

# Automatic Target Recognition in Satellite Imagery

Nate DiRenzo

# Agenda

- Statement of Need
- Project Goals
- Evaluation Metrics
- Dataset
- Model Results
- Conclusions

The background image is a high-angle aerial photograph of a large industrial complex. The facility features numerous rectangular buildings arranged in a grid-like pattern, likely storage tanks or processing units. A dense network of roads, walkways, and possibly railway tracks crisscrosses the area. In the upper right corner, there is a larger, more complex building complex with several white structures and some greenery. The overall scene is dark and industrial.

# Statement of Need

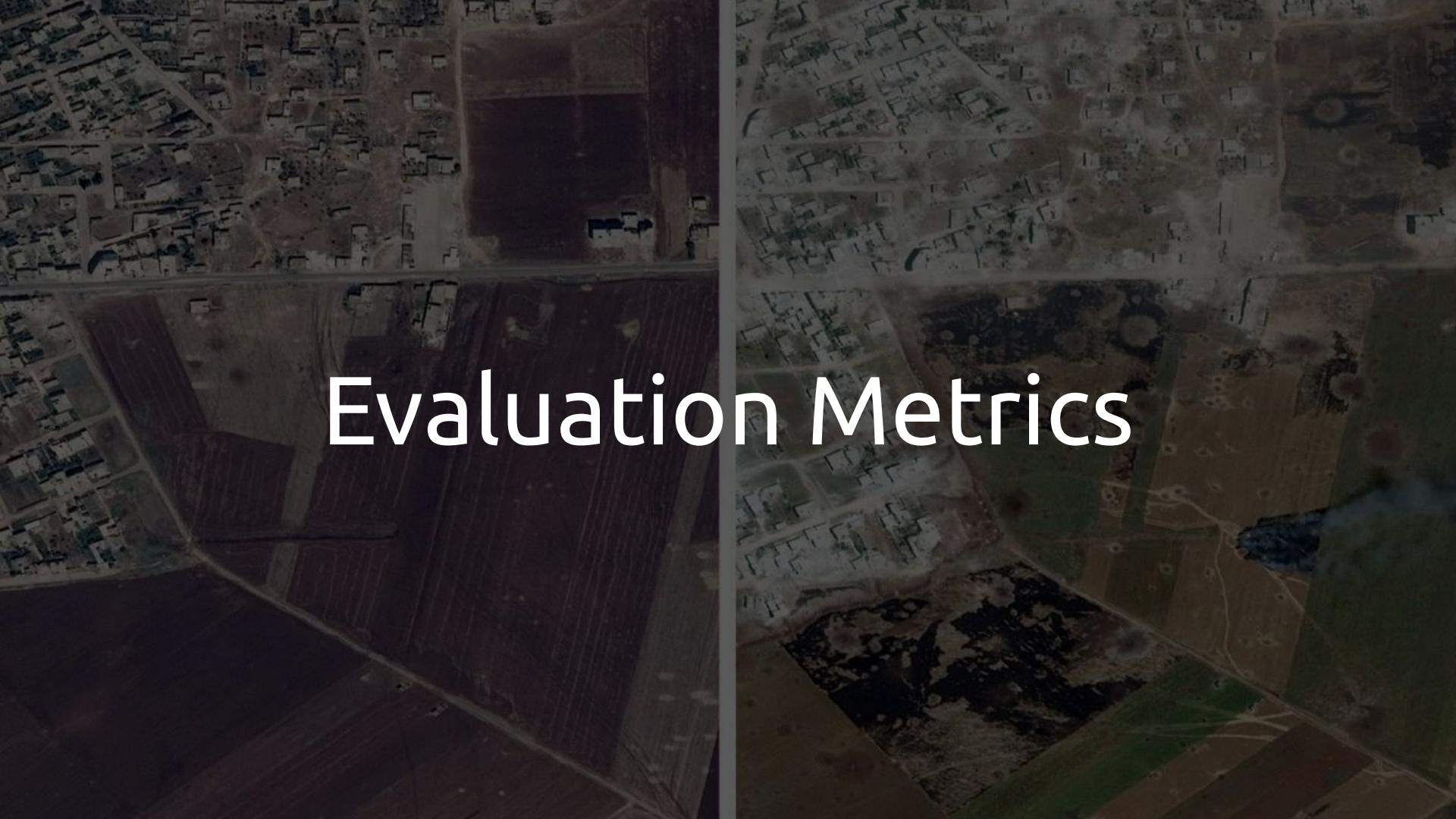
- Proliferation of publicly-available satellite imagery.
- Use of satellite images by journalists, open-source intelligence analysts, human rights organizations, and combatants
- Visibility into inaccessible regions of the world.
- Russian invasion of Ukraine highlights the use and importance of satellite imagery in modern conflict.
- Using deep learning models to identify objects of interest in satellite imagery.



