Machine learning based prediction of visibility selection in a satellite communication ground network

Kyle Polich

CCAAW 2023

ATLAS SPACE OPERATIONS

Ground Software as a Service

Ground Software as a Service

- Freedom™ Software Platform
- Flex Scheduler
- Cognitive Constellation Scheduling
- Insights program

Visibility

A period of **time** when a spacecraft has visual contact with a ground station.

Task Request

A period of **time** when a customer requests use of a Visibility.

Task

A (tentative) allocation of resources for communication.

Schedule

A list of Tasks.

The Scheduling Problem

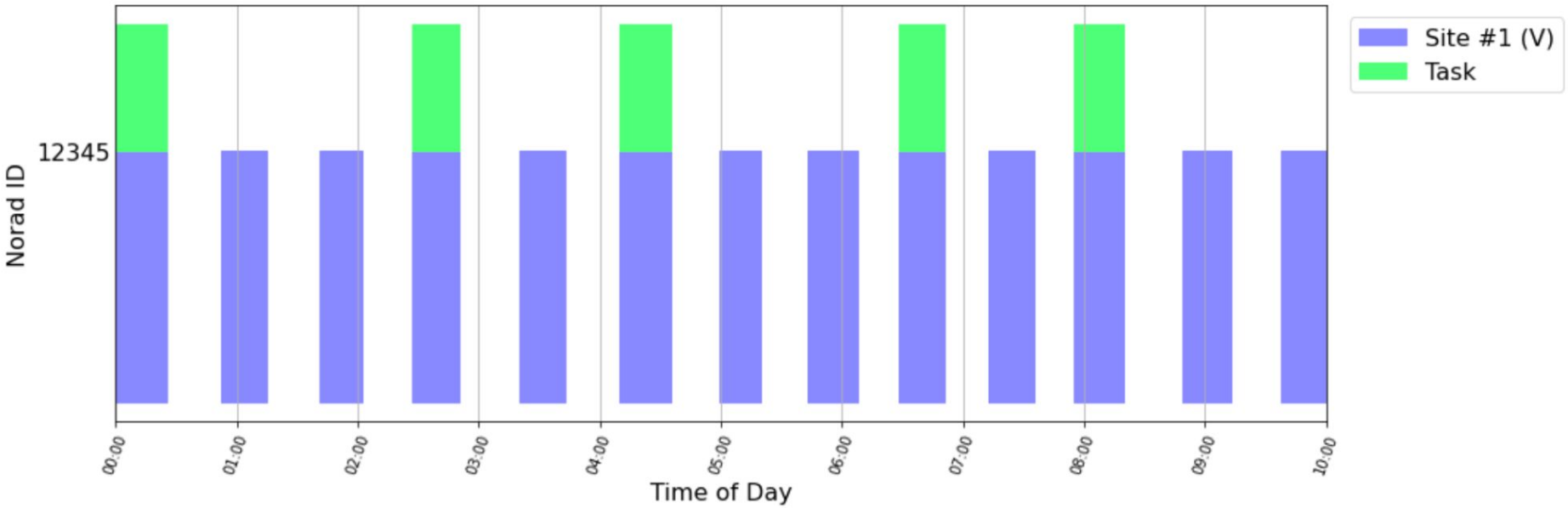
Input: Task Requests & System Data

Output: Schedule

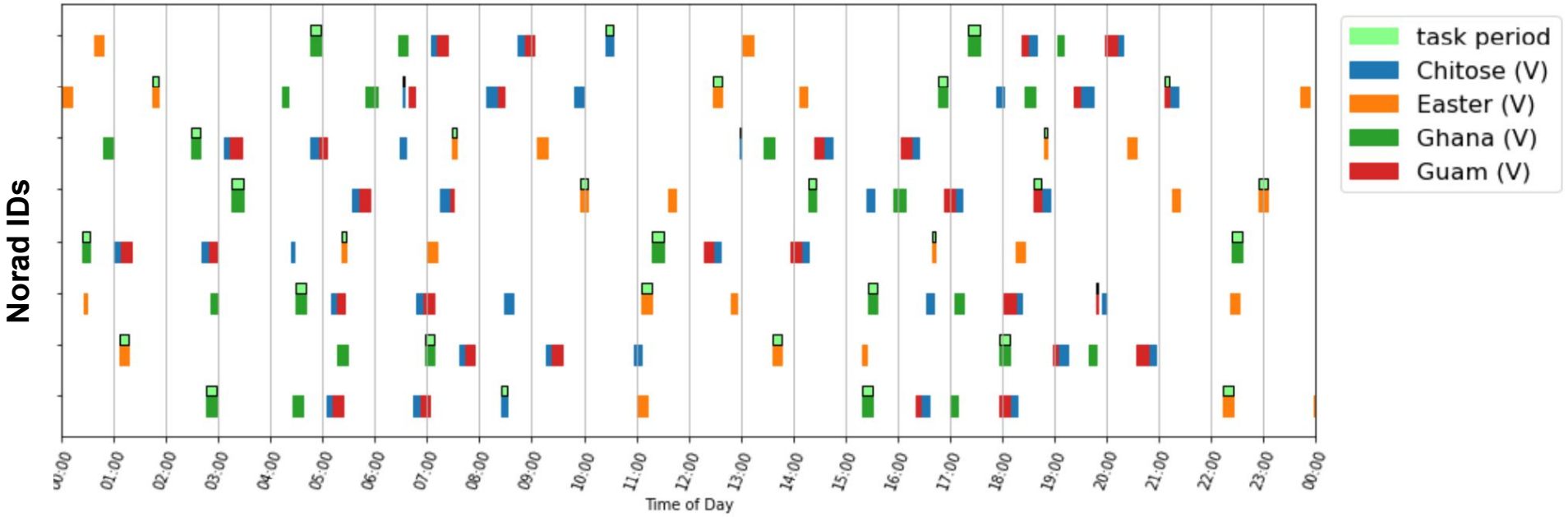
Challenge: How to resolve conflicts?

How to minimize disappointment?

