NVIDIA GTC SILICON VALLEY MAR 17-21 2019

SI ANALYTICS

# How AI is Changing the Way To Understand the Earth and Us?

GPU Tech Conference 2019 (S9495)

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Founder and CEO
SI Analytics

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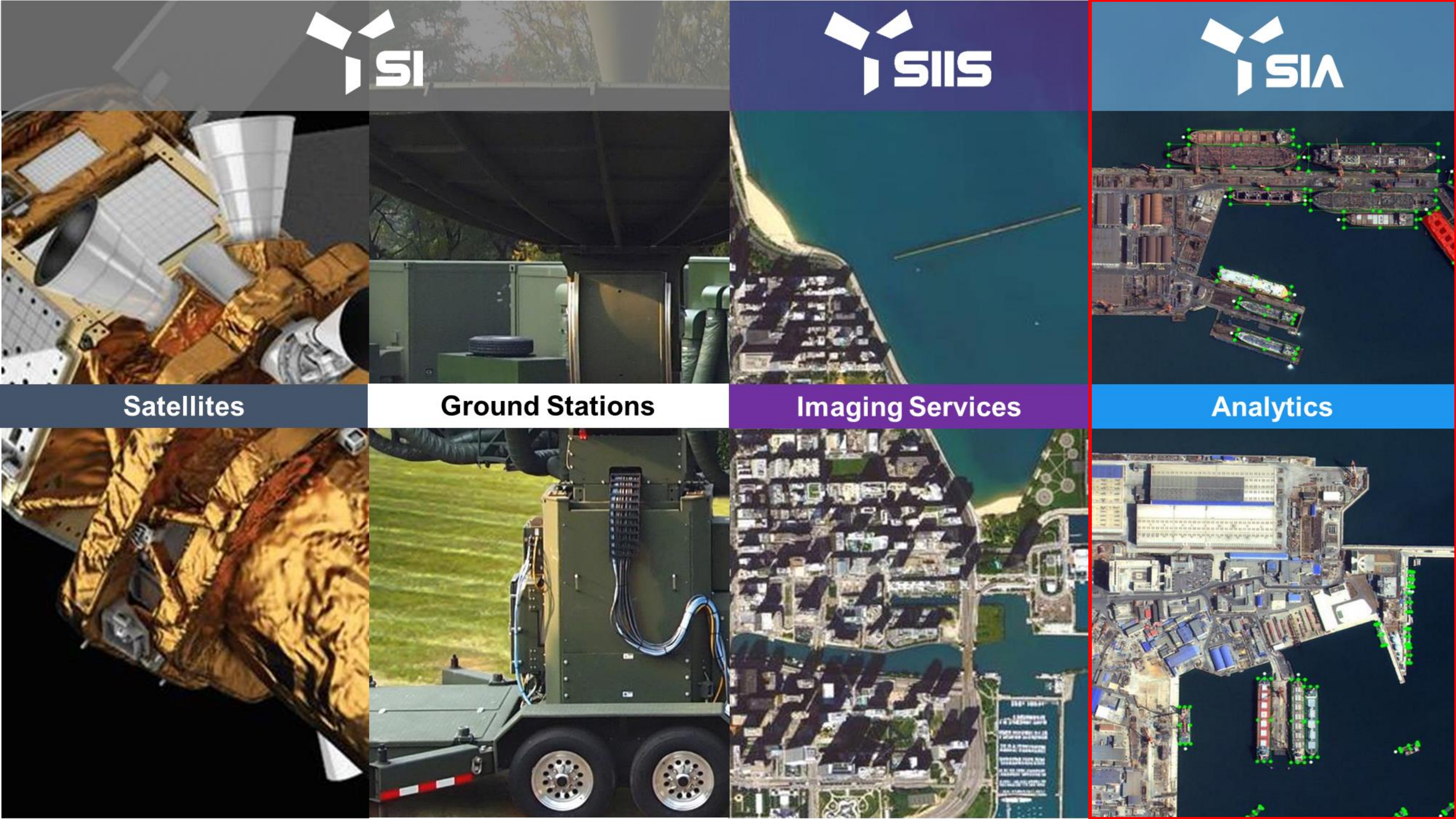
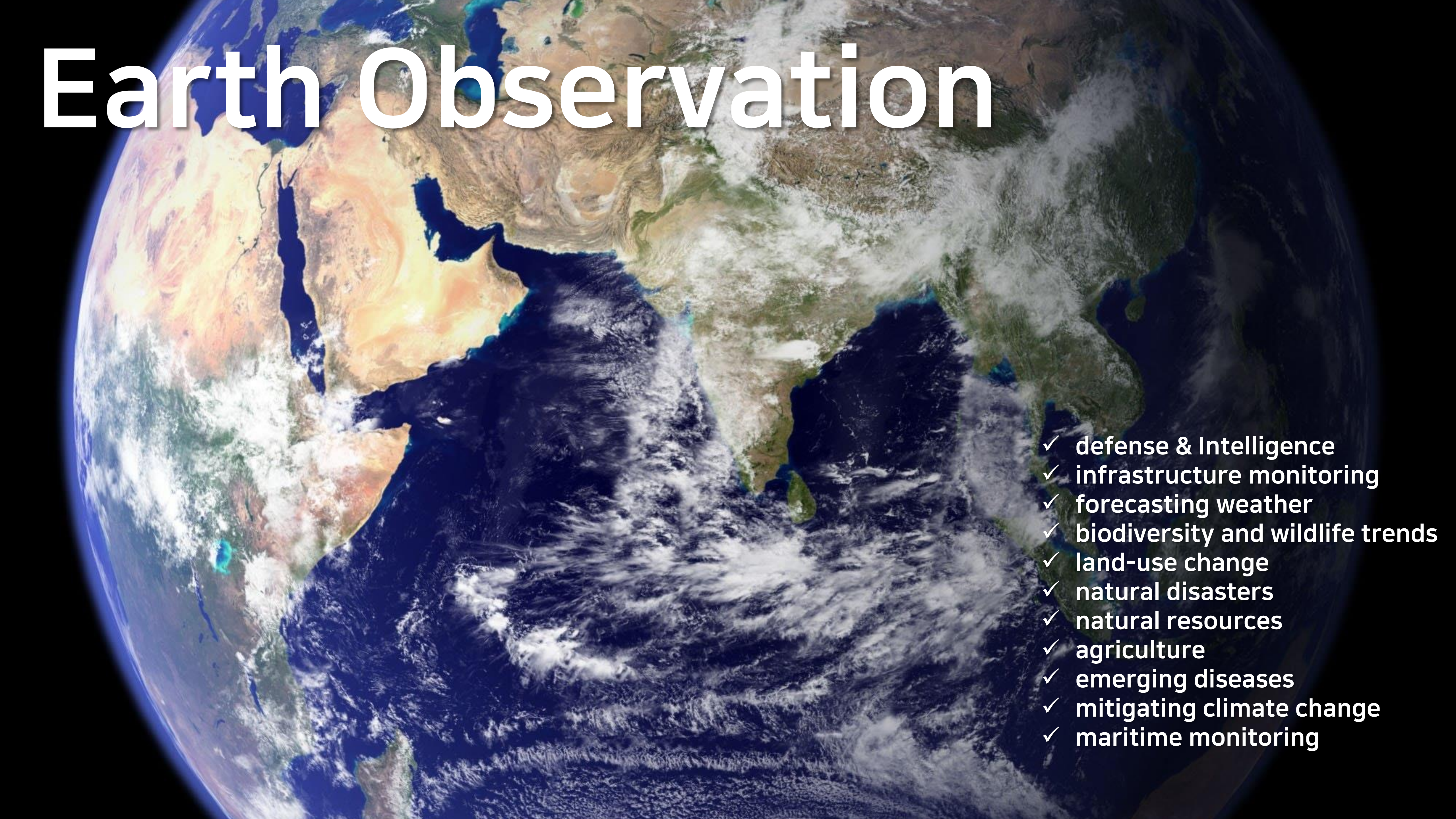
- Case #1: **Object Detection and Classification with TensorRT**
- Case #2: **Road Extraction** (DeepGlobe Challenge)

- **Conclusions**

# 01 Earth Observation


SI
SIIS
SIA
Satellites
Ground Stations
Imaging Services
Analytics



# Earth Observation

- ✓ defense & Intelligence
- ✓ infrastructure monitoring
- ✓ forecasting weather
- ✓ biodiversity and wildlife trends
- ✓ land-use change
- ✓ natural disasters
- ✓ natural resources
- ✓ agriculture
- ✓ emerging diseases
- ✓ mitigating climate change
- ✓ maritime monitoring

KITSAT-1 (1992)
GSD: 400m

KITSAT-2 (1993)
GSD: 200m

KITSAT-3 (1999)
GSD: 13m

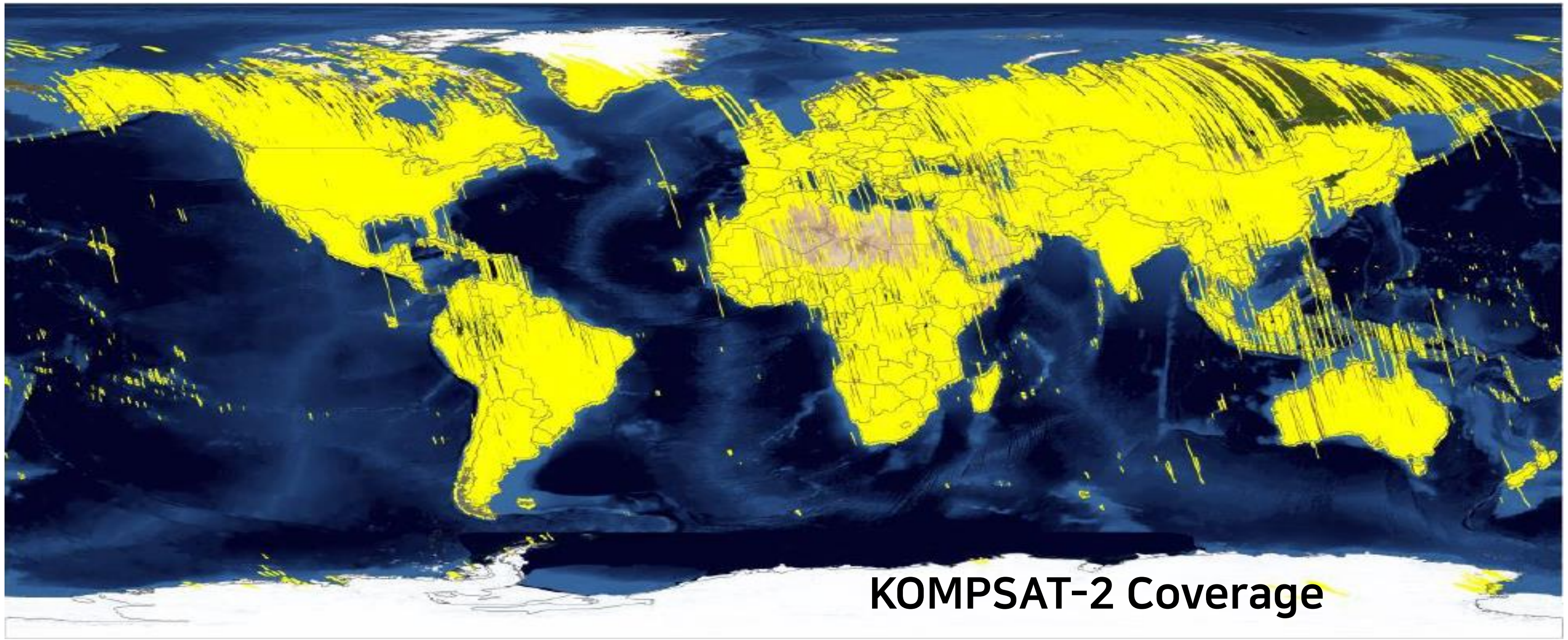

KOMPSAT-3A
(2015)
GSD: 0.55m

This image of New York City, taken Nov. 4, 2015, by South Korea's Kompsat-3A satellite, is an example of the products that SI Imaging Services of Korea has begun selling on the market.

