

AI at the Frontlines: A counterterrorism case study

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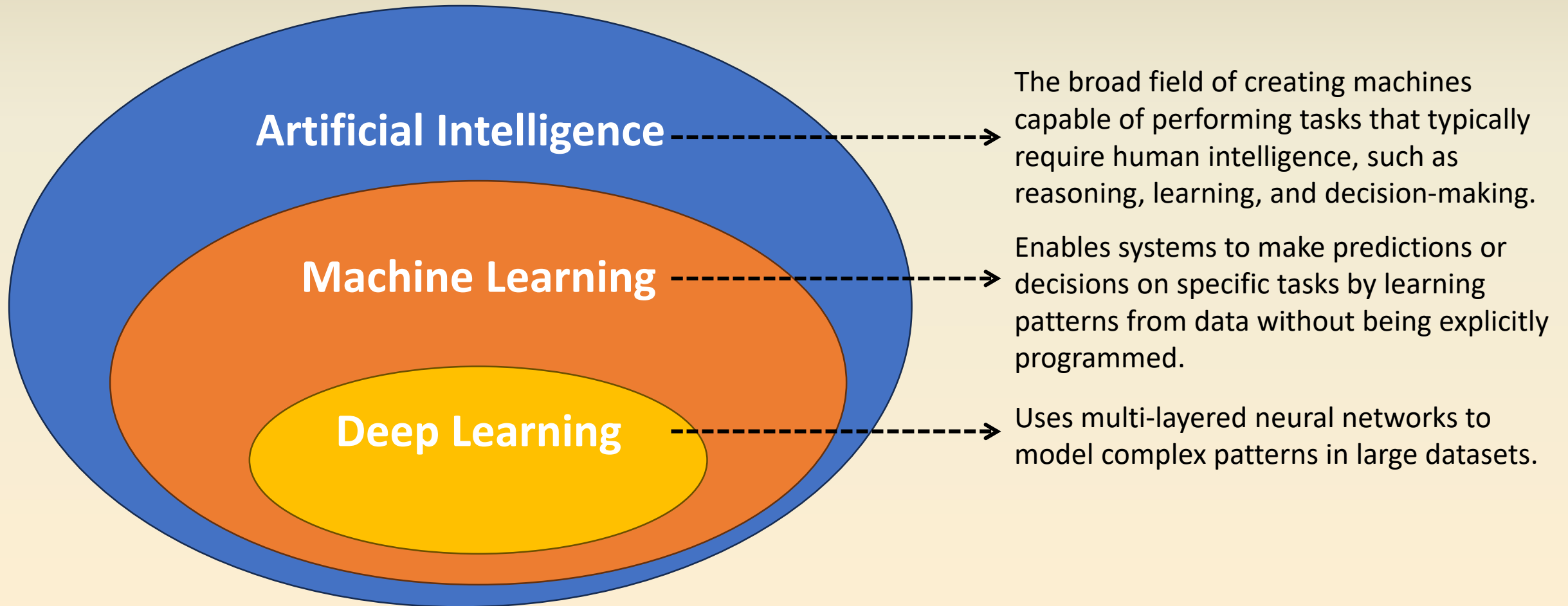
Talk Outline

- A Brief History of AI
- Machine Learning Pipeline: From Data to Action
- Operationalizing Machine Learning for Threat Detection
- NTEWS: Northwestern Terror Early Warning System

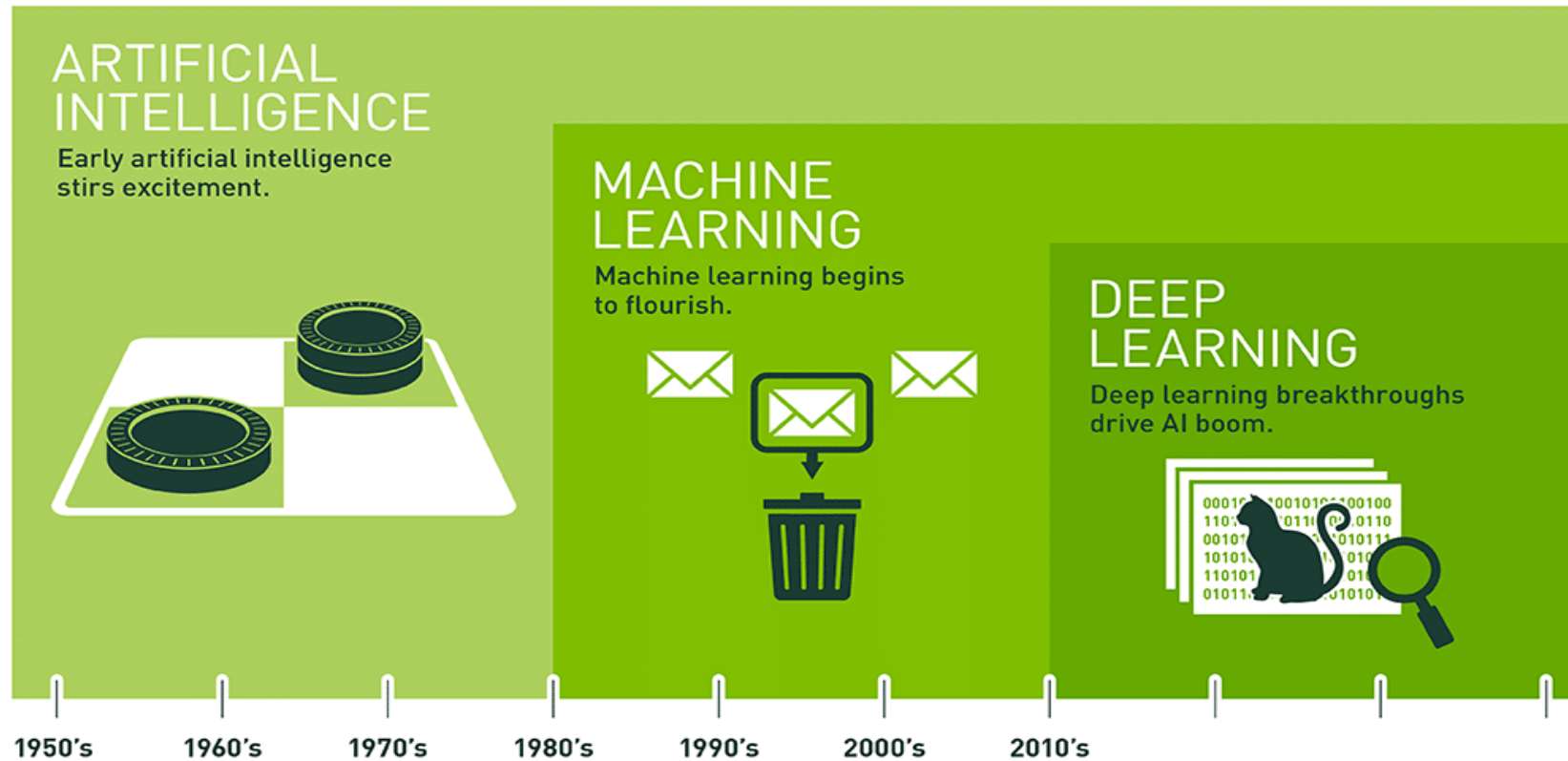
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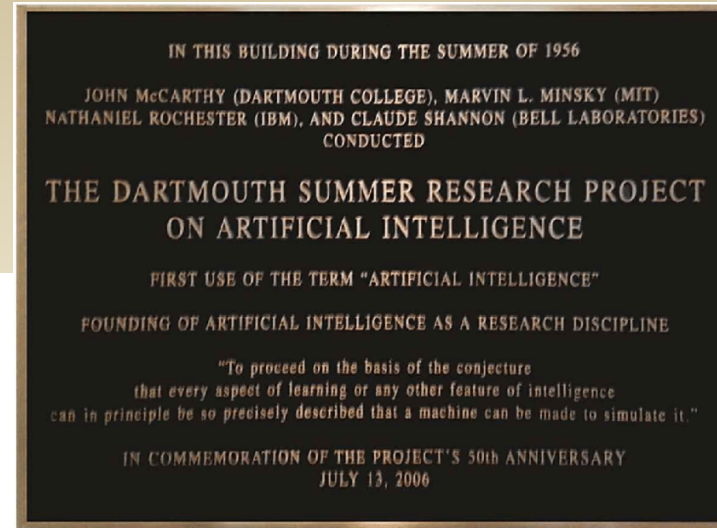
The AI Landscape



