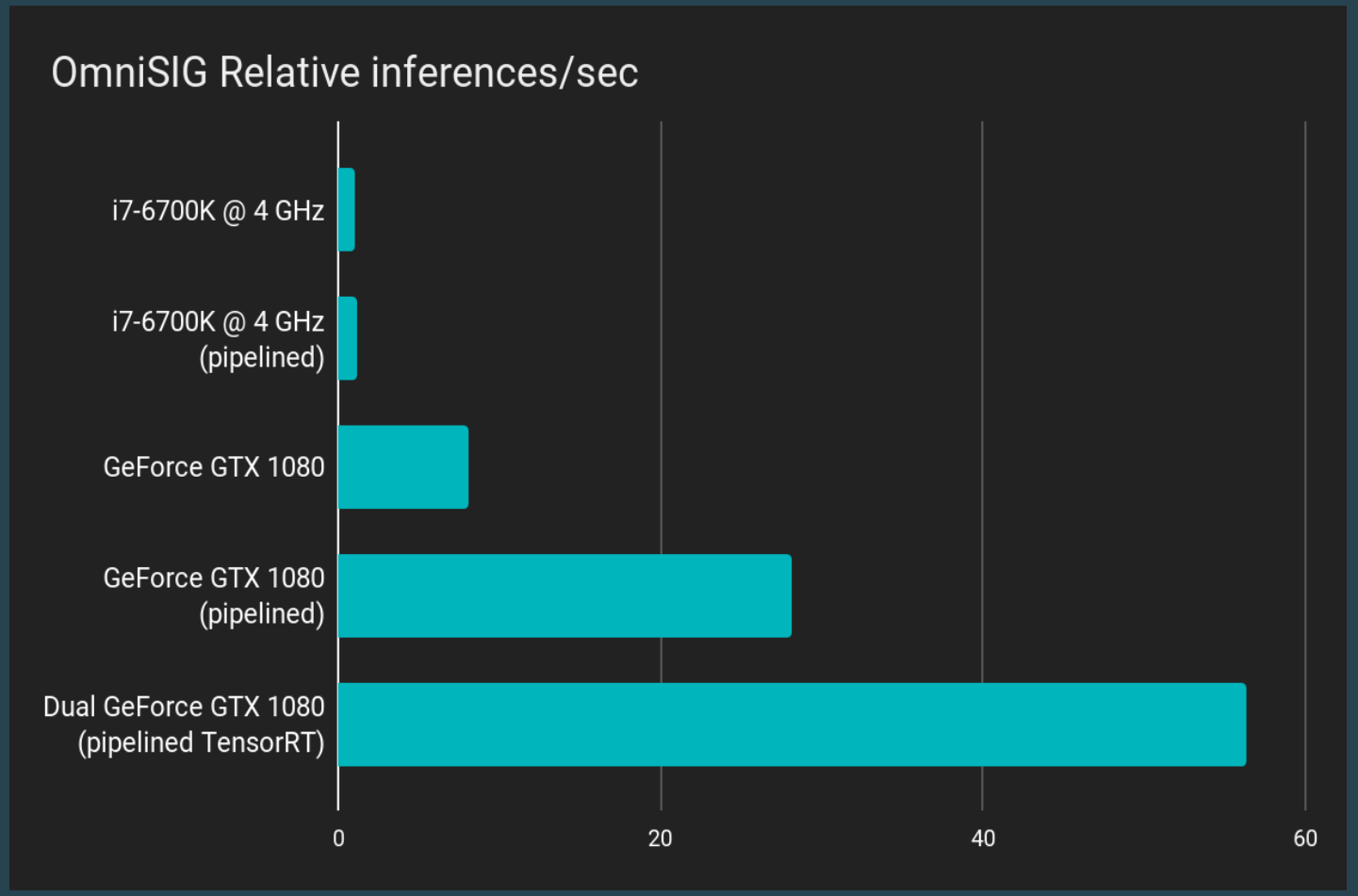
Building RF Sensing Systems with Deep Learning