# Earth Observation with Artificial Intelligence

| | Traditional EO | EO with AI |
|---|---|---|
| **ORDERING** | On-demand data<br>Reactive tasking based on single satellites | On-demand analysis<br>Reactive tasking based on constellations |
| | Data cost is driven by the data source (higher CAPEX system equates to higher data prices); lower-cost systems would imply lower data prices and services development | |
| **PROCESSING** | Owned data analysis<br>Manual/automated operations on desktop or internal network | Cloud approach + Owned data analysis<br>Deep Learning based on Big Data |
| **DELIVERING** | Ad hoc services, ordering through reseller or web-portal tasking<br>Reselling network, privileged distributors (government user focused) | Service subscription basis<br>Platform deliveries (private sector focused) and reselling network for governments |

# Coverage




| KOMPSAT Archive | KOMPSAT-2 (EO) | KOMPSAT-3 (EO) | KOMPSAT-3A (EO) | KOMPSAT-5 (SAR) |
|---|---|---|---|---|
| **Scenes** (Dec 15, 2016) | 2,645,022 | 781,389 | 80,340 | 52,245 |
| **Data volume** (TB) | 743 TB | 700 TB | 59 TB | 104 TB |
| **Coverage per day** ($km^2$) | 1,700,000 | 300,000 | 240,000 | Up to 1,000,000 |


South Korea
(100,210 $km^2$)

England
(243,610 $km^2$)

USA
(9,834,000 $km^2$)

# Volume

0.7KB

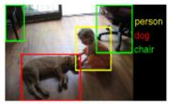
**MNIST**

(28,28,1)

150KB

**ImageNet**

(224,224,3)



87MB

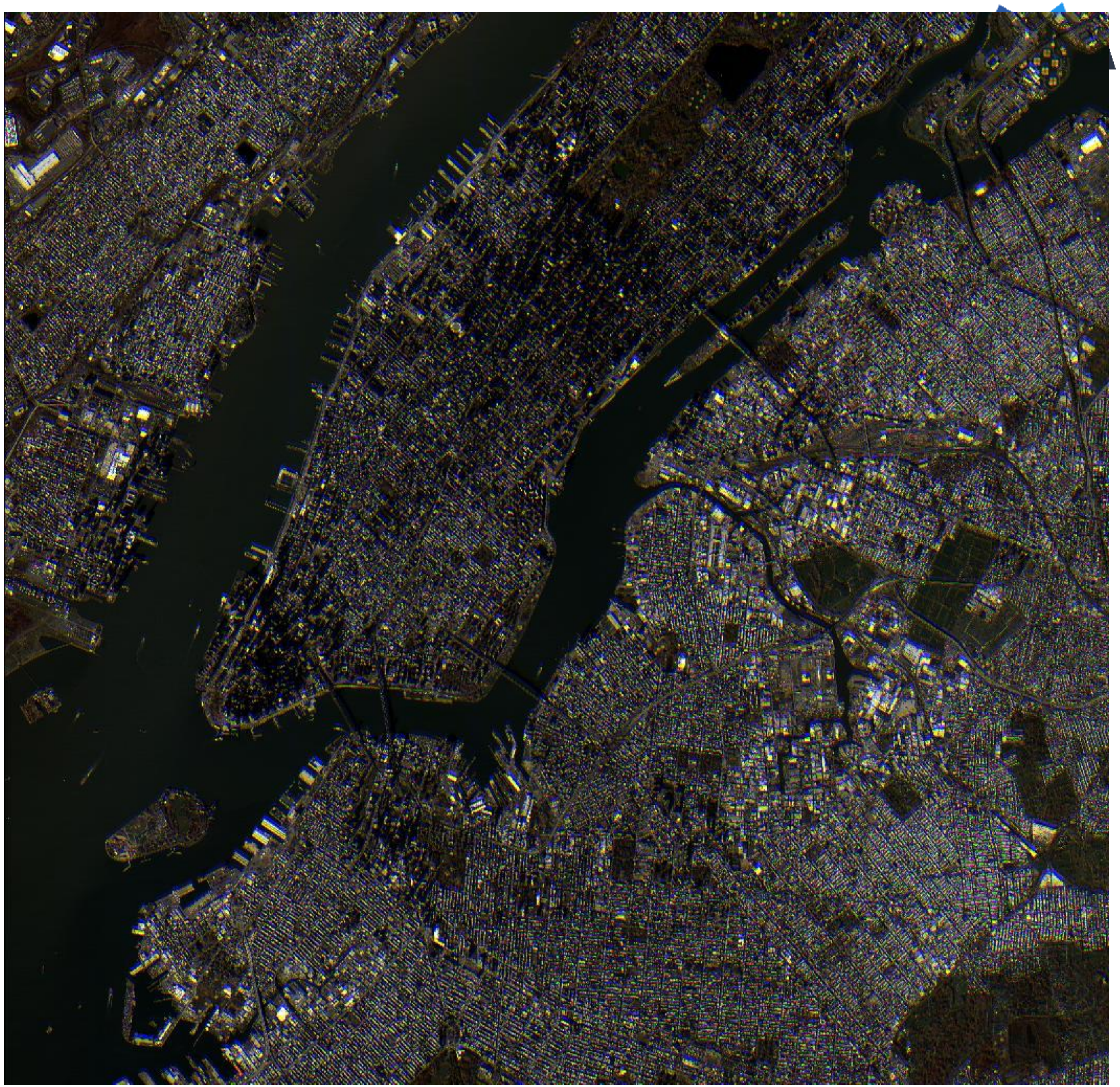
**SpaceNet**

(3K,3K,8)

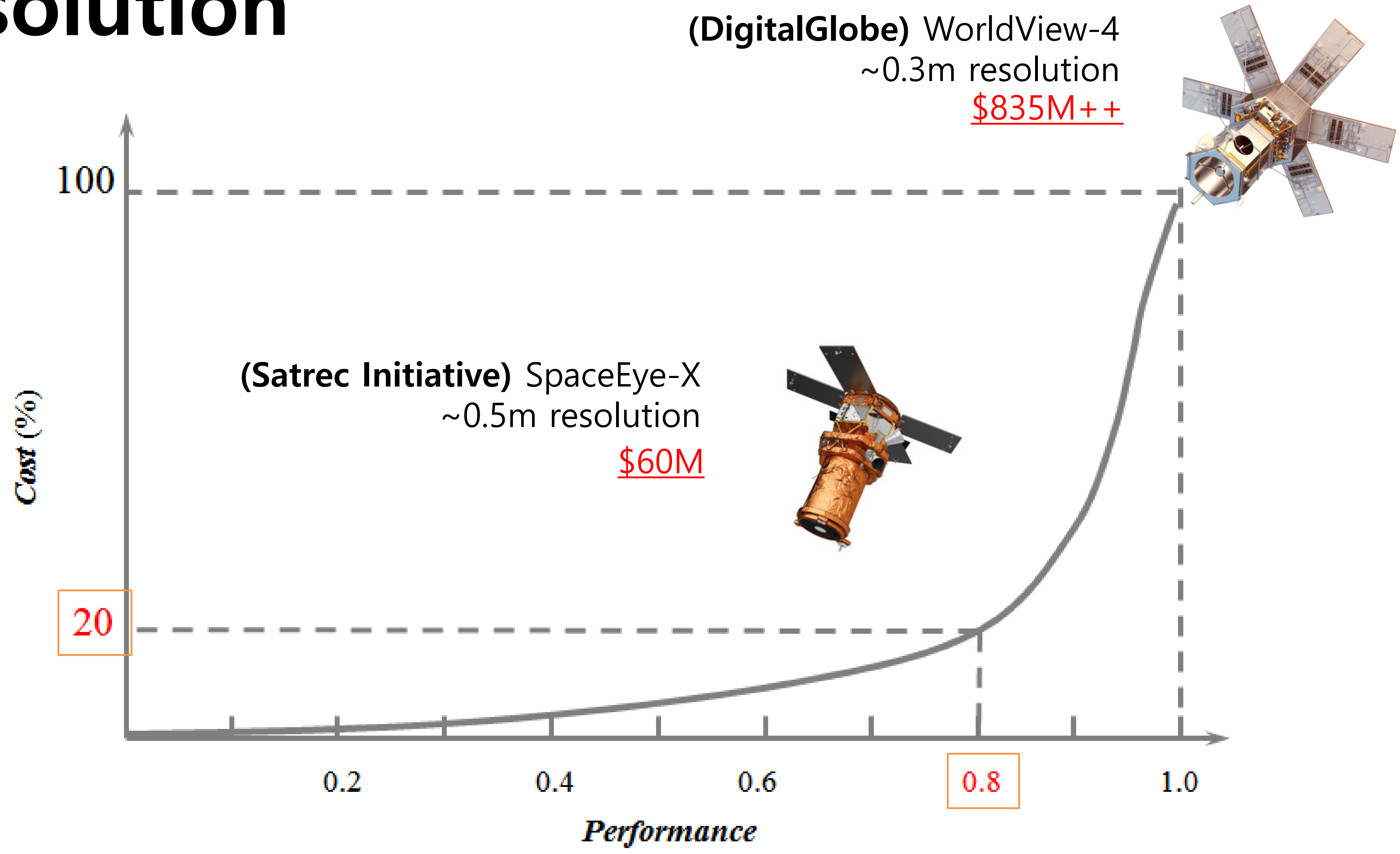
2.5GB

**Satellite Scene**

(25K, 25K, 4)