The AI Landscape



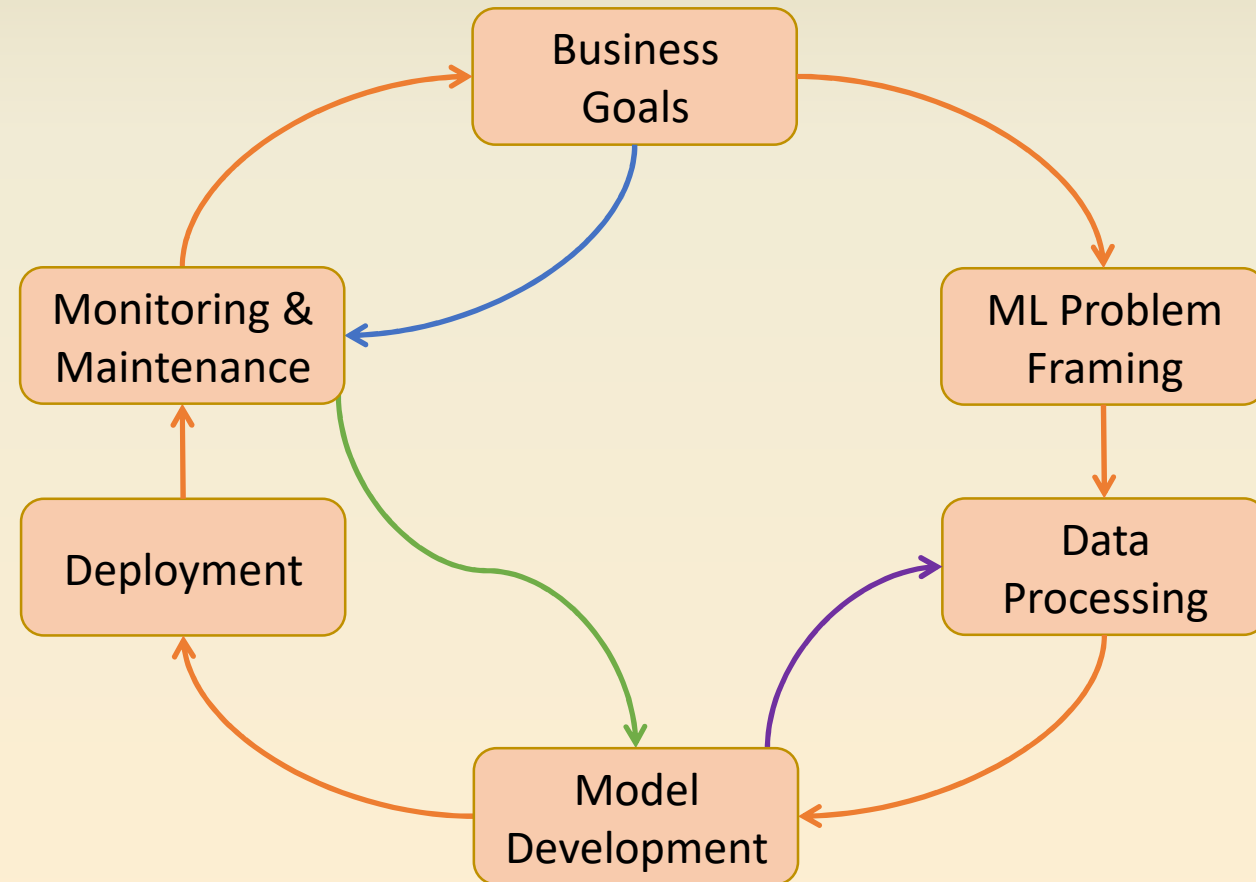
Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.