# Project Goals

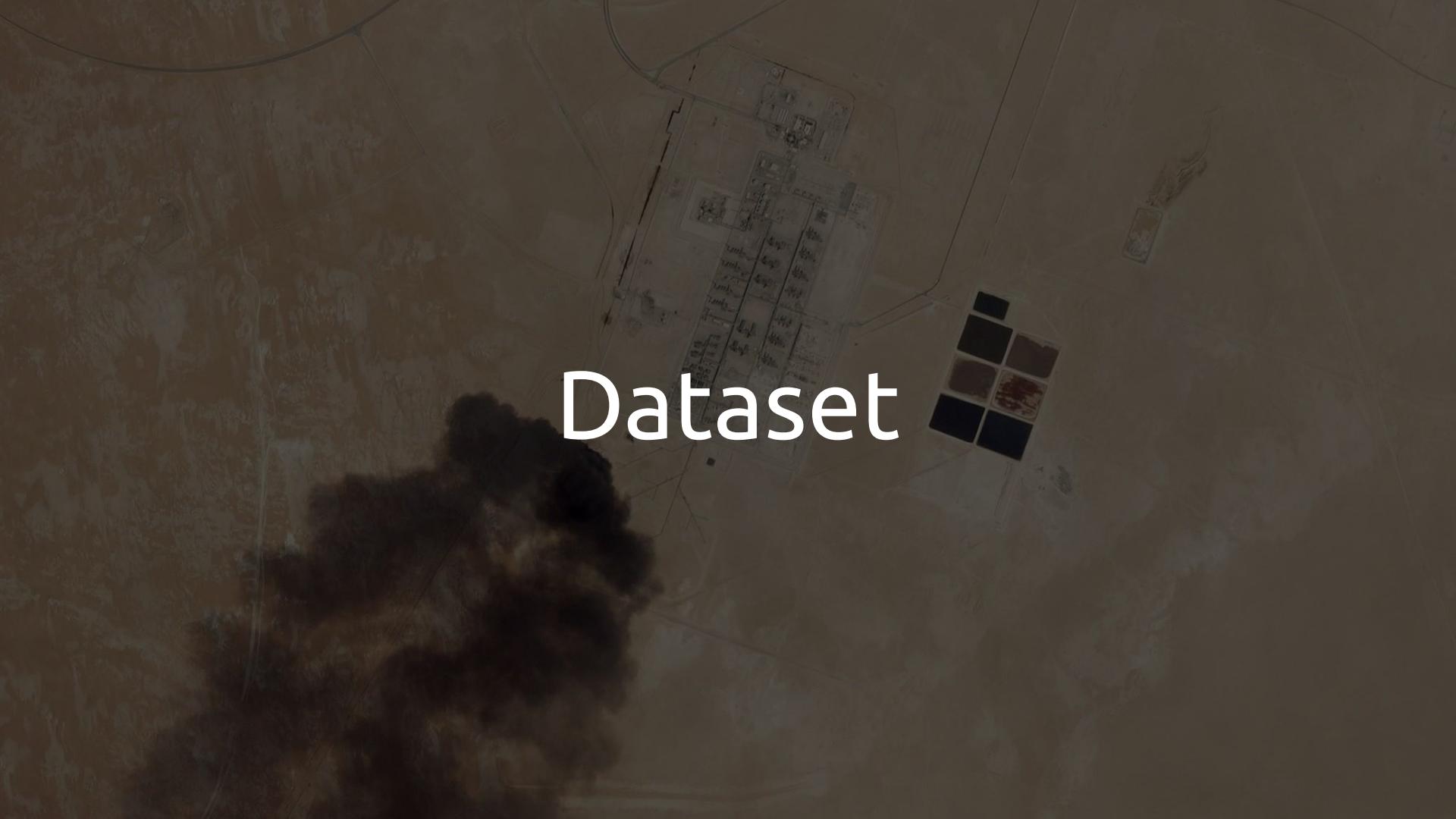
Evaluate efficacy of using deep learning model to classify different classes of military land vehicles in synthetic aperture radar (SAR) imagery.