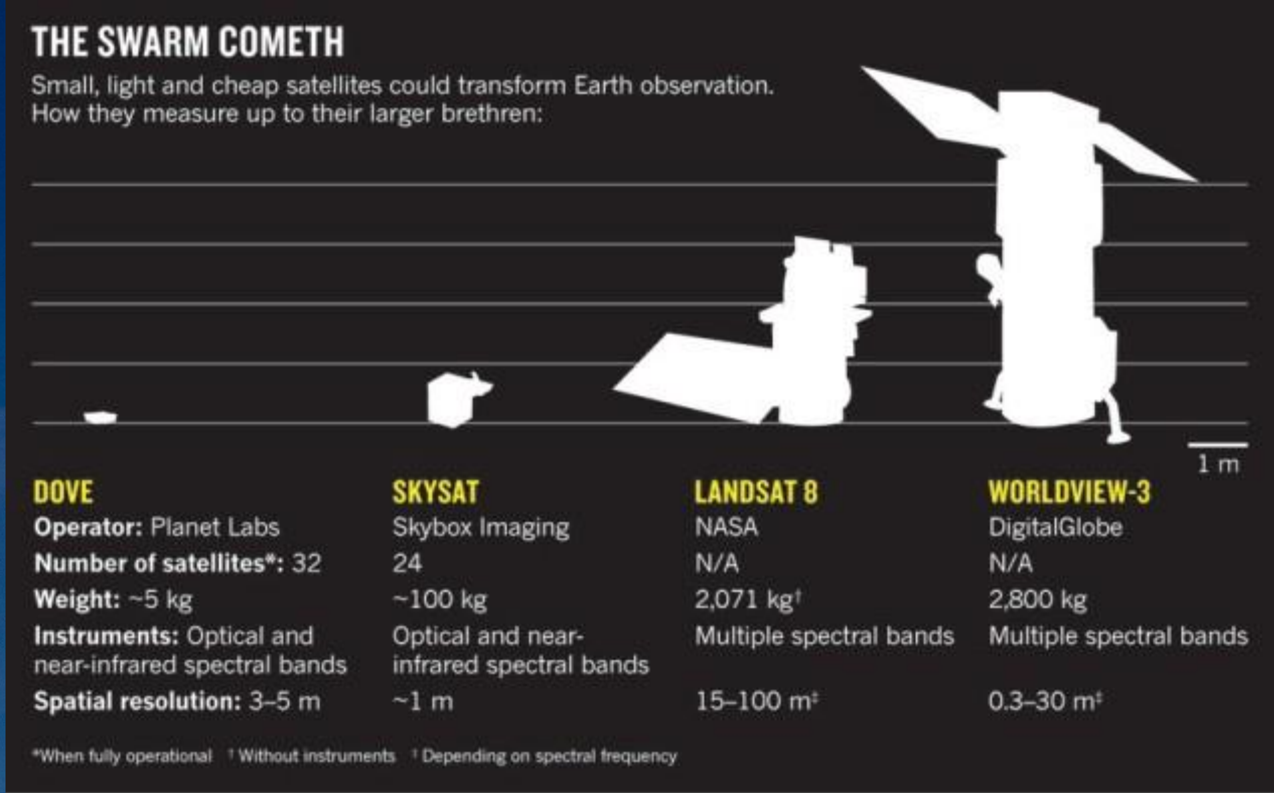


# Resolution


(DigitalGlobe) WorldView-4
~0.3m resolution
$835M++
(Satrec Initiative) SpaceEye-X
~0.5m resolution
$60M
100
20
Cost (%)
0.2
0.4
0.6
0.8
1.0
Performance

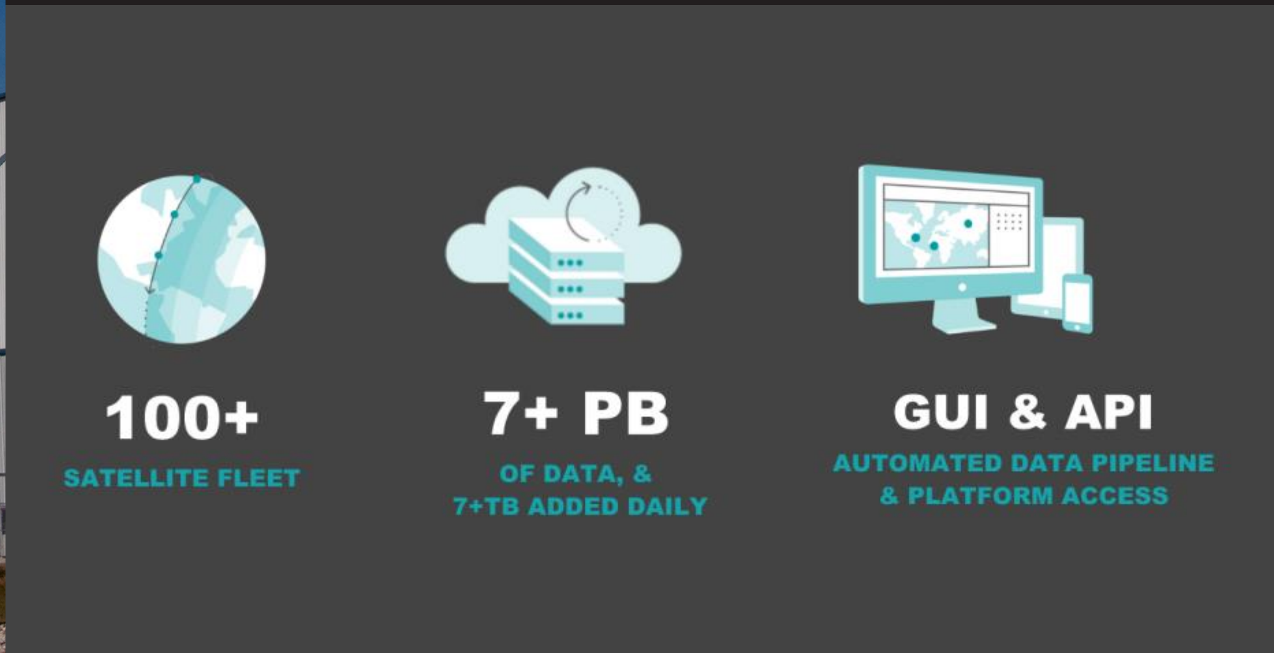
# Reusable rocket and Constellation space program

- ✓ Low launch cost
- ✓ Low manufacturing cost
- ✓ Huge daily data


| | DOVE | SKYSAT | LANDSAT 8 | WORLDVIEW-3 |
|---|---|---|---|---|
| **Operator:** | Planet Labs | Skybox Imaging | NASA | DigitalGlobe |
| **Number of satellites*:** | 32 | 24 | N/A | N/A |
| **Weight:** | ~5 kg | ~100 kg | 2,071 kg† | 2,800 kg |
| **Instruments:** | Optical and near-infrared spectral bands | Optical and near-infrared spectral bands | Multiple spectral bands | Multiple spectral bands |
| **Spatial resolution:** | 3–5 m | ~1 m | 15–100 m‡ | 0.3–30 m‡ |

*When fully operational †Without instruments ‡Depending on spectral frequency



02

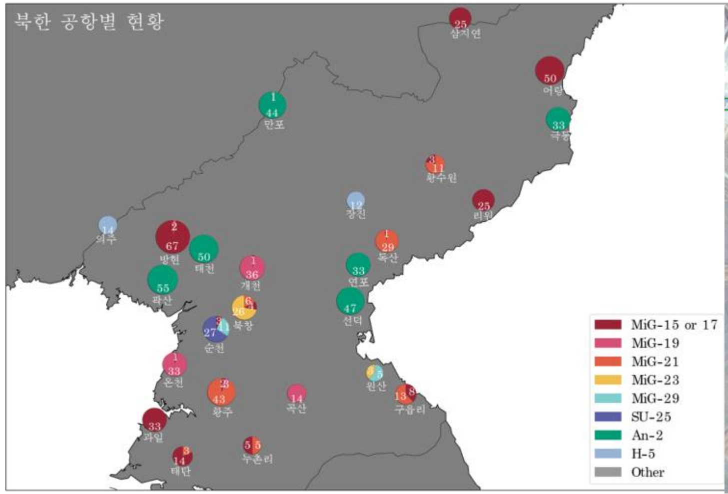
# Object Detection and Classification

# Detection and Classification

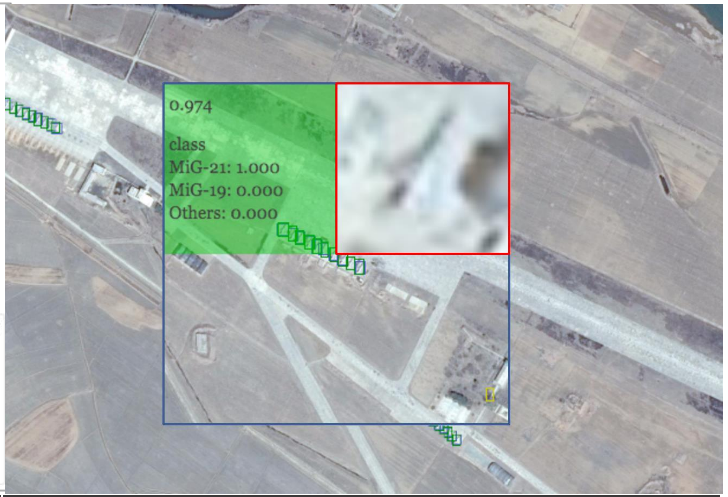
- <u>**Aircraft Detection & Classification**</u>
  - **Task:** Detect and classify all aircraft on North Korea Airforce bases
  - **Construct Own Dataset** for civil aircraft and military fighters
  - **Compatibility:** Transfer Learning (GoogleEarth & KOMPSAT 2, 3, 3A)
  - **Detection Accuracy**: 89%
  - **Classification Accuracy**: 95.2%
  - **Target Area**: All NK Airforce bases
  - **Fill the gap for rare observation:** Combine synthetic data from GAN

Detection Results (Haneda Airport from KOMPSAT-2, 3, 3A)

Detection and Classification (NK Airforce bases from GoogleEarth)