- OmniSIG is the state of the art in applied wideband RF object detection
  - Making sense out of the RF firehose
  - Gbits of raw RF samples → kbits of SIGMF JSON describing all activity in the spectrum
  - Now deployed with a range of customers and signal sets – continuing to improve performance daily



Building RF Sensing Systems with Deep Learning

- Accelerating inference using TensorRT and optimized concurrent C++ deployment
- Managing concurrency throughout the application is critical
- Pipeline and data parallelism
- Performance scaling across CPU, to GPU, to TensorRT+GPU
- Still more optimization to come!



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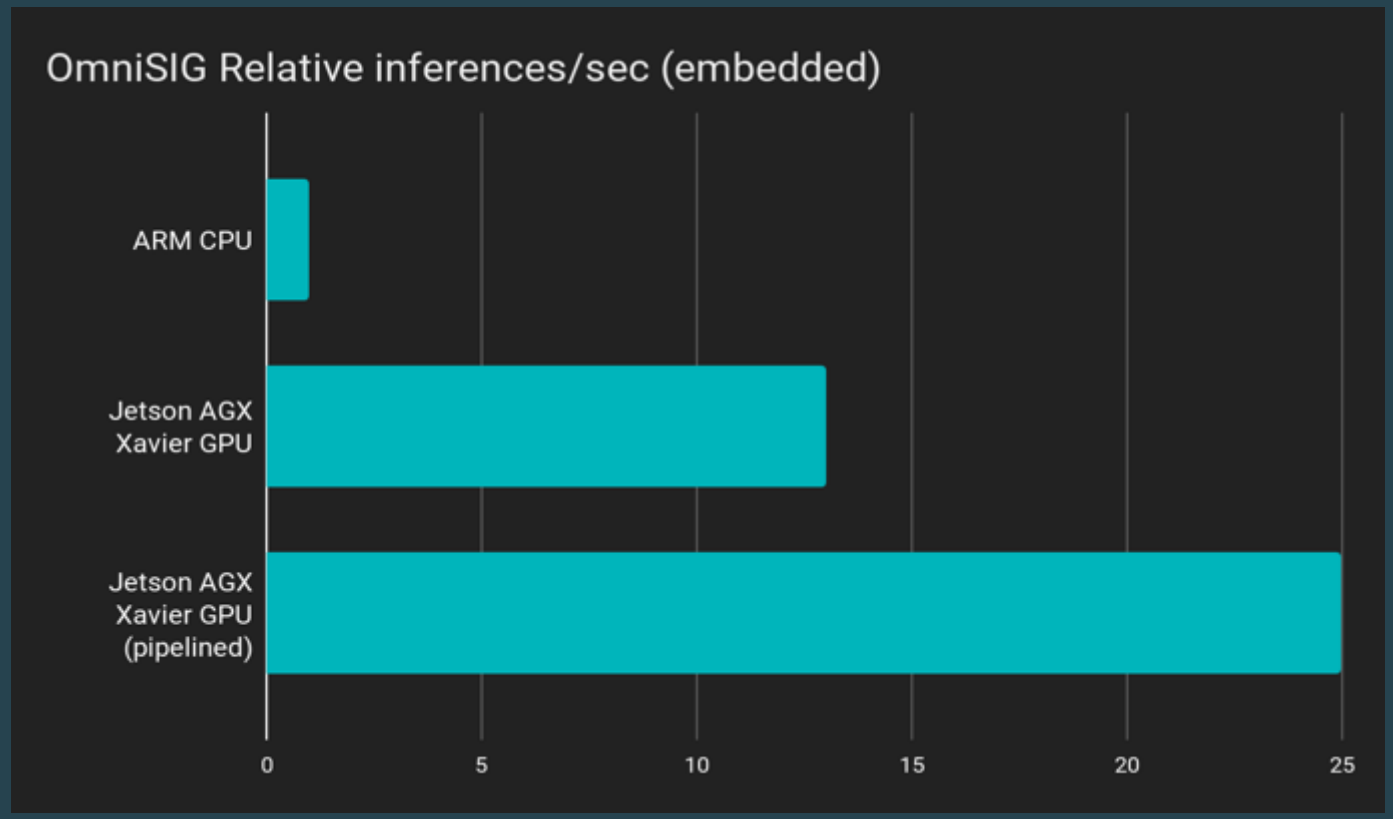
Building RF Sensing Systems with Deep Learning