The background of the image is a high-resolution aerial photograph of a residential urban area. The image shows a grid of streets, numerous houses, and some larger institutional or industrial buildings. The colors are earthy tones of brown, tan, and green, typical of satellite imagery. The overall scene is a dense urban sprawl.

# Evaluation Metrics

- Categorical Accuracy - Avg. Accuracy for all classes
- Weighted Average  $F_2$  score - Weight avg. of  $F_2$  scores for all classes
- Matthews Correlation Coefficient - 1=Perfect Classifier, 0=Random Guessing
- Confusion Matrices - Detailed view of predictions, patterns of ambiguity
- Prediction on unseen data
  - Image of T72 from First Gulf War
- Classes of particular interest
  - T62/T72, D7, SLICY

The background image shows an aerial perspective of a rural landscape. It features a network of white irrigation canals winding through a patchwork of agricultural fields. In the lower-left foreground, a massive, dark, billowing plume of dust or smoke dominates the scene, suggesting a recent explosion or fire. The surrounding land is a mix of brown earth and green vegetation. In the upper right, there's a cluster of buildings, possibly a farm or industrial facility, surrounded by more fields.

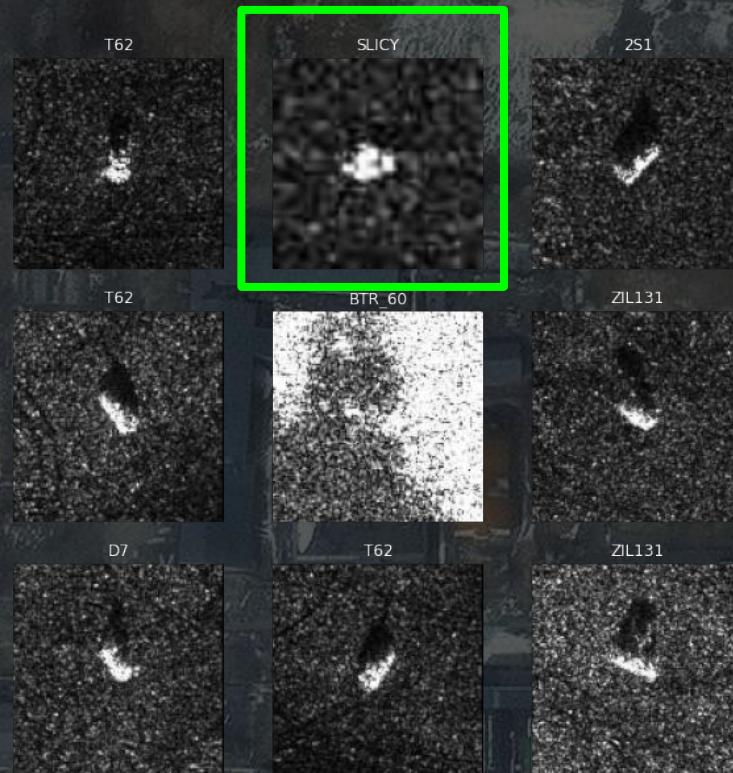
Dataset

- Moving and Stationary Target Acquisition and Recognition (MSTAR)

- produced 1995-1997 by Defense Advanced Research Projects Agency (DARPA) and Air Force Research Labs



- 9 Classes
- ~1200 Images per class



# Results

# Multi-layer Perceptron (MLP)

- **Categorical Accuracy:** .625
  - **F<sub>2</sub>:** .603
  - **MCC:** .589



Predicted 2S1 w/ %25.36 confidence

	2S1	BRDM_2	BTR_60	D7	SLCY	T62	T72	ZL131	ZSU_23_4
2S1	172	1	0	0	0	0	2	9	1
BRDM_2	1	231	0	0	0	0	4	0	0
BTR_60	0	0	54	0	0	0	18	133	0
D7	6	1	0	25	0	0	3	58	3
SLCY	1	0	0	0	192	0	4	0	4
T62	3	0	0	0	0	17	99	0	83
T72	95	0	0	0	0	0	45	26	13
ZL131	7	0	0	0	0	0	0	170	0
ZSU_23_4	33	0	0	0	18	0	13	7	151
Predicted Values	2S1	BRDM_2	BTR_60	D7	SLCY	T62	T72	ZL131	ZSU_23_4