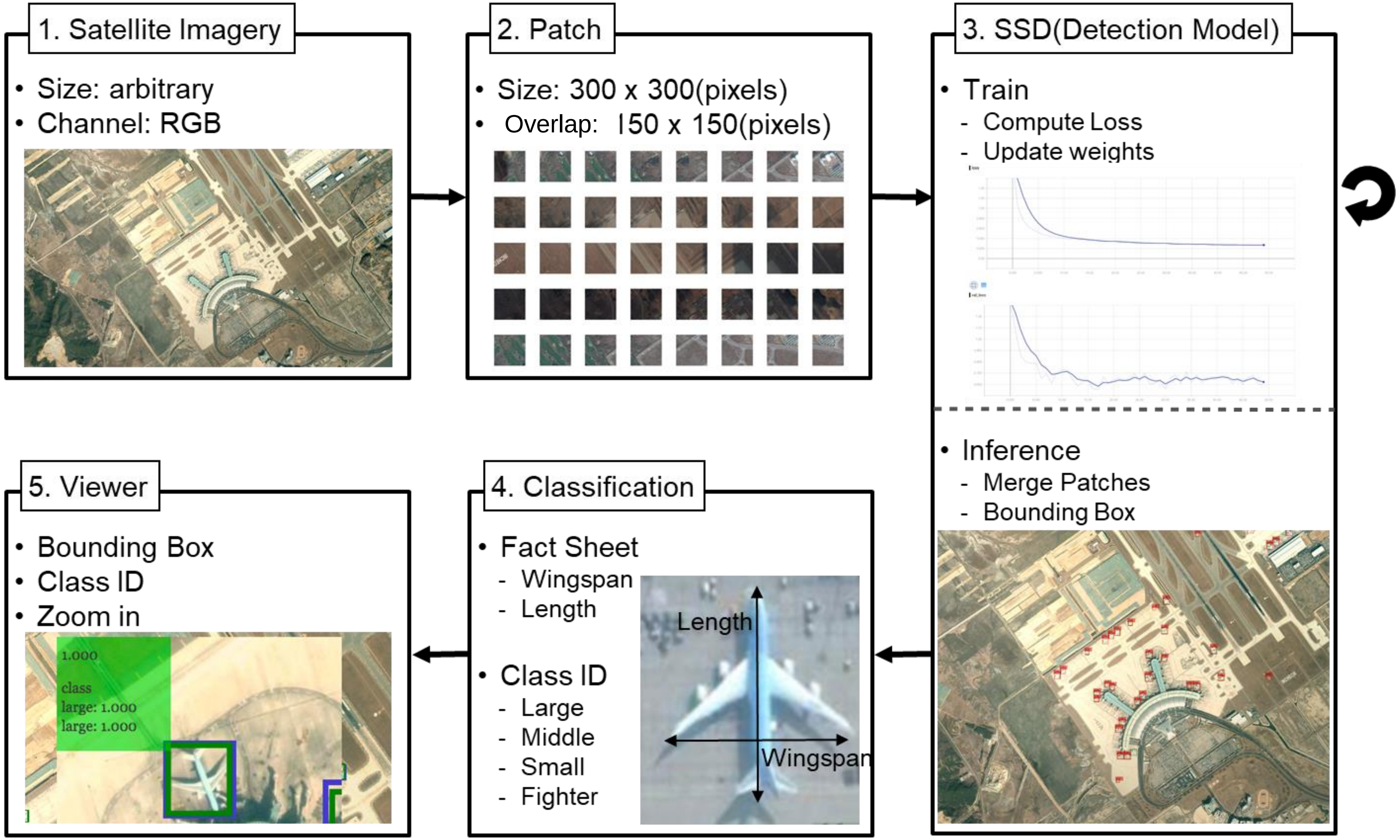

Automatically generated deployment status report (NK Airforce)



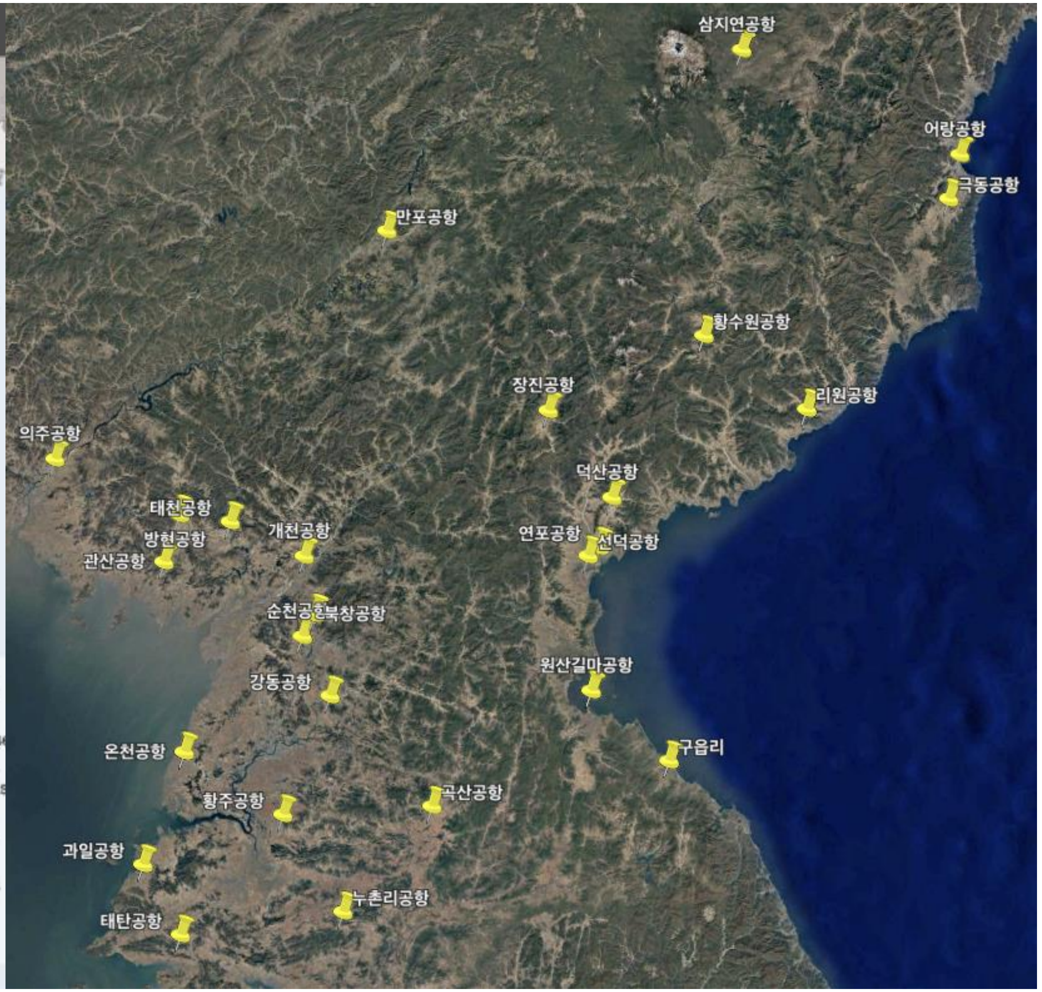

User Interface for Detection and Classification

# Detection and Classification

- **Objective**: Detect aircraft and fighter, then classify the types of aircraft

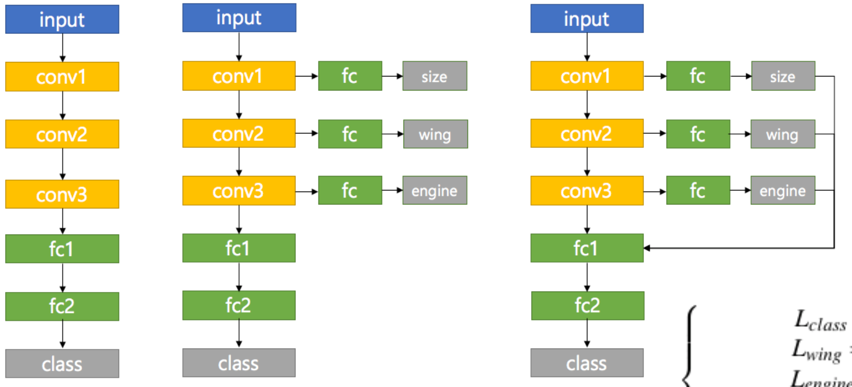


# North Korean Air Forces (25 regions)

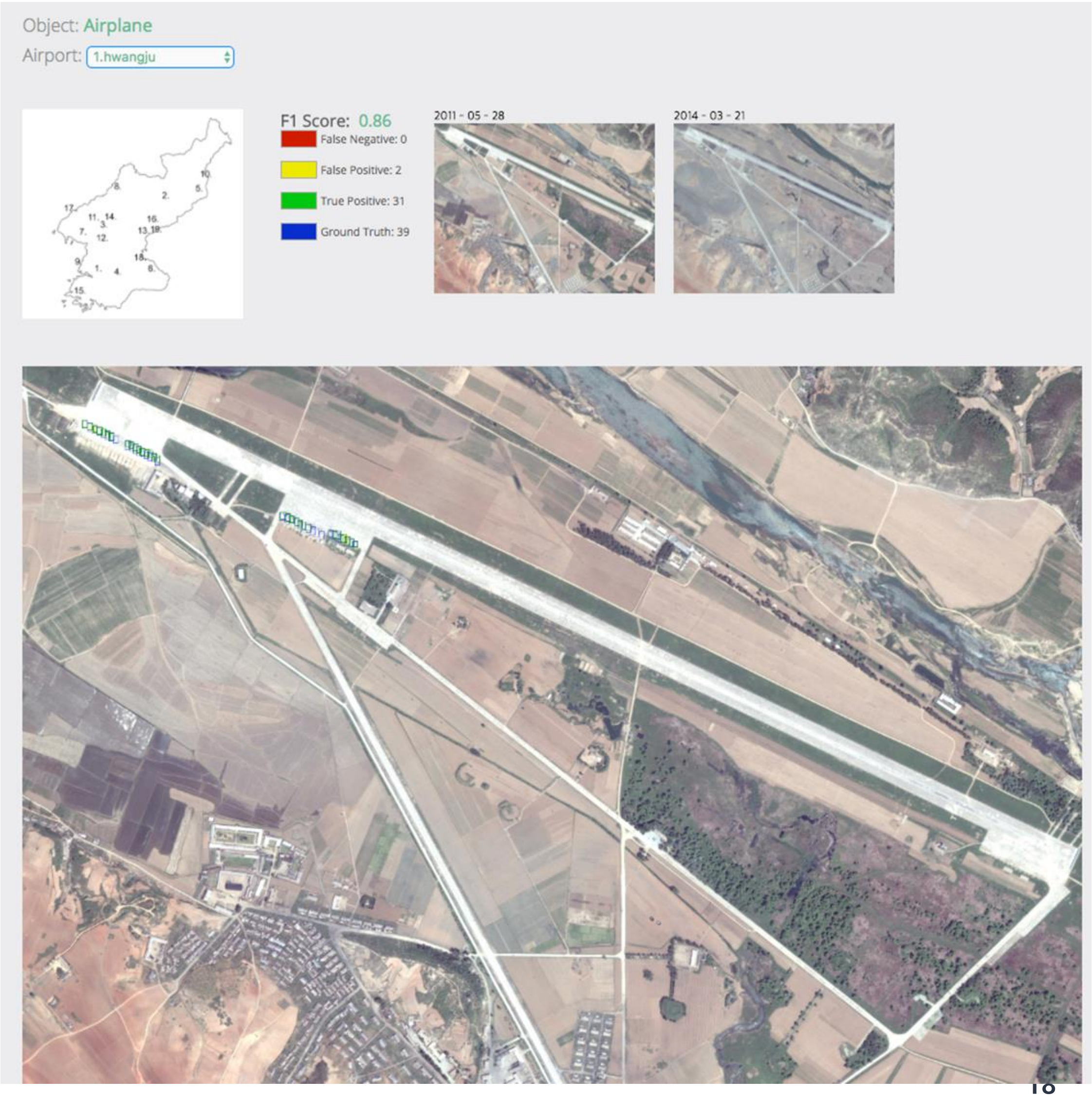
# Detection Results

- ROI: 25 Airports (North Korea)
- Detection results:
  Precision (0.84), Recall (0.79), F1 (0.82)
- Classification results:
  Top-1 (91.5%), Top-3 (95.4%)




(a) (b) (c)