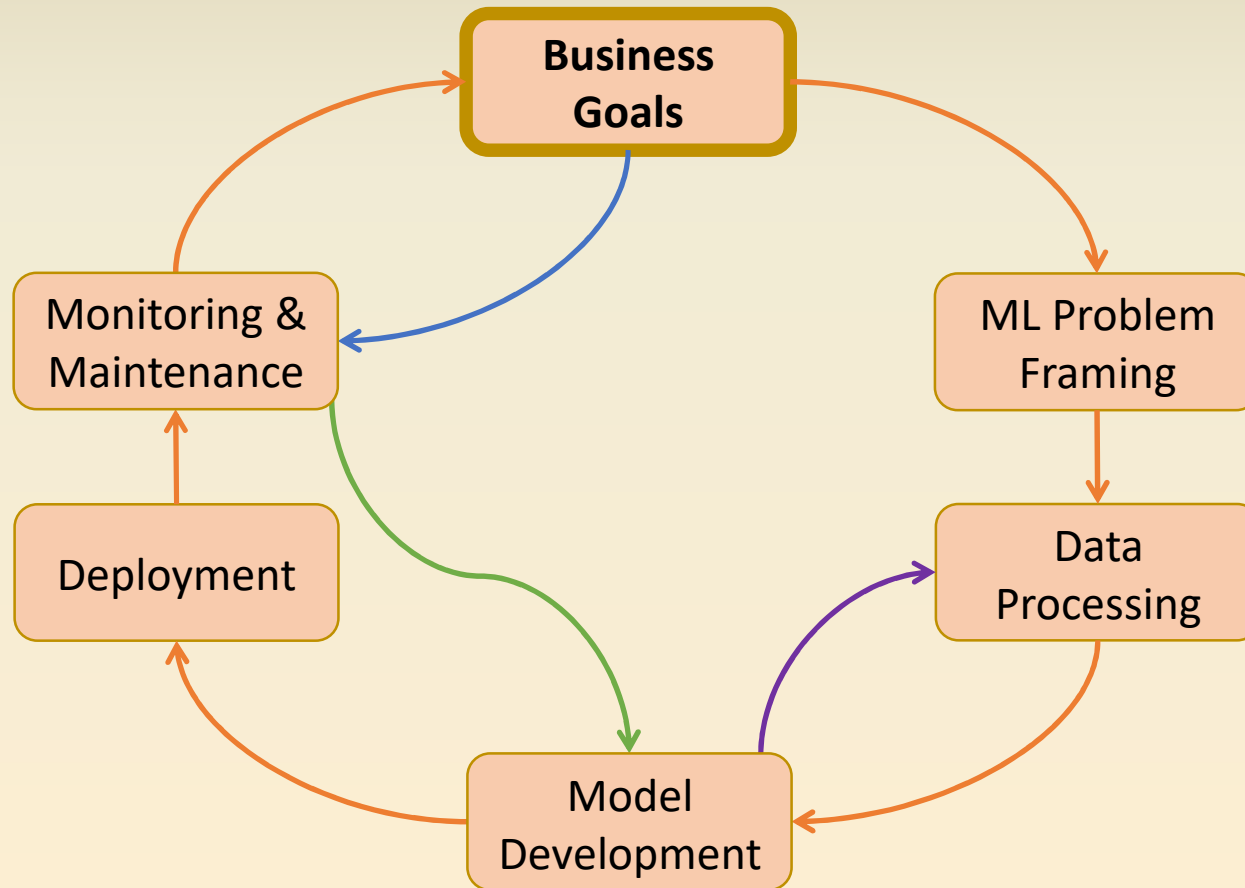
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Machine Learning Lifecycle



Machine Learning Lifecycle – Business Goals



Every business project ultimately aims to boost profits:

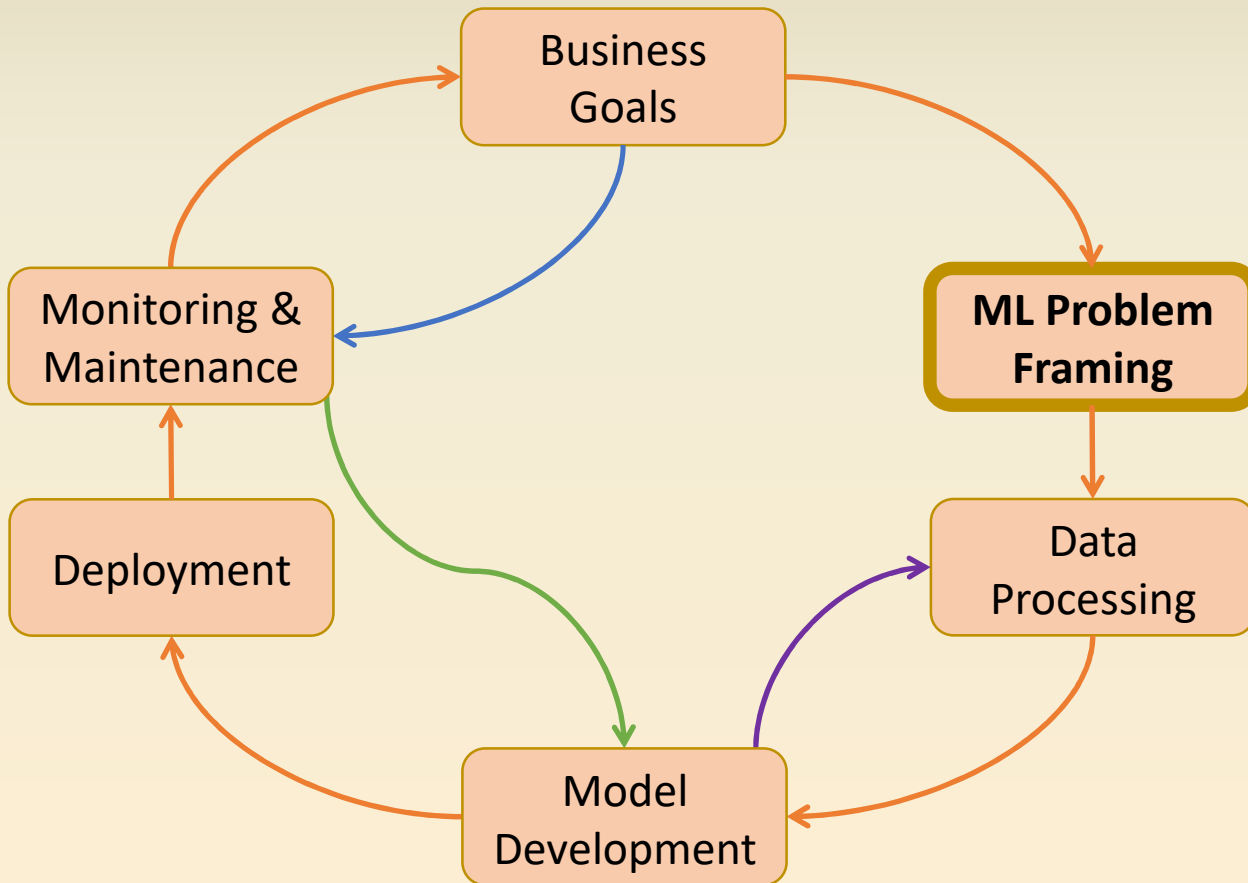
- *directly* through increased sales and reduced costs, or
- *indirectly* via improved customer satisfaction and engagement.

Most companies don't care about the fancy ML metrics.



For an ML project to succeed within a business, it's crucial to tie the performance of an ML system to the overall business performance.

Machine Learning Lifecycle – ML Framing



Context: a company producing industrial equipment.

Business Goal: Use ML to speed up maintenance support.