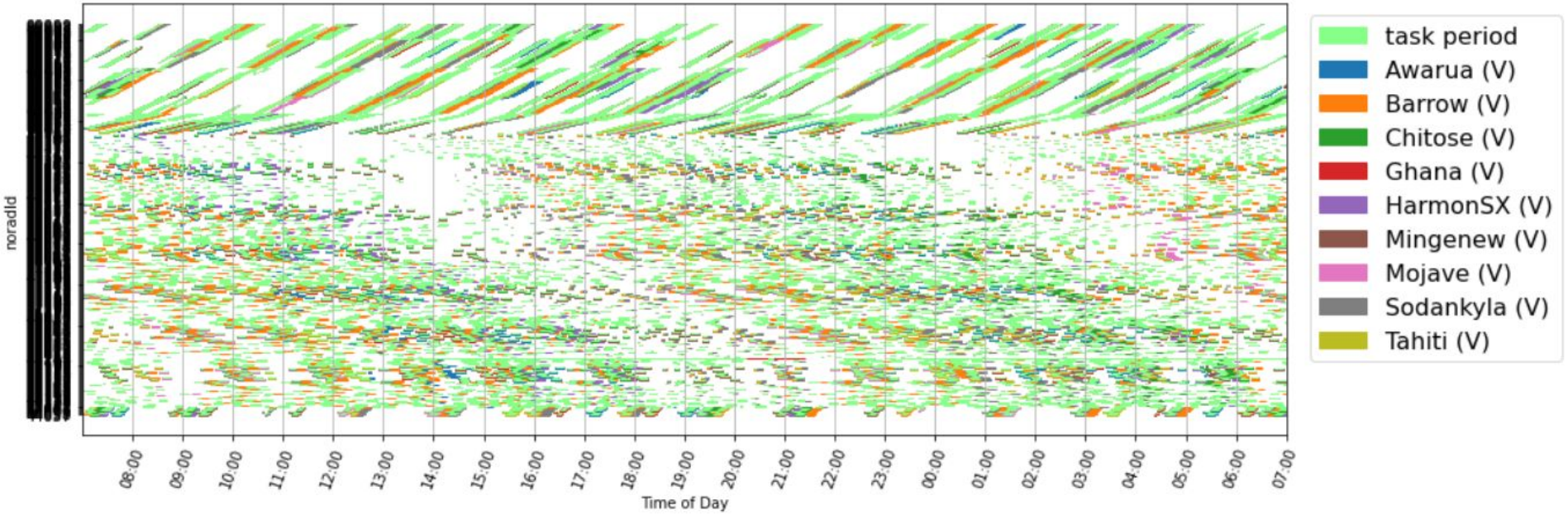
Example Schedule at one Site



Partial real world example



Scaling up Scheduling



Scheduling & De-Confliction

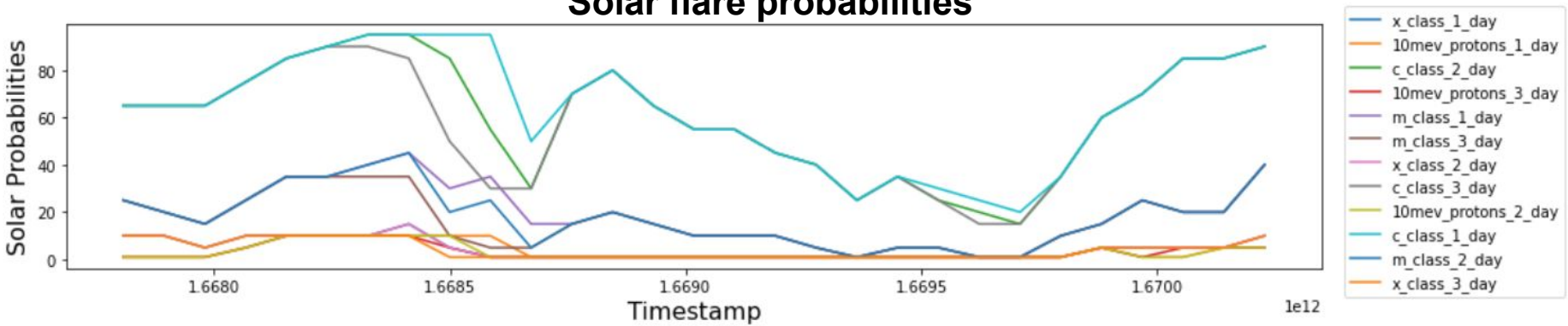
When two users want the same resource at the same time, who “wins”?

- Simulations are run during onboarding
- Contractual obligations can exist
- Flexibility enables efficient sharing of resources
- Cognitive constellation management allows autonomous scheduling
- Predictive analytics and machine learning automation **(this talk!)**

Data Lake Strategy

Scheduling decisions are informed by a variety of data.

All the data. One place.