- Accelerating and deploying inference at the edge on Xavier AGX
- Leveraging TensorRT to accelerate inference
- Closing gap between server and edge class devices
- Real time comms and sensing from low SWaP UAS platforms



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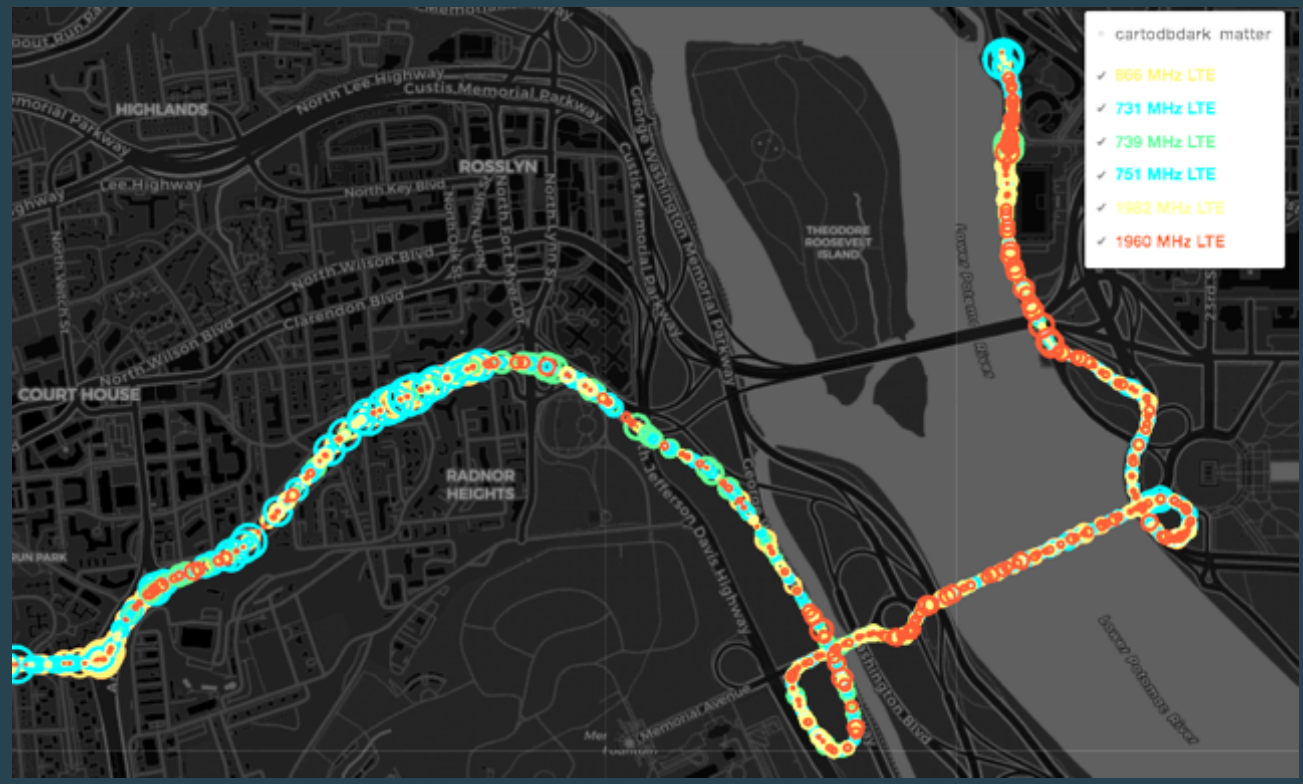
Building RF Sensing Systems with Deep Learning