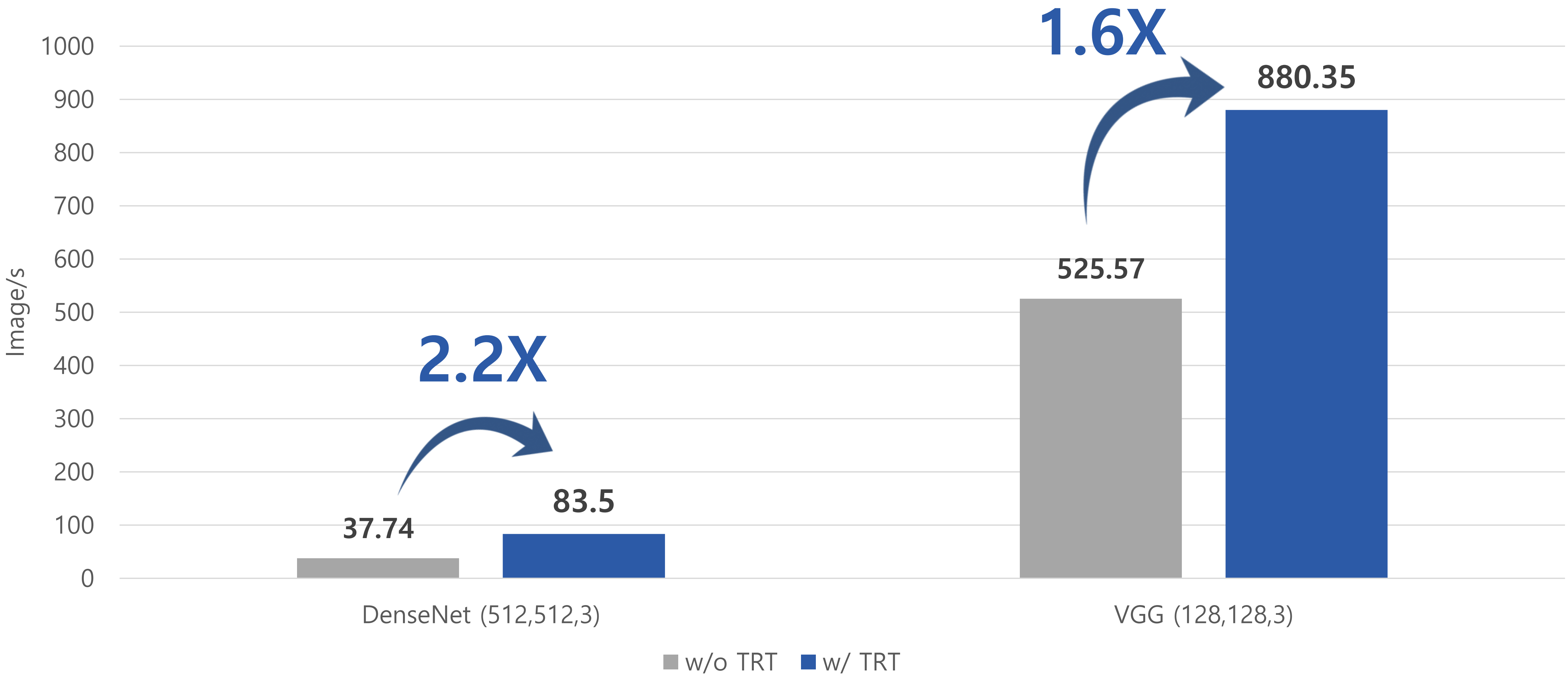
$$
\begin{cases}
L_{class} = -\sum_i c_i' \log(c_i) \\
L_{wing} = -\sum_i w_i' \log(w_i) \\
L_{engine} = -\sum_i e_i' \log(e_i) \\
L_{size} = (x - x')^2 + (y - y')^2 \\
L_{total} = L_{class} + L_{size} + L_{wing} + L_{engine}
\end{cases}
$$



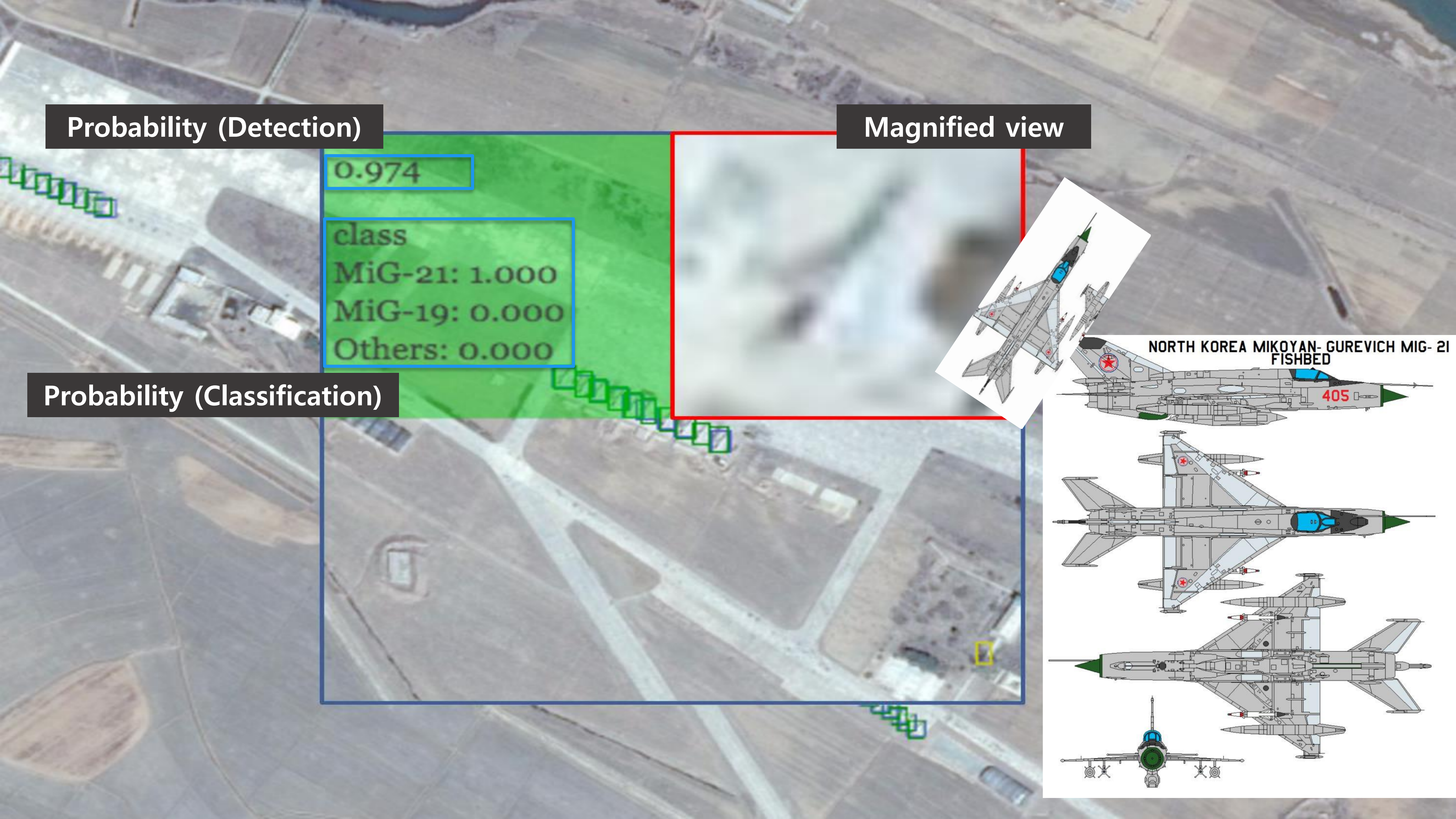


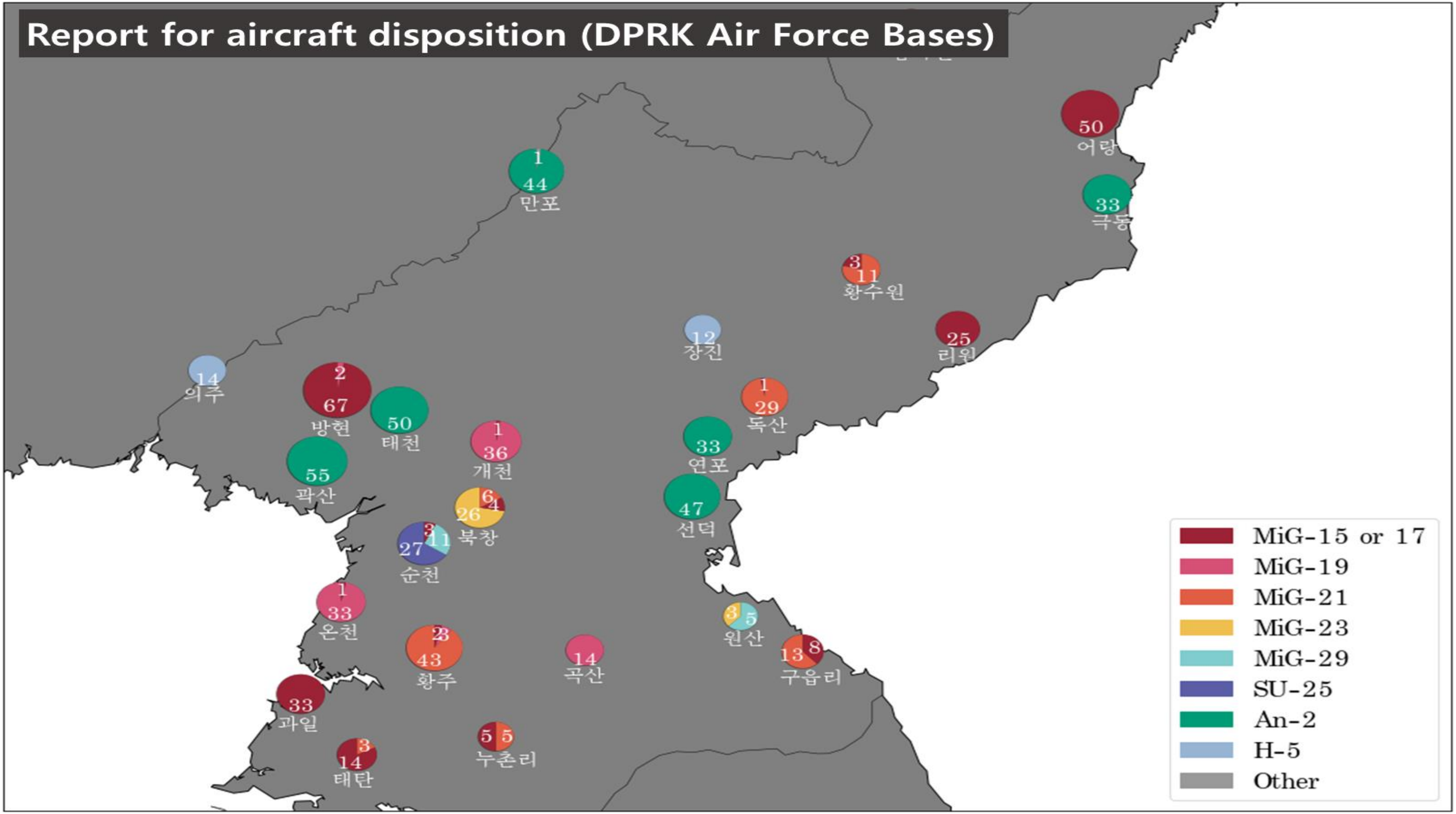

S. Jeon, J. Seo and T. Jeon, **"Multi-task Learning for Fine-grained Visual Classification of Aircraft"**, *MLAIP Workshop @ ACML (2017)*