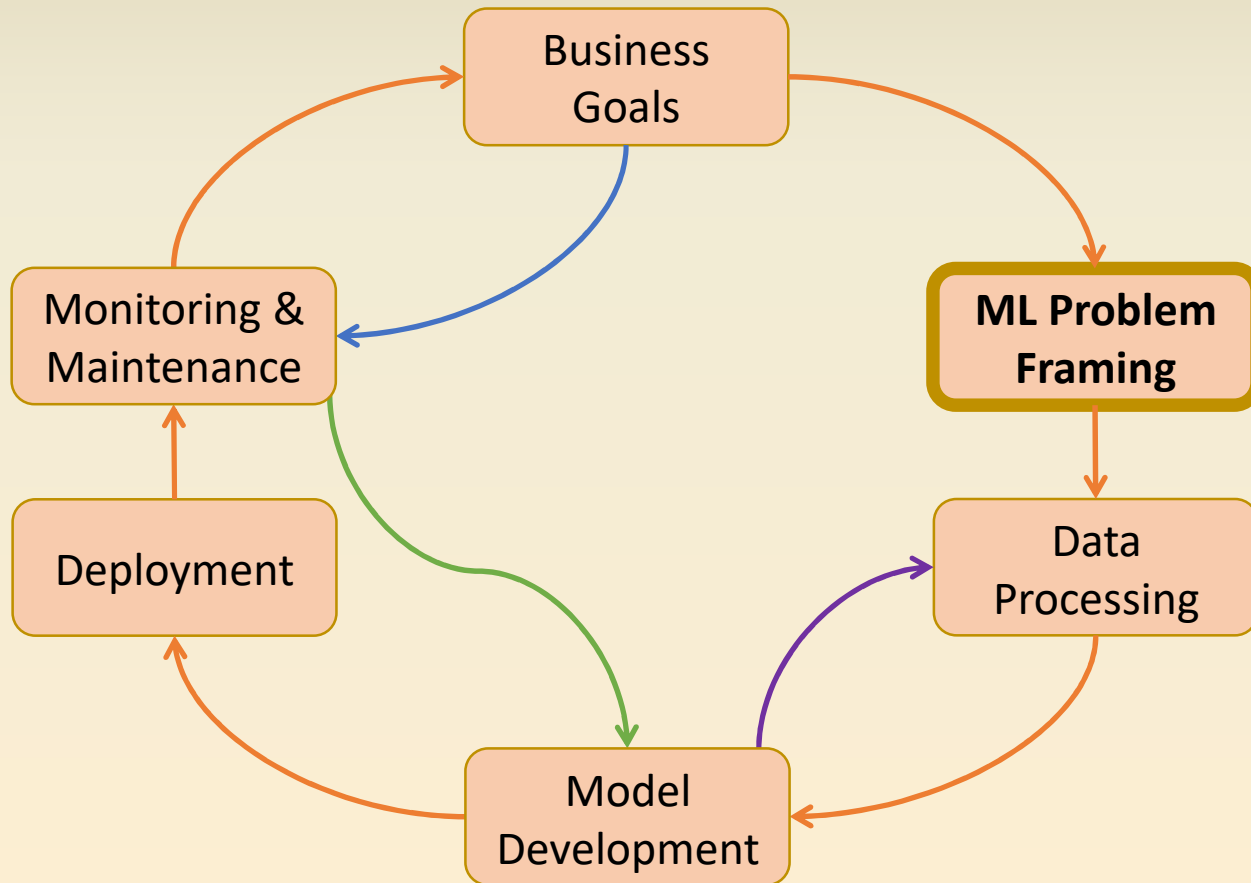
Reality: This isn't yet an ML problem.
ML problems require Inputs, Outputs, Objective function.

Investigation: the bottleneck lies in routing incoming maintenance requests to the correct technician team—electrical, mechanical, hydraulic, or software.

ML Framing: predict which team should handle each request.

- Input: Maintenance request text
- Output: Technician team
- Objective: Minimize misclassification between predicted and actual team assignment

Machine Learning Lifecycle – ML Framing



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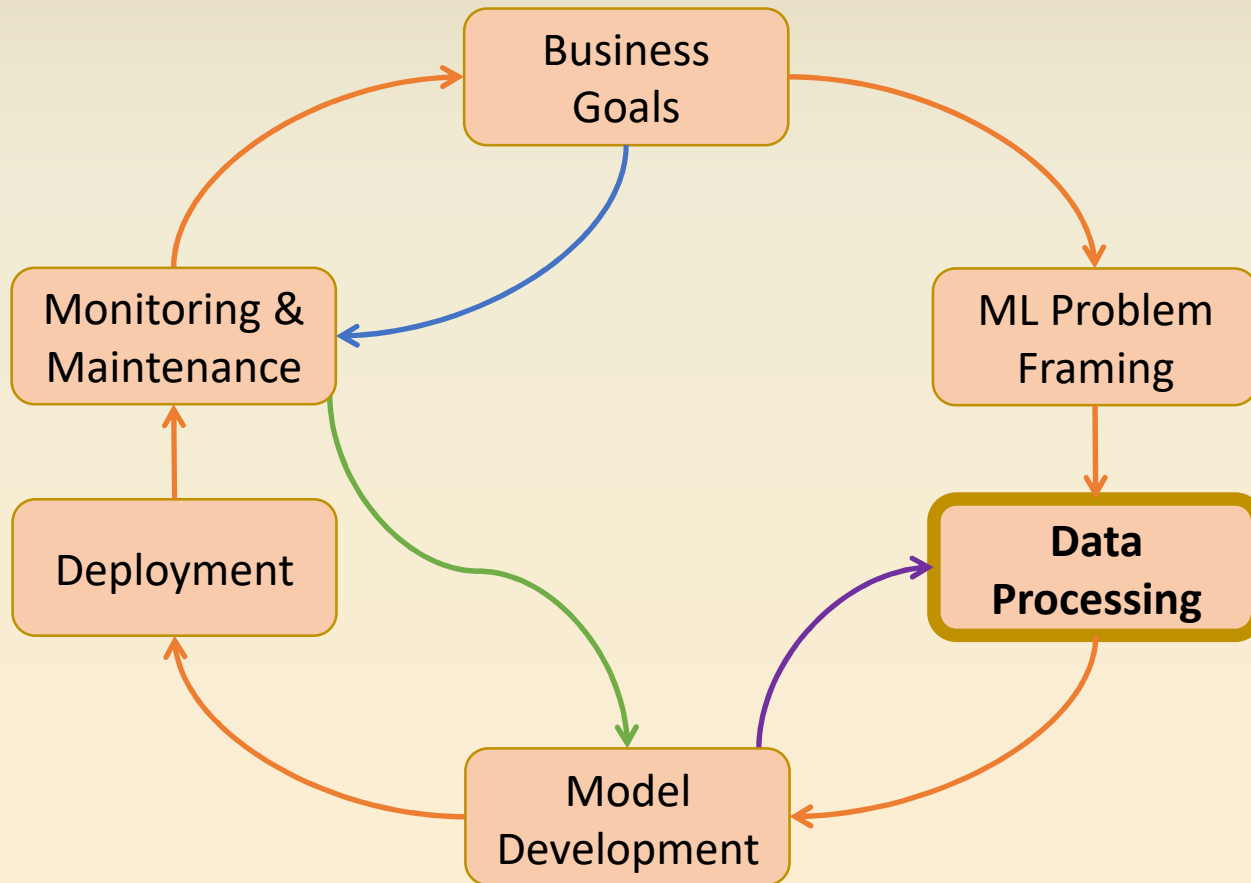
Reality: This isn't yet an ML problem. ML problems require Inputs, Outputs, Objective

**Machine learning can't solve vague problems:
Translate it into a task it understands.**

ML Framing: predict which team should handle each request.