# Convolutional Neural Network (CNN)

- **Categorical Accuracy:** .995
- **F<sub>2</sub>:** .995
- **MCC:** .994



True Values	ZSU_23_4	ZL131	T72	T62	SLICY	D7	BTR_60	BRDM_2	2S1
Predicted Values	221	0	0	0	0	0	0	0	1
ZSU_23_4	0	0	0	0	0	0	0	0	1
ZL131	0	0	0	0	0	0	0	0	0
T72	0	0	178	0	0	0	0	0	0
T62	0	0	0	202	0	0	0	0	0
SLICY	0	0	0	0	201	0	0	0	0
D7	0	0	0	0	96	0	0	0	0
BTR_60	0	0	0	205	0	0	0	0	0
BRDM_2	0	0	0	0	0	0	0	236	0
2S1	183	0	0	0	0	0	0	0	2

Predicted BRDM-2 w/ %20.32 confidence

# VGG2019 Architecture

- **Categorical Accuracy:** .867
- **F<sub>2</sub>:** .864
- **MCC:** .852



		Predicted Values									
		2S1	BRDM_2	BTR_60	D7	SLICY	T62	T72	ZIL131	ZSU_23_4	
True Values	2S1	121	34	13	0	0	1	12	0	4	
	BRDM_2	1	233	1	0	0	0	1	0	0	
BTR_60	BTR_60	0	0	205	0	0	0	0	0	0	
	D7	0	0	0	91	0	0	0	1	4	
SLICY	SLICY	0	2	0	0	193	0	4	0	2	
	T62	0	1	0	0	0	200	0	0	1	
T72	T72	1	31	15	0	0	3	129	0	0	
	ZIL131	8	2	0	5	0	0	0	162	0	
ZSU_23_4	ZSU_23_4	0	28	0	0	0	14	0	1	179	