# Classification with TensorRT




* Experiments on DGX-Station

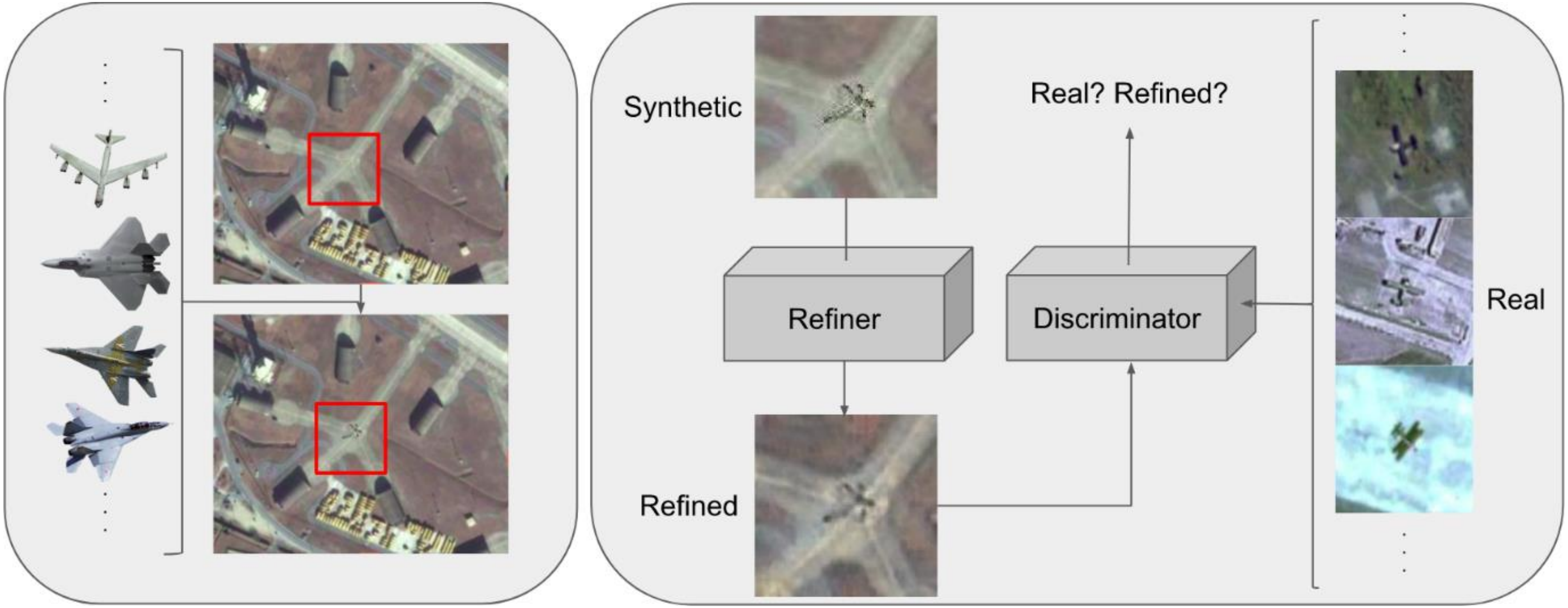

Probability (Detection)
Magnified view
0.974
class
MiG-21: 1.000
MiG-19: 0.000
Others: 0.000
Probability (Classification)
NORTH KOREA MIKOYAN- GUREVICH MIG- 21
FISHBED
405



Report for aircraft disposition (DPRK Air Force Bases)
50
어랑
33
극동
1
44
만포
3
11
황수원
25
리원
12
장진
14
의주
2
67
방현
50
태천
1
29
독산
1
36
개천
33
연포
55
곽산
6
4
26
북창
47
선덕
3
11
27
순천
1
33
온천
3
5
원산
2
3
43
황주
14
곡산
13
8
구읍리
33
과일
3
14
태탄
5
5
누촌리
MiG-15 or 17
MiG-19
MiG-21
MiG-23
MiG-29
SU-25
An-2
H-5
Other

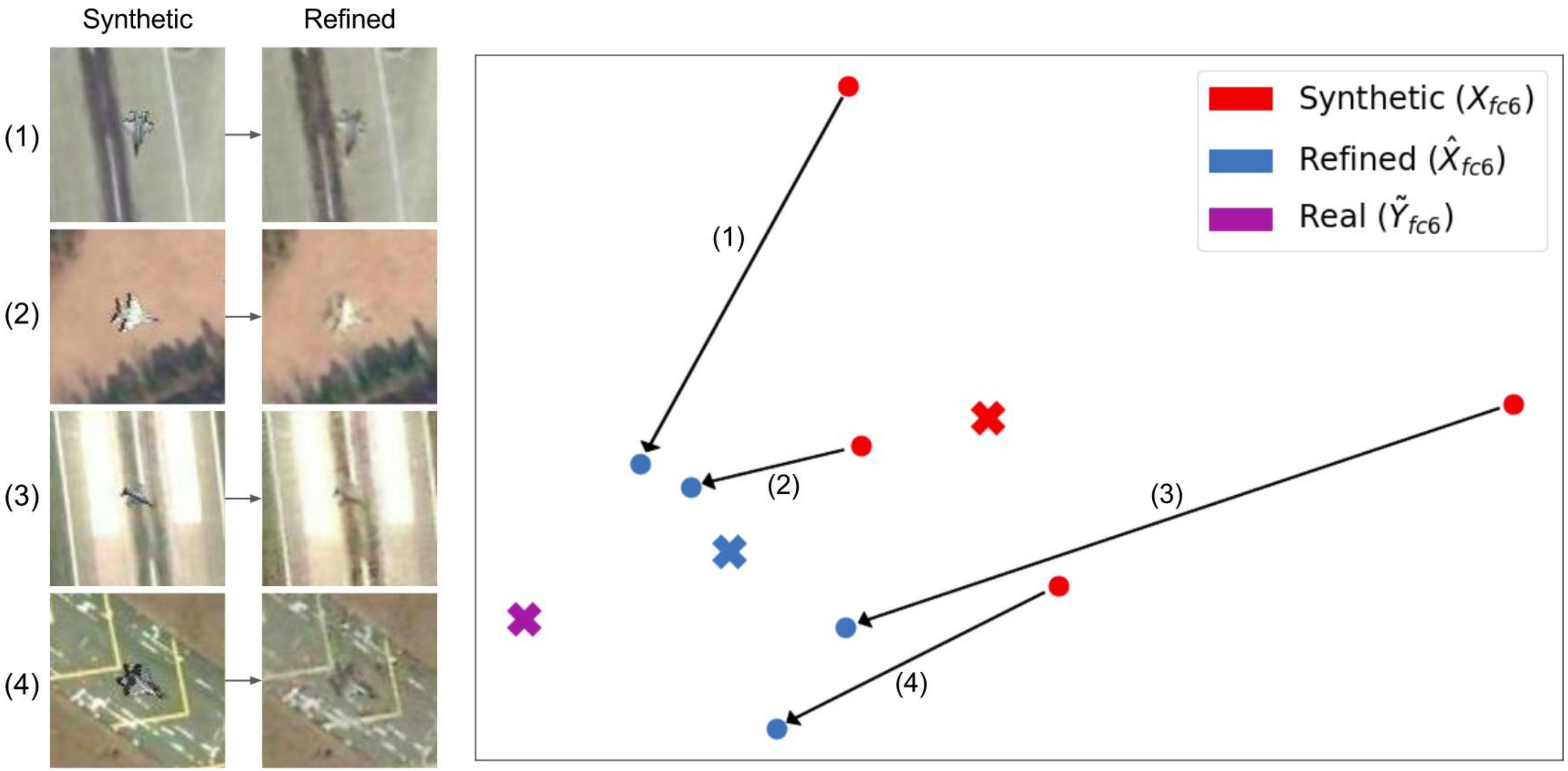
# Synthetic Data Generator and Refiner

J. Seo, S. Jeon and T. Jeon, **"Domain Adaptive Generation of Aircraft on Satellite Imagery via Simulated and Unsupervised Learning"**, *MLAIP Workshop @ ACML (2017)*




**Adversarial Learning to refine the synthetic images from reference images**

# Synthetic Data Generator and Refiner




Qualitative and Quantitative Evaluation

# Summary

- **Task:** Detect and classify all aircraft on North Korea Airforce bases
- **Construct Own Dataset** for civil aircraft and military fighters
- **Compatibility:** Transfer Learning between GoogleEarth and KOMPSAT 2, 3, 3A
- **TensorRT**: Speed-up to 2.2X (DenseNet) and 1.6X (VGG).
- **Fill the gap for rare observation:** Combine synthetic data from GAN

# 03 Road Extraction

# Road Extraction

- **Automatic Mapping from Image to Road**

- Usages
  - Automated Map Update
  - Urban Planning
  - City Monitoring
  - Road Navigation
  - Operation of Unmanned Vehicles
  - Attention of Safety Road

# DeepGlobe Challenge (CVPR 2018)

DEEPGLOBE - CVPR18 | Home | Challenge | Leaderboard | Workshop | Committee | Resources

## Challenge Tracks

### Road Extraction

In disaster zones, especially in developing countries, maps and accessibility information are crucial for crisis response. We would like to pose the challenge of automatically extracting roads and street networks from satellite images. This will be a binary segmentation problem to detect all the road pixels in each area. The evaluation will be based on the accuracy of

### Building Detection

Modeling population dynamics is of great importance for disaster response and recovery, and detection of buildings and urban areas are key to achieve so. We would like to pose the challenge of automatically detecting buildings from satellite images. This problem is formulated as a binary segmentation problem to localize all building polygons in

### Land Cover Classification

Automatic categorization and segmentation of land cover is of great importance for sustainable development, autonomous agriculture, and urban planning. We would like to introduce the challenge of automatic classification of land cover types. This problem is defined as a multi-class segmentation task to detect areas of urban, agriculture,