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Machine Learning Lifecycle – Data Processing



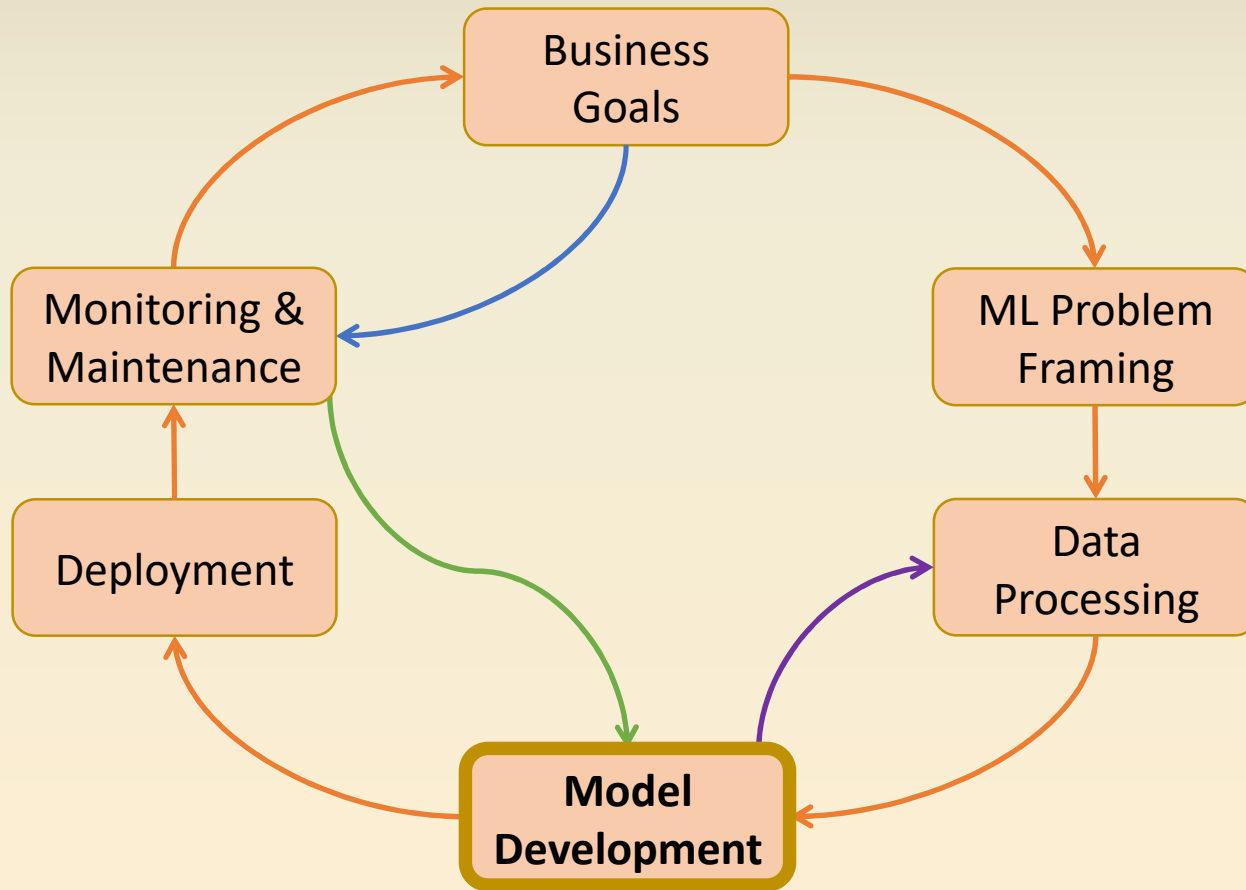
Clean, structured data is essential for building reliable ML models.

There are several stages:

1. Data Collection. Gather raw data from sensors, logs, databases, news articles, user input data.
2. Data Cleaning. Remove noise, handle missing values, correct inconsistencies.
3. Feature Engineering. Transform raw data into meaningful inputs for ML models.

The performance of an ML model depends heavily on the quality and quantity of the labeled data it's trained on.