Predicted 2S1 w/ %15.09 confidence

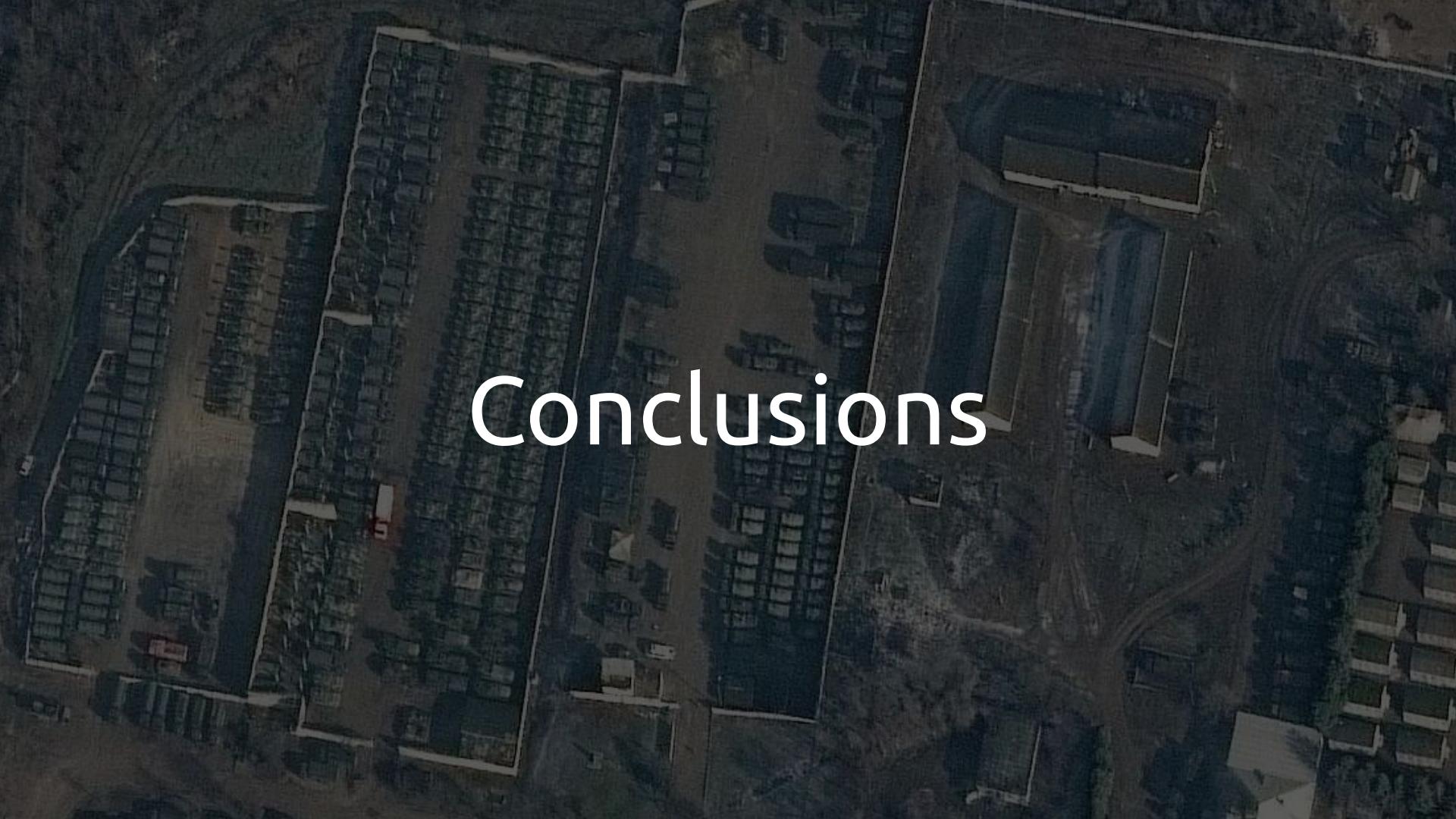
# Custom CNN (Xception/VGG19 architectures)

- **Categorical Accuracy:** .975
- **F<sub>2</sub>:** .976
- **MCC:** .972



True Values	ZSU_23_4	ZL131	T72	SLICY	TB2	D7	BTR_60	BRDM_2	ZS1
ZS1	46	1	0	0	0	0	2	0	0
BRDM_2	0	82	0	0	0	0	1	0	0
BTR_60	0	0	54	0	0	0	0	0	0
D7	0	0	0	22	0	0	0	0	1
SLICY	0	0	0	0	55	0	0	0	0
TB2	0	1	0	0	0	41	0	0	0
T72	0	1	0	0	0	0	35	0	0
ZL131	0	1	0	0	0	0	0	41	0
ZSU_23_4	0	0	0	0	0	0	2	0	50

Predicted BRDM-2 w/ %22.98 confidence

The background of the slide is a dark, grainy aerial photograph of a rural or semi-rural landscape. It shows a grid-like pattern of agricultural fields, some with green crops and others appearing dry or fallow. Interspersed among the fields are numerous small, simple houses with dark roofs, likely mud-brick or similar materials. A few larger buildings, possibly schools or community centers, are also visible. The overall scene suggests a developing or underdeveloped region.

# Conclusions

- CNN's performed exceptionally well at correctly classifying object classes in the dataset.
- Initial expectations for areas of ambiguity did not bear out
  - T62/T72 delineation was clear
  - D7/SLICY had high categorical accuracy
- The model failed to generalize to images outside the MSTAR dataset.
- Model serves as a valid proof of concept but has limited practical utility without further work.

# Areas for Future Work

- More, and more varied data for more utility
  - Modern, high-resolution imagery
  - Noise, clutter, obfuscation that better simulates conflict zones
  - Synthetic Data
  - Angles, perspectives, distances
    - How important was vehicle's shadow?
    - Does time of day play a role?
- Region-based Convolutional Neural Net
  - Identifying different vehicle classes in the same image
  - Finding appropriate level of class specificity

The background of the image is a dark, grainy aerial photograph of a rural area. In the lower center, there is a bright red fire truck positioned near a small, white, rectangular building, possibly a house or a garage. The surrounding land is a mix of dark fields and lighter-colored roads or paths.

Thank you

# Appendix