SIA

facebook

IEEE GRSS Geoscience and Remote Sensing Society

DigitalGlobe

UBER

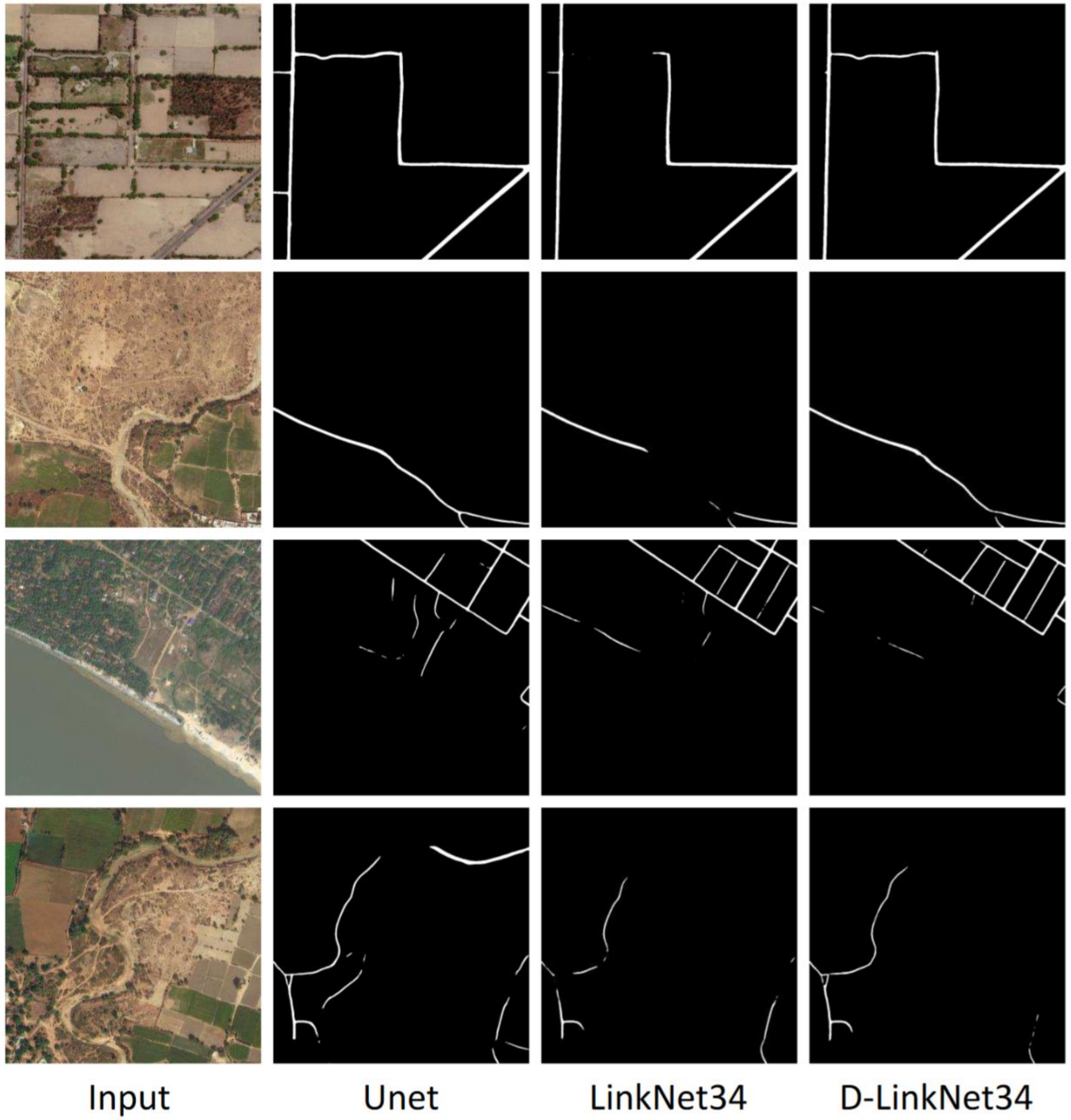
planet

# Challenges of Road Extraction

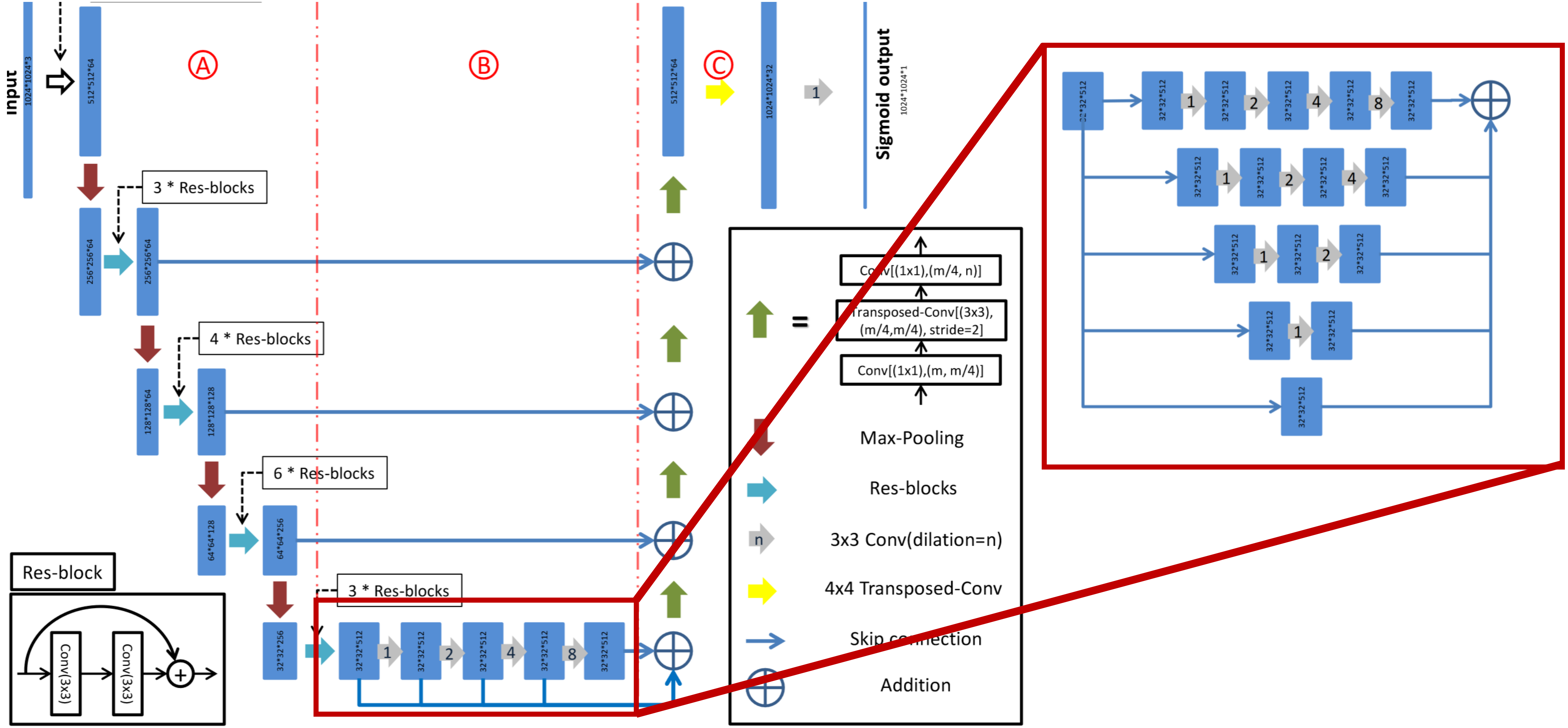
- Wide-area Processing
- Noisy Labeling & Ambiguity
- Extraction of Road Network Topology
- *Model Efficiency*
- *Intrinsic Noise of Road Image*

# D-LinkNet: 1st Winner of the 2018 Challenge

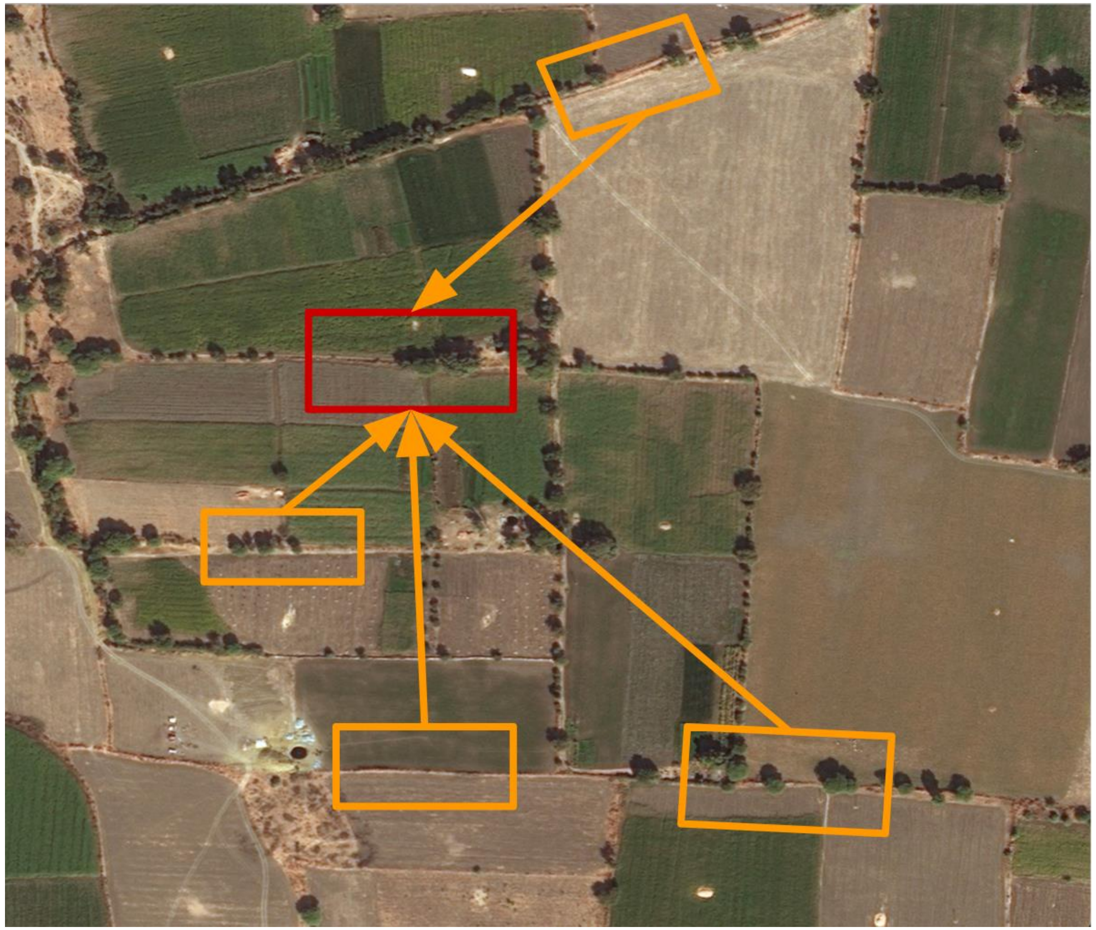
| Model | IoU on validation set |
|---|---|
| Unet (7 pooling layers, no-pretrain) | 0.6294 |
| LinkNet34 (pretrained encoder) | 0.6300 |
| Ensemble of Unet and LinkNet34 | 0.6394 |
| D-LinkNet (pretrained encoder) | 0.6412 |



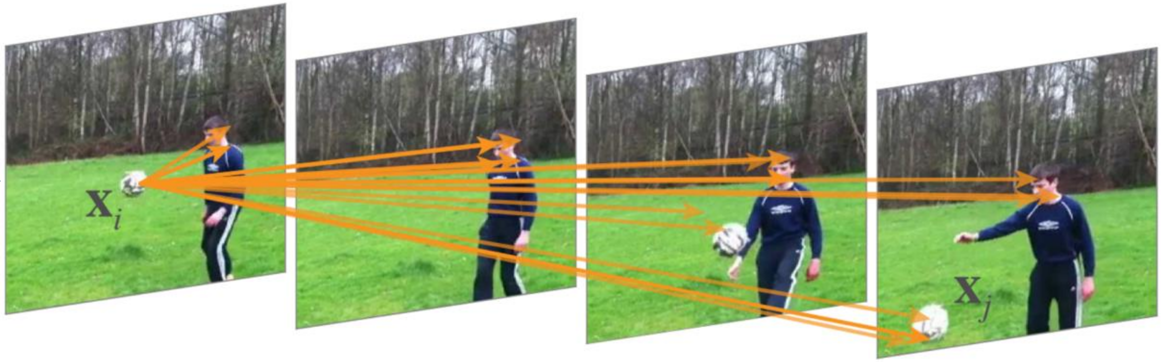
# D-LinkNet: 1st Winner of the 2018 Challenge