- Real time detection makes new applications possible
- Streaming wideband RF signal detection, mapping, L1 statistics monitoring, and analysis
  - Rich performance measurement and drive analysis tools
  - Rapid propagation modeling and analysis tools for cellular planning and prediction
- Streaming anomaly detection and band change detection
- Streaming interference detection
- Physical perimeter security
- Cell deployment planning

OmniSig Mobile Cellular Performance Analytics



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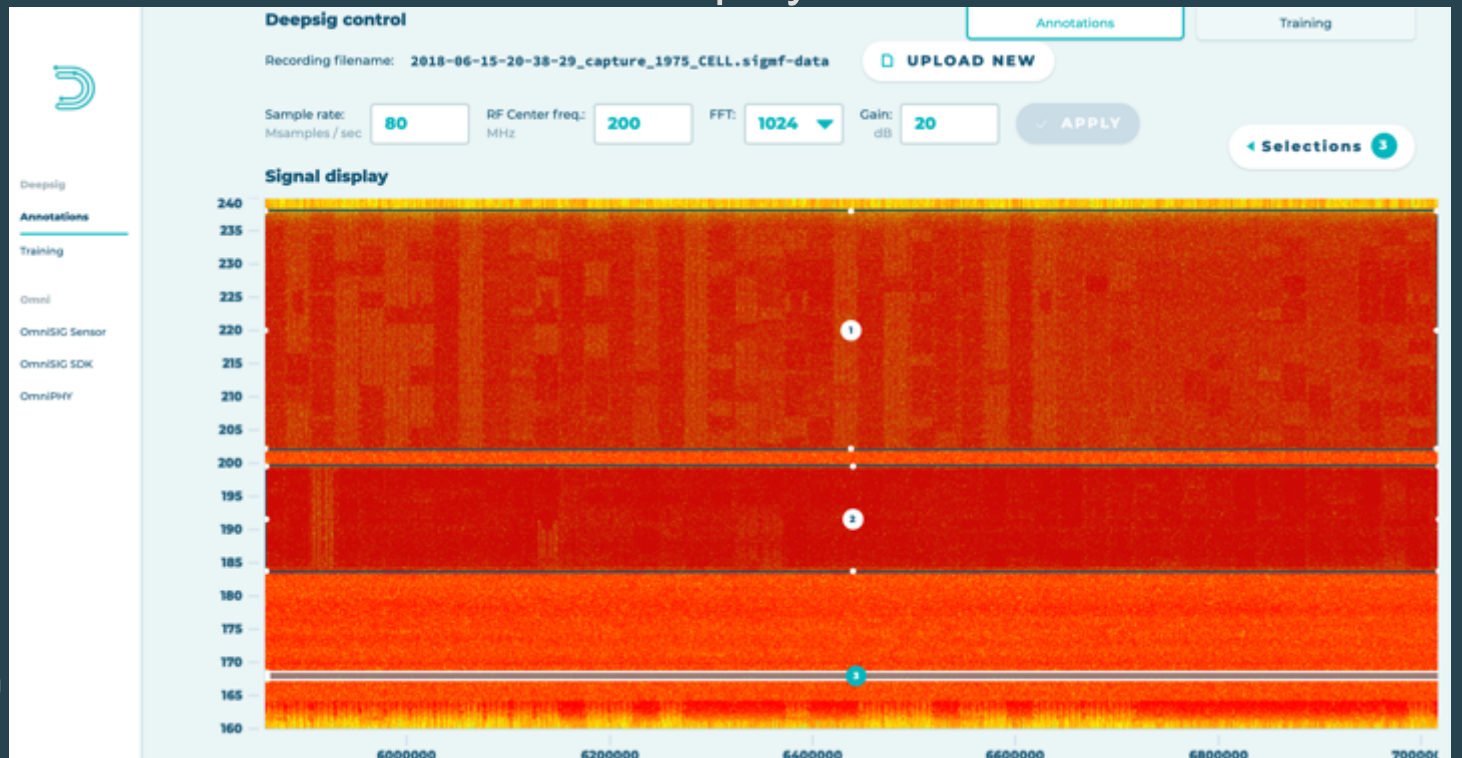
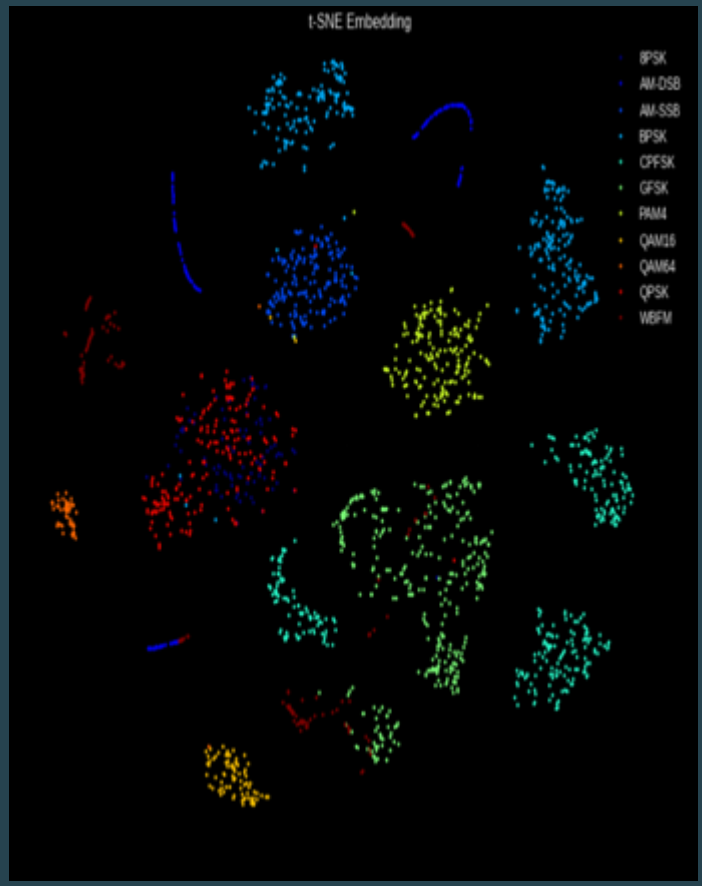
Building RF Sensing Systems with Deep Learning

- **OmniSIG SDK** – Learning on your data
- SDK tools to rapidly annotate and curate RF datasets
  - Make massive unlabeled RF data manageable
- Rapidly update OmniSIG on new datasets
- Makes DL based sensing widely accessible to others for many apps
- Convenient cloud and web based deployment





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IEEE Machine Learning for Communications ETI

- Growing interest in this area throughout research in industry and academia
- DeepSig is actively leading professional society initiatives
- IEEE Emerging Technology Initiative :: Machine Learning for Communications
  - Specifically focused on applications in the Physical Layer
  - Led by Jakob Hoydis, Nokia Bell Labs; Tim O'Shea, DeepSig; Elisabeth de Carvalho, Aalborg U.
  - http://mlc.committees.comsoc.org

  - Initial activities include:
    - MLC: Tutorials, Special Issues, Possible Summer School
    - MLC: Datasets & Competitions
      - Several current data competitions, culminating at IEEE Comm. Theory Workshop
    - MLC: Industry relationships, blog posts, mail list
    - MLC: Research paper library, references, curation

Thanks

DeepSig Inc.
3100 N. Clarendon Blvd.
Suite #200
Arlington, VA, 22201

info@deepsig.io
(703) 340-1451

https://deepsig.io

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