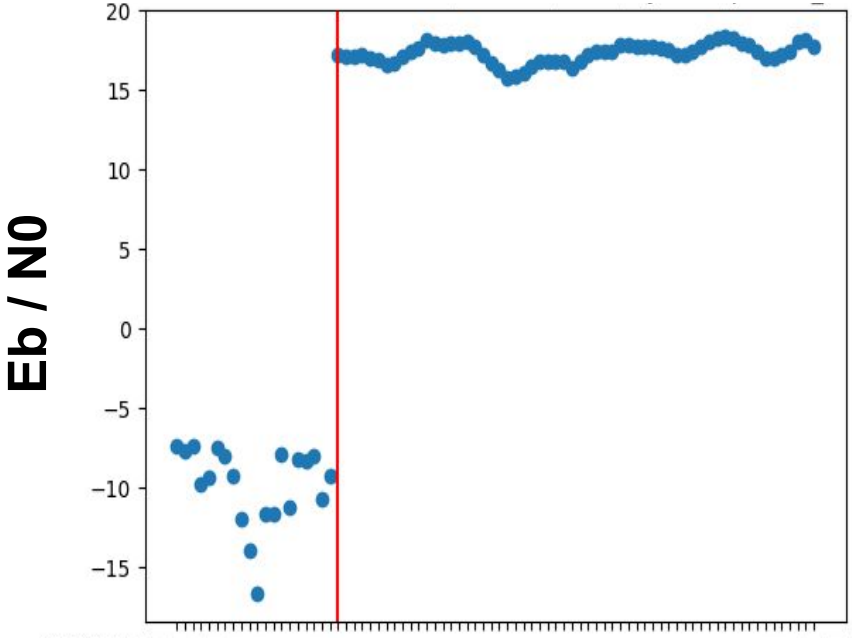
Motivations to link data sources

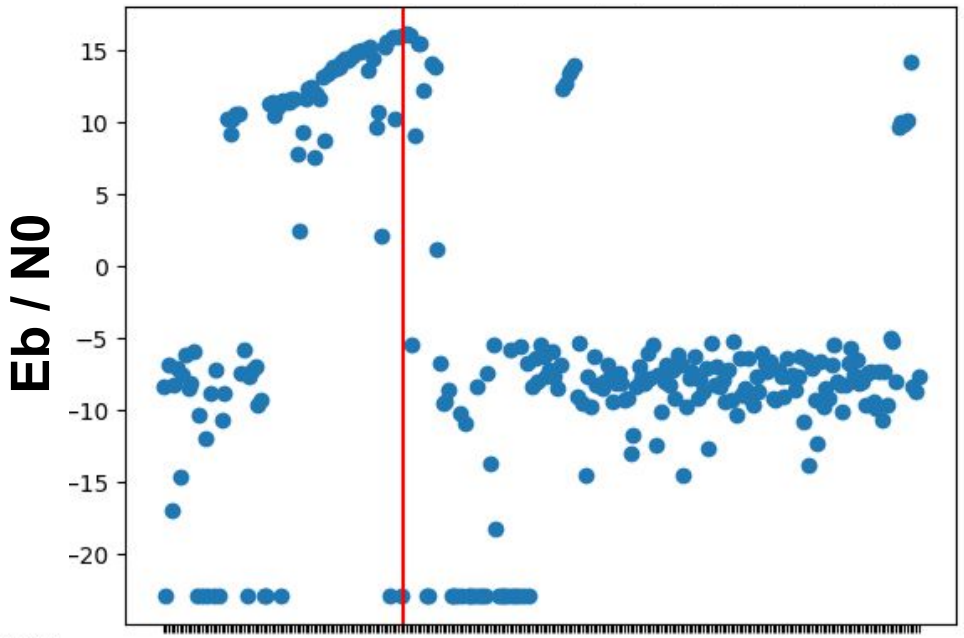
- Pro-active detection of issues
- Reduce time to resolution
- Space Weather impacts us!
  - https://spaceweatherarchive.com/2022/02/09/the-starlink-incident/
  - 2022 Hunga Tonga-Hunga Ha'apai eruption and tsunami
- Rare events require additional context