Machine Learning Lifecycle – Model Development

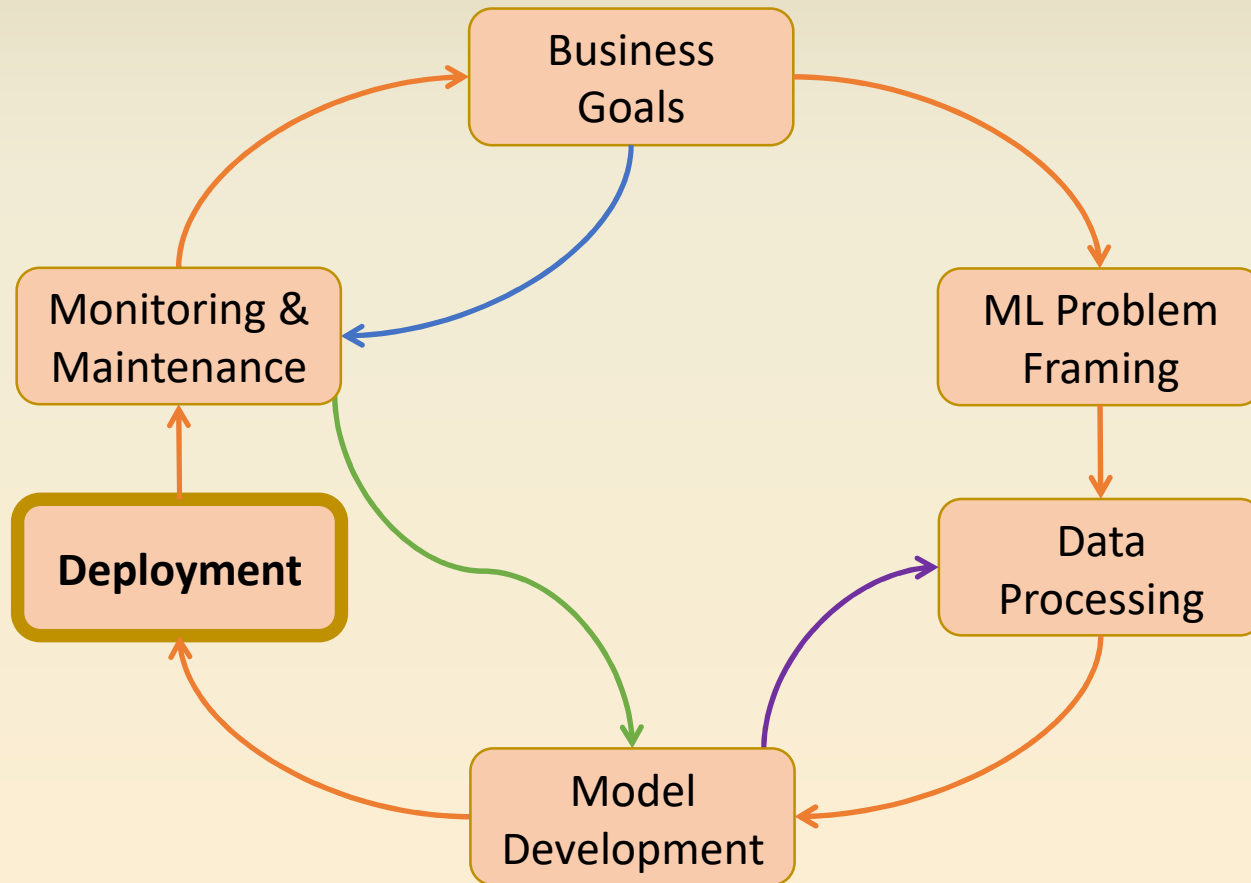


There are several stages:

1. Model Selection. Choose the right algorithm based on task type and data size.
2. Training. Feed labeled data into the model to learn patterns. Adjust model settings to improve accuracy and generalization.
3. Validation. Evaluate model performance on unseen data.

Model development is iterative—After every training cycle, assess performance gains and decide if the model is ready to deploy.

Machine Learning Lifecycle - Deployment

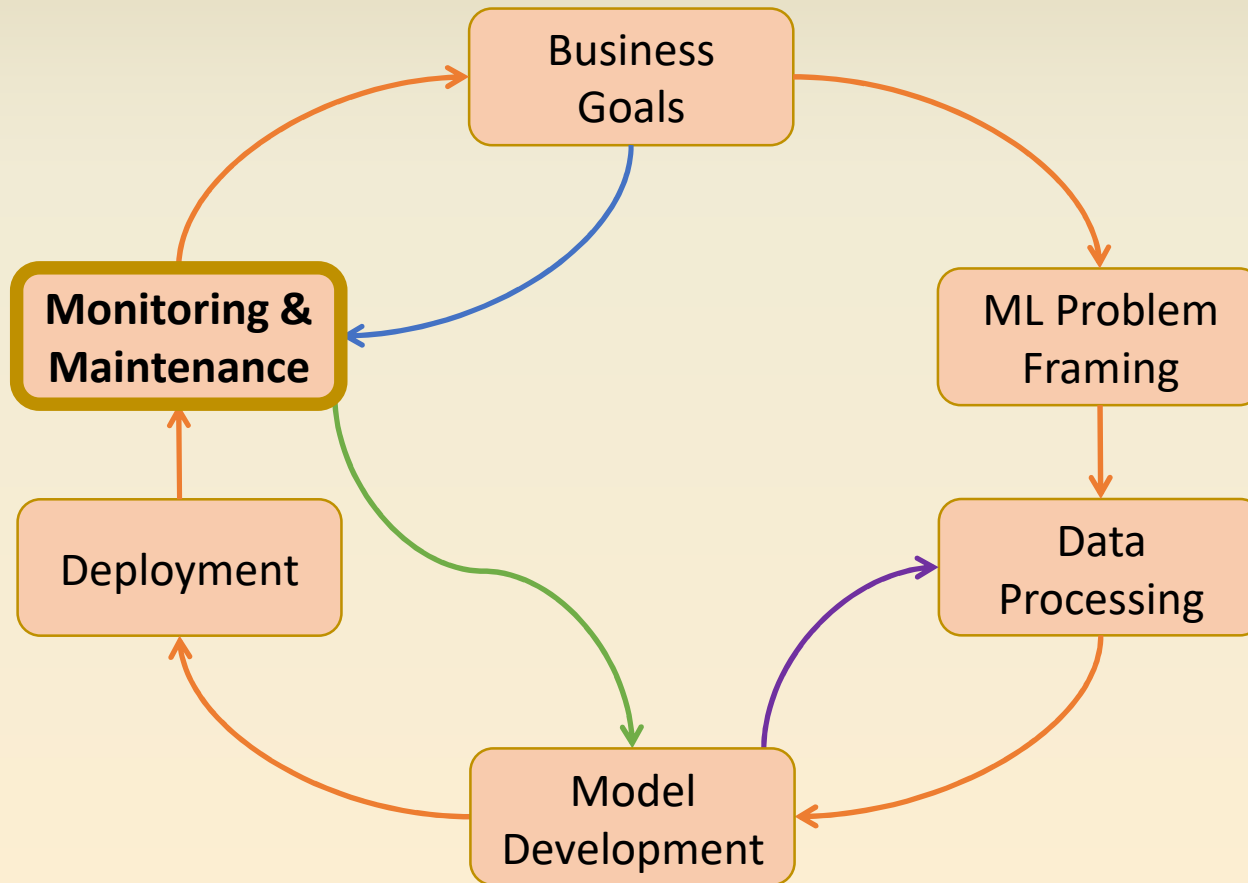


Deploying an ML model means integrating it into a production environment

The deployment complexity varies based on what that environment is: It can range from polished plots for business reviews to scalable systems serving millions daily.

Companies typically have many, many ML models.

Machine Learning Lifecycle - Maintenance



A model's performance decays over time.

Once deployed, ML models must be continuously refined and maintained.

We have to continually monitor their performance to detect issues as well as deploy updates to fix these issues.

Machine learning isn't a one-and-done process: there is a lot of back and forth between different steps.

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An ML based Model of BH – Business Goals

- Define a **Boko Haram behavior model** that accurately identifies the conditions under which Boko Haram carries out attacks of different types.

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Who Is Boko Haram?

An ML based Model of BH – ML Problem

Who Is Boko Haram?

- Founded in northeastern Nigeria in the early 2000s
- Name loosely translates to “Western education is forbidden”
- Extremist Islamist group seeking to establish an Islamic state
- Known for bombings, kidnappings, and attacks on schools
- Responsible for tens of thousands of deaths and mass displacement
- Pledged allegiance to ISIS in 2015

Distribution of deaths attributed to Boko Haram across Nigerian states, from 2011 to 2022.