# Our Motivation

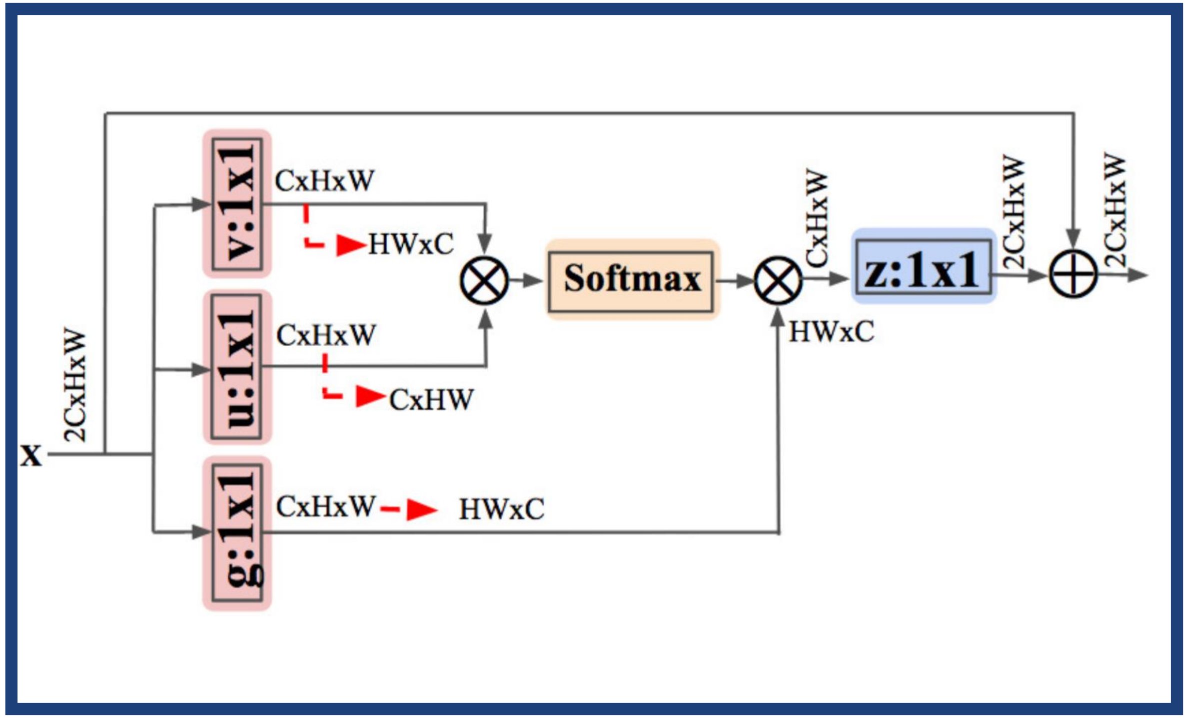


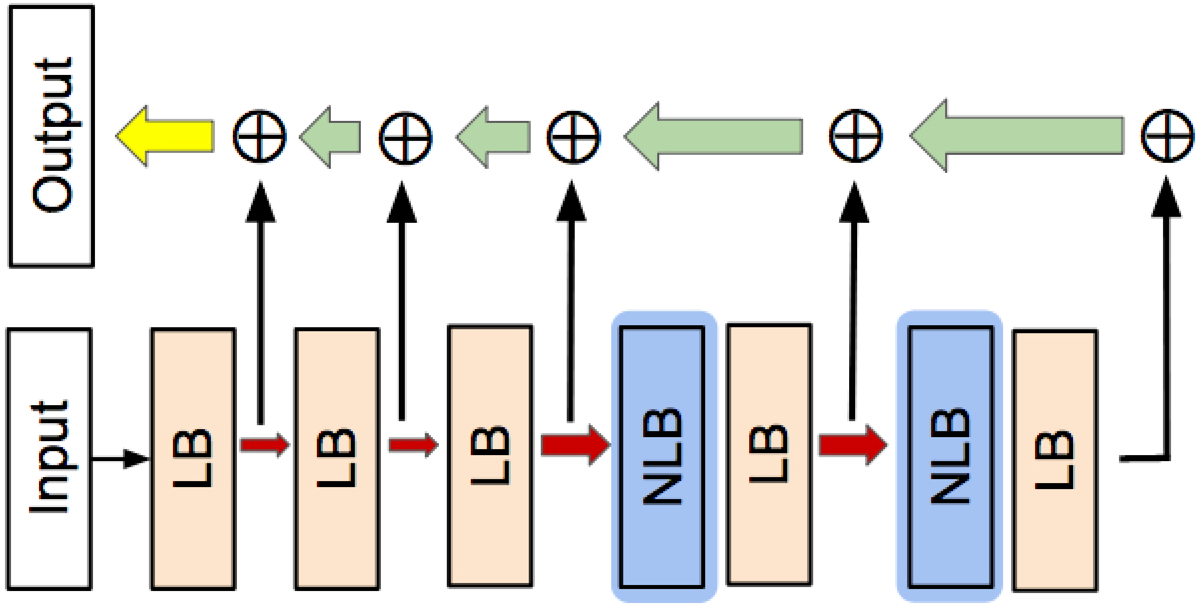
## Non-Local Operations



# Non-Local LinkNet (NL-LinkNet)

## Non-Local Block (NLB)



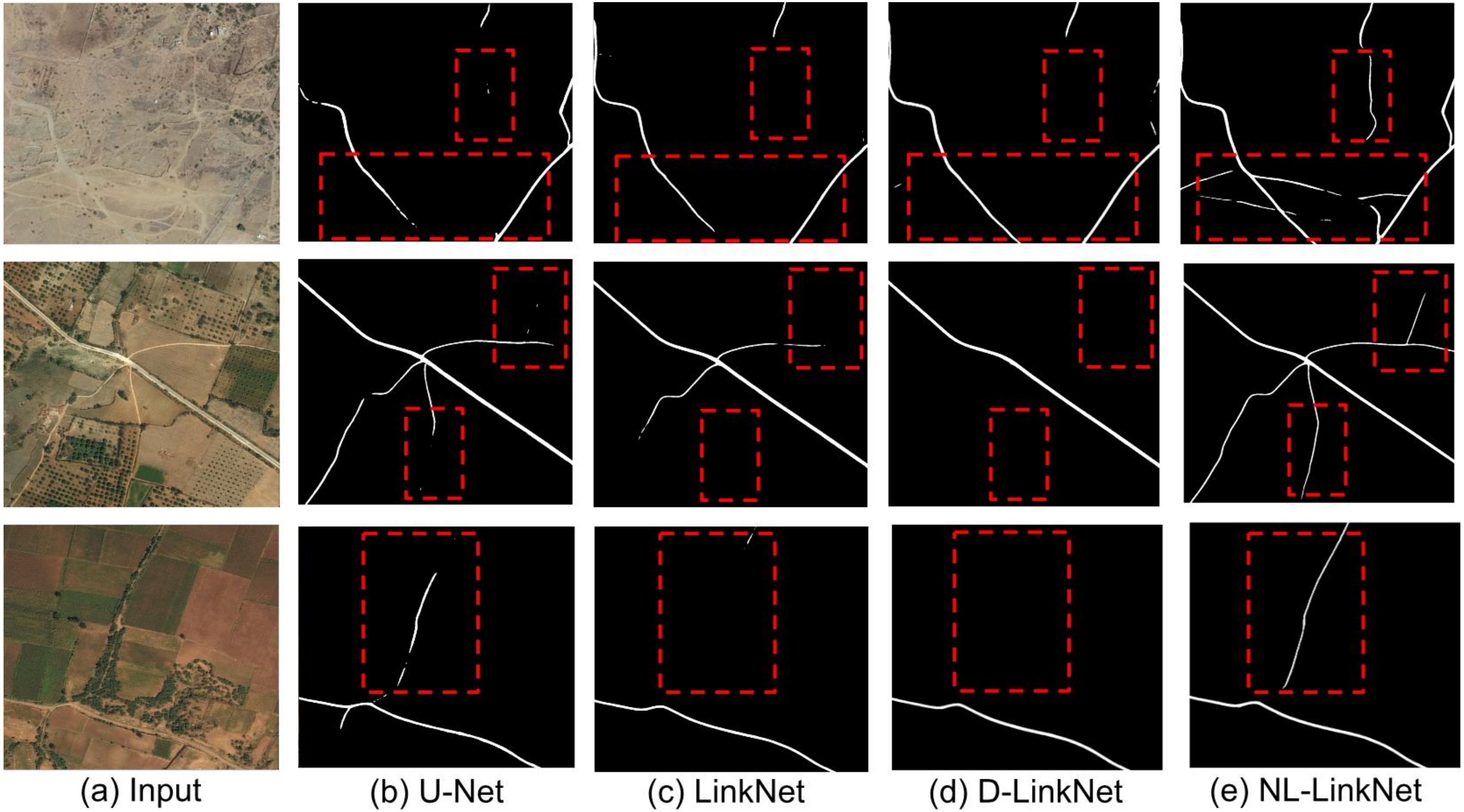

Overall Architecture

# Quantitative Comparison

TABLE I
BENCHMARKS FOR DEEPGLOBE ROAD EXTRACTION CHALLENGE

| BenchMarks | mIOUs | Remarks |
|---|---|---|
| EosResUNet [23] | 55.96 | |
| StackedUNet [24] | 60.60 | 4th place |
| ResInceptSkipNet [25] | 61.30 | 3rd place |
| U-Net [12] | 62.94 | from [15] |
| LinkNet [13] | 63.00 | |
| FCN [10] | 64.00 | 2nd place |
| D-LinkNet [15] | 64.12 | 1st place |
| NL34-LinkNet | 64.59 | Ours |
| **NL34-LinkNet+MS** | **65.00** | **Ours** |

# Visual Comparison



# Model Efficiency

TABLE II

PERFORMANCES OF NON-LOCAL BLOCKS ADDED INTO DIFFERENT STAGES

| Models | NLB3 | NLB4 | DB | mIOUs | Params |
|---|---|---|---|---|---|
| Baseline | X | X | X | 63.07 | 21.657M |
| D-LinkNet | X | X | O | 64.12 | 31.096M |
| NL3-LinkNet | O | X | X | 64.15 | **21.690M** |
| NL4-LinkNet | X | O | X | 64.40 | 21.789M |
| NL34-LinkNet | O | O | X | **64.59** | 21.822M |

# Summary

- Core Idea: Non-local Operations

- Non-Local Block is better than traditional convolutional ops.

# 04 Conclusions

# Conclusions

- **Object Detection and Classification:** Use case for Defense
- **TensorRT:** Speed-up to 2.2X (DenseNet) and 1.6X (VGG).
- **Fill the gap for rare observation:** Combine synthetic data from GAN
- **Non-Local Block**: Extraction of Road Network Topology

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# Thank you for attention!

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