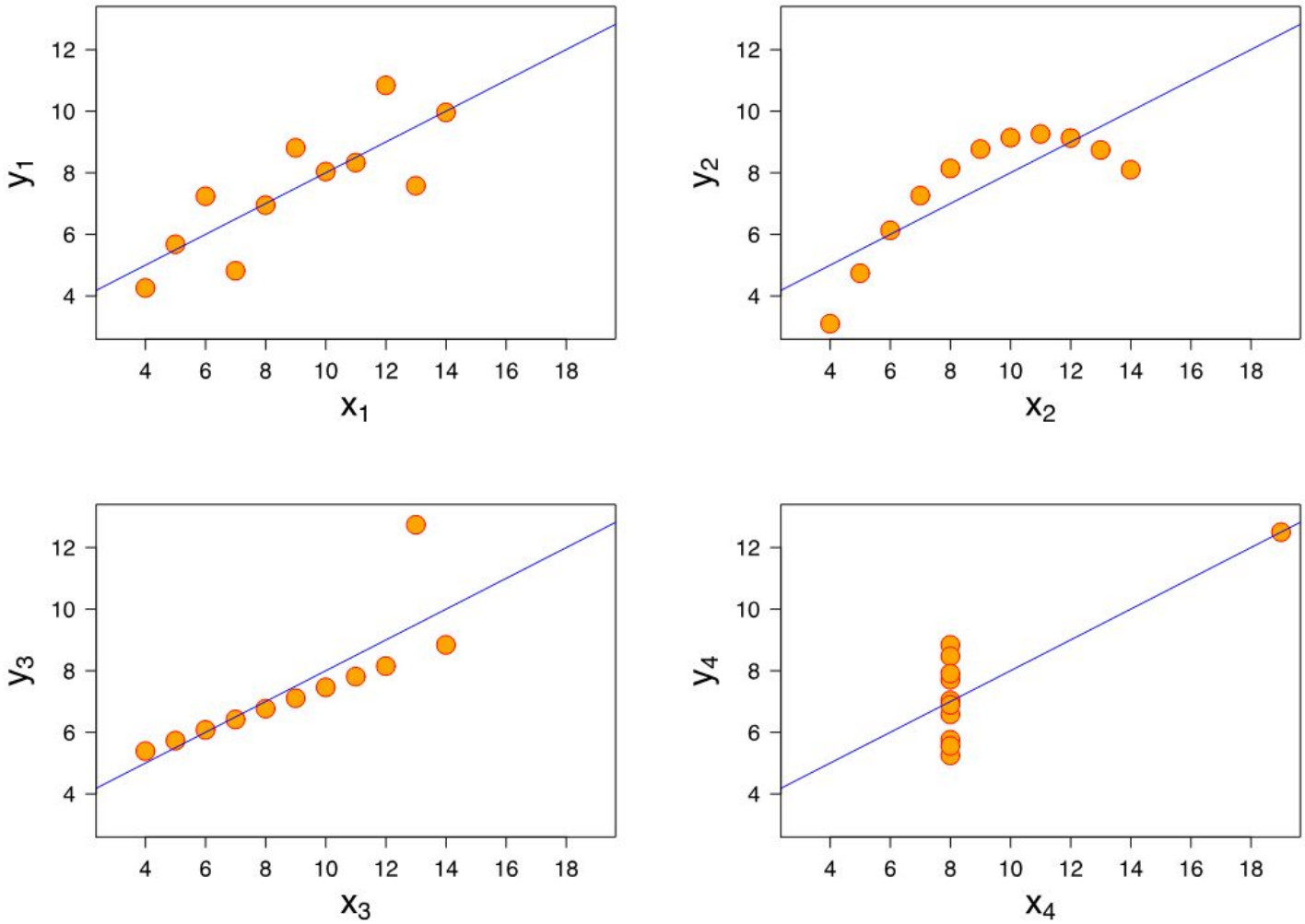
Data Lake Strategy

- Space weather
- Terrestrial weather
- Ground site telemetry metrics (e.g. rf power)
- Pass telemetry metrics (e.g. Eb / N0)
- Hardware logs
- Software logs