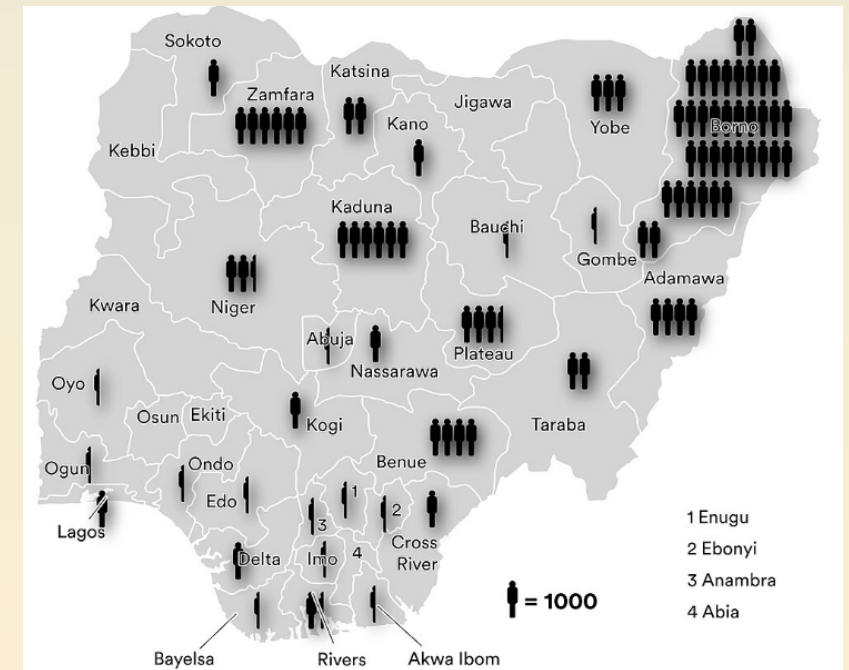


Image by FrankvEck, CC BY-SA 4.0, via Wikimedia Commons.

An ML based Model of BH – ML Problem

- Develop a data-driven, predictive models that provide analysts with 1-7 months of advance warnings of the types of targets the Boko Haram might strike over the next few months
- The proposed predictive model must satisfy the following three properties:
 - **Accuracy.** The predictive model must be highly accurate and make correct predictions.
 - **Explainable.** Decision makers need predictions that can be succinctly explained in relatively plain English – in addition to the prediction itself, they need to know the justification for a prediction.
 - **Actionable.** Decision makers would like attack predictions to be accompanied by suggestions about specific actions they can take to mitigate the risk and intensity of attacks.

An ML based Model of BH – Data

- Database consists of social, cultural, economic, political, and military events and situations involving Boko Haram
- **Time Frame:** July 1 2009 to present (16 years);
- **Independent variables** (aka “*features*”) describe the environment surrounding Boko Haram during each month in the July 2009-current period.
 - nature of the leadership;
 - the infrastructure they possess;
 - whether there is intra-organizational conflict;
 - information about the membership of the group;
 - Information about actions taken by other actors.
- **Dependent variables** represent both occurrence and non-occurrence of different types of *attacks* carried out by Boko Haram such as:
 - Abductions, sexual violence, targeting government officials, arson, and more.
- **Variables:** 48 dependent variables, 105 independent variables
- **Open sources:** Lexis-Nexis, Jane’s, reports from the US Government, think tanks and international organizations (such as the UN).

An ML based Model of BH – Data

Month-Year	Abduction	Assassination	SexualViolence	Arson	AttackGovernment	Hit&Run	AttackProductionSite	AttackPublicSite	AttackSchool
Jul-09	0	0	0	1	0	0	0	0	0
Aug-09	0	0	0	0	0	0	0	0	0
Sep-09	0	0	0	0	0	0	0	0	0
Oct-09	0	0	0	0	0	0	0	0	0
Nov-09	0	0	0	0	0	0	0	0	0
Dec-09	0	0	0	0	0	0	0	0	0
Jan-10	0	0	0	0	0	0	0	0	0
Feb-10	0	0	0	0	0	0	0	0	0
Mar-10	0	0	0	0	0	0	0	0	0
Apr-10	0	0	0	0	0	0	0	0	0
May-10	0	0	0	0	0	0	0	0	0
Jun-10	0	0	0	0	0	0	0	0	0
Jul-10	0	0	0	0	0	0	0	0	0
Aug-10	0	0	0	0	0	0	0	0	0
Sep-10	0	0	0	0	0	0	0	0	0
Oct-10	0	1	0	0	1	0	0	0	0
Nov-10	0	0	0	0	1	0	0	0	0
Dec-10	0	0	0	0	0	0	0	0	0
Jan-11	0	1	0	1	1	0	0	0	0
Feb-11	0	0	0	0	0	0	0	0	0
Mar-11	0	0	0	0	1	0	0	0	0
Apr-11	0	0	0	0	0	0	0	0	0
May-11	0	0	0	0	0	0	0	0	0
Jun-11	0	0	0	0	0	0	0	0	1
Jul-11	0	0	0	0	1	0	0	0	0

An ML based Model of BH – Development

- 48 attack types analyzed across 1–7 month lead times
- For each (attack, lead time) pair, we trained and evaluated multiple ML models:
 - Support Vector Machines
 - Multi Layer Perceptrons
 - Restricted Boltzmann Machines
 - Random Forest
 - Adaptive Boosting (AdaBoost)
 - Decision Trees
 - Naïve Bayes
 - K-Nearest Neighbors (KNN)
- Result: ~336 distinct model instances, each tailored to a specific attack and forecast horizon.

An ML based Model of BH – Development

	1 month	2 months	3 months	4 months	5 months
Abductions	0.899	0.951	0.845	0.913	0.962
Assassination	0.696	0.853	0.946	0.795	0.69
Member killed by Co-Member	0.786	0.726	0.816	0.825	0.783
Sexual Violence	0.706	0.834	0.833	0.666	0.861
Armed Clashes	0.829	0.761	0.807	0.847	0.81
Arson	0.877	0.832	0.819	0.889	0.867
Attack on Government Institution	0.83	0.792	0.804	0.854	0.795
Attack on Production Site(s)	0.795	0.919	0.834	0.759	0.817
Attacks on School	0.872	0.714	0.797	0.727	0.84
Attempted Bombing	0.818	0.898	0.77	0.622	0.807

Predictive Accuracy (AUC)

An ML based Model of BH – Example Prediction

Predicted Probability of a Boko Haram Suicide Bombing

Prediction Date	Period of Prediction	Probability of Suicide Bombing
Feb 29 '20	Mar-Aug '20	96.3%
Mar 31 '20	Apr-Aug '20	76.9%
Apr 30 '20	May-Aug '20	97.9%
May 31 '20	Jun-Aug '20	94.8%
Jun 30 '20	July-Aug '20	86.6%
Jul 31 '20	Aug '20	62.1%

Boko Haram Child Soldier Suicide Bombing on August 1-2 2020



IMAGE:

<https://www.hrw.org/news/2020/08/25/cameroon-boko-haram-suicide-bombers-strike-displacement-site>

An ML based Model of BH – Forecast Explanation

- Introduced Temporal Probabilistic (TP) rules

$$C_1 \& C_2 \& \dots \& C_m \xrightarrow{p, \delta} \pm A.$$

If conditions $C_1, C_2, \dots, C_m$ are all true in a given month (M), then Boko Haram will carry/not carry out attack A δ months later (i.e. in month $M + \delta$) with probability p .

- Extracted several million TP rules capable of explaining different types of attacks. Many redundant.
- Statistics for each rule:
 - **Confidence**: Probability attack A occurs in month $M+\delta$ given that C holds in month M ;
 - **Negative Confidence**: Probability attack A occurs in month $M+\delta$ given that C does not hold in month M ;
 - **Support**: % of months in which condition C held in month M and the attack happened in month $M+\delta$

An ML based Model of BH – Example Rules

TP rule 1:

- If BH recruits, trains, and/or deploys young individuals, then

They will carry out *suicide bombings* in the next month with

- **Probability 79%**
- **Negative Probability 25%** [when BH does not recruit/train/deploy young individuals in a given month, there is only a 25% probability of a suicide bombing in the next month]
- **Support 26%**

TP rule 2:

- If BH does not recruit, train, and/or deploy young individuals, then

They will not carry out *sexual violence* in the next month with

- **Probability 72%**
- **Negative Probability 7%**
- **Support 48%**

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The presence of **child soldiers** is directly linked to multiple kinds of attacks:

- Suicide bombings
- Sexual violence
- Abductions
- Arson
- Attempted bombings

Disrupting Boko Haram's recruitment and militarization of children is critical to reducing future violence.

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NTEWS - Predicting, Explaining, and Reshaping Terror Group Behavior

First publicly available resource that predicts the behavior of terror groups such as Boko Haram, Al-Qaeda in the Sahel, and others.

Goals:

- **Learn** predictive models of terror groups
- **Forecast** terror outlook for next 1 month, next 2 months,..., next 7 months
- **Explain** learned predictive models to policymakers in English
- **Reshape** behavior of terror groups via *policy generation* algorithms

NTEWS - LLM-Generated Report

BOKO HARAM FORECAST REPORT

NOVEMBER 8, 2024

SUMMARY OF FORECAST

Our machine learning models predict Boko Haram is likely to carry out

- *Abductions, atrocities, arson, attacks resulting in civilian casualties, non-suicide bombings, looting, attacks targeting security installations, and attacks targeting civilians based on their belief* in the next month, as well as in the next 2, 3, 4, and 5 months.
- *Suicide bombings* within the next month, as well as in the next 2 months.
- *Attacks targeting public sites* within the next month, as well as in the next 3 months.
- *Extortion, ransom, and robbery* within the next two months, as well as in the next 3, 4, and 5 months.
- *Attacks on worksites and attacks targeting public transportation* within the next 4 and 5 months
- *Attacks targeting civilians based on their profession* within the next month, as well as in the next 3, 4, and 5 months.
- *Armed clashes resulting in casualties, and hit-and-run attacks on security forces* within the next three months, as well as the next 4 and 5 months.

- *Mass casualty attacks* within the next month, as well as in the next 2 and 5 months.
- *Assassinations* within the next three months, as well as in the next 5 months.

PERIOD OF STUDY

This forecast was based on data about Boko Haram from January 1, 2009, through September 30, 2024.



Figure 1. Locations of the attacks carried out by Boko Haram in September 2024.

SEPTEMBER 2024 ACTIVITIES

In September 2024, Boko Haram carried out abductions and several attacks that resulted in casualties.¹

Abductions

11 September 2024. Boko Haram militants abducted a shopkeeper and a trader in Gakara, demanding money for their release.

27 September 2024. Three girls working in a field were abducted by Boko Haram militants. Fortunately, they were later found by the military without any clashes.

Armed Clashes with Casualties

4 September 2024. Boko Haram militants ambushed and clashed with a self-defense militia at a security fence in Chougoule, located in the Mokolo, Mayo-Tsanaga, and Extreme-Nord regions of Cameroon. The clash resulted in the deaths of two people, including the leader of the self-defense militia and a village chief named Lawan.

14 September 2024. Boko Haram militants clashed with the self-defense militia in Mavoumal. One self-defense militia was killed. The militants looted several houses.

Arson

30 September 2024. An online video claiming that the government intended to convert a study center into an IDPs camp for repentant Boko Haram members sparked arson attacks at the National Open University Study Centre and the residence of a former Senator in Ezeoke-Nsu. The video coincided with an inspection of the center by the Federal Commissioner for Refugees, Migrants, and Internally Displaced Persons. The former Senator's house was burned as a form of punishment for accompanying the Commissioner during the inspection.

Attacks with Civilian Casualties

1 September 2024. Boko Haram militants shot and killed the driver of a broken-down truck at Boudja in the Waza area of Logone-et-Chari, Extreme-Nord. The driver and other passengers were waiting for a repairman when they were attacked.

2 September 2024. Boko Haram militants carried out a deadly attack in Dizla, killing two men and one woman.

17 September 2024. Boko Haram militants attacked and killed a civilian at Camwater in Mora.

27 September 2024. Militants believed to be from Boko Haram or ISWAP attacked and killed a truck driver on the outskirts of Igawa, in the Mayo-Sava region of Extreme-Nord. Two of the victim's assistants escaped. The militants looted goods from the truck.

Bombing

16 September 2024. A military patrol in the village of Bori was hit by an IED likely planted by Boko Haram (JAS), resulting in the deaths of 5 soldiers.

28 September 2024. An IED likely planted by Boko Haram damaged a civilian vehicle on the Baroua road, resulting in the deaths of between 2 and 7 people and injuring 3 others.

Extortion

5 September 2024. Ten Boko Haram militants demanded 10,000 Naira from each fish trader in Bargaram as a form of intimidation and control over the area.

NTEWS PREDICTIONS

Prediction 1

Boko Haram is likely to carry out an abduction within approximately three months.

Rationale: Our predictive models show there is a probability of 0.74 that Boko Haram will carry out an abduction attack within three months if there are no news reports of Boko Haram explicitly seeking a religious government, the group is not negotiating through a third party, and there are no messages of solidarity in the current month.

Thank you!

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