Example Pass Metric

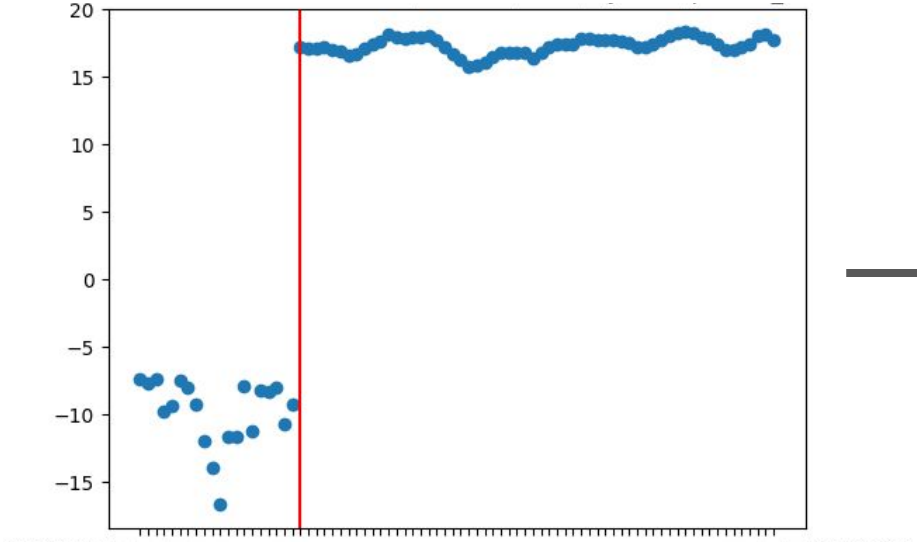





y1
x1
y2
x2
y3
x3
y4
x4
4
6
8
10
12
14
16
18

ETL and Feature Engineering

- **Hand Engineered Features**

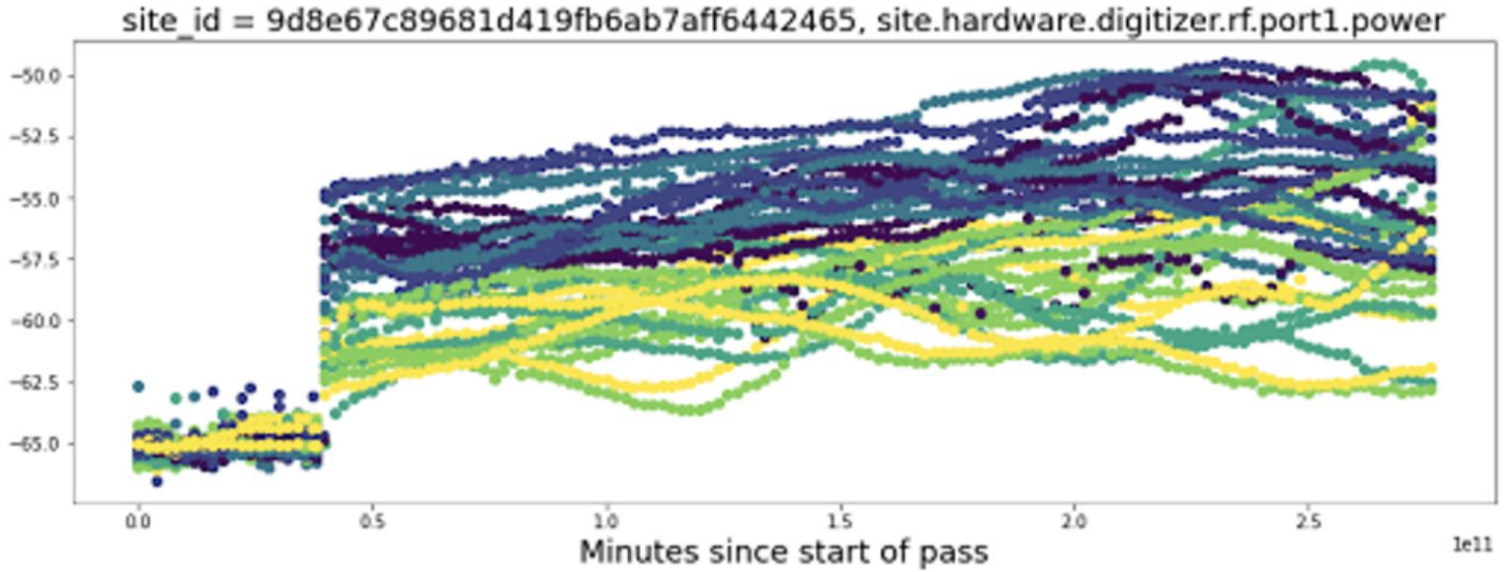


Eb / N0 pass becomes 9 features

- Time until start
- min/mean/stdev/max before lock (4)
- min/mean/stdev/max after lock (4)

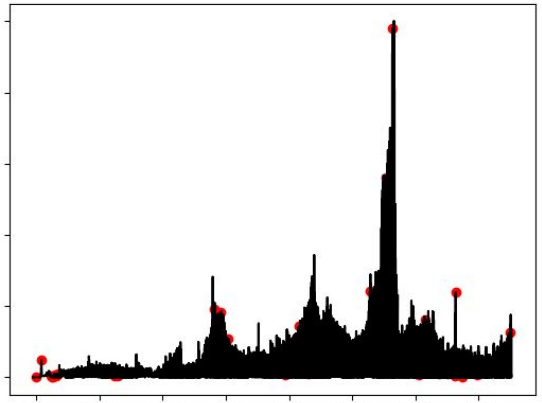
ETL and Feature Engineering

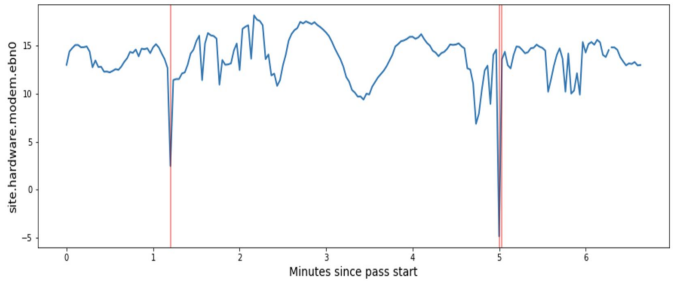
- Hand Engineered Features
- **Historical Profiles**

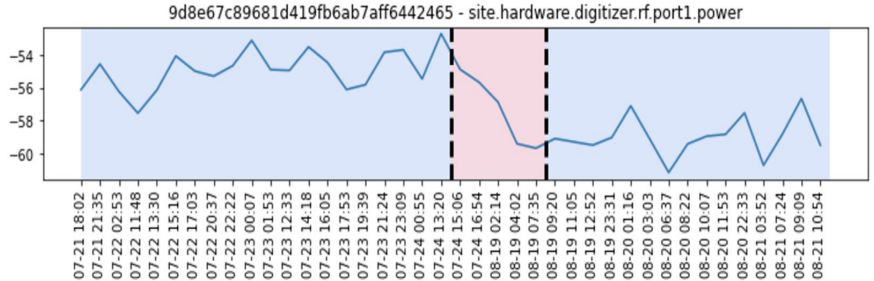


ETL and Feature Engineering

- Hand Engineered Features
- Historical Profiles
- **Anomaly detection**
  - **Bollinger bounds**
  - **Pruned Exact Linear Time (PELT)**
  - **Ruptures python library**
  - **FB prophet forecast vs. actual**







ETL and Feature Engineering

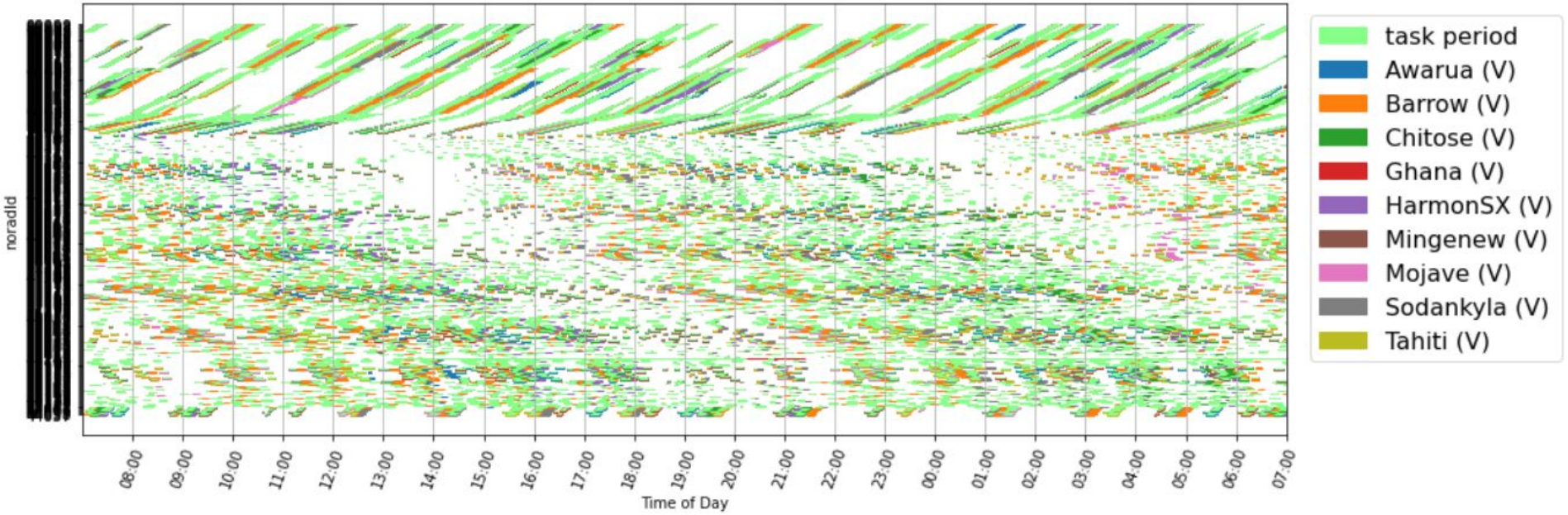
- Hand Engineered Features
- Historical Profiles
- Anomaly detection
- **Frequency counters** - How often did Event X happen in period Y?
- **Summary statistics** - mean, stdev, median, skewness, kurt., percentiles
- **Windowed calculations** - e.g. rolling average

Visibility Prediction Problem

Can we predict
if a future **Task Request**
will target a particular **Visibility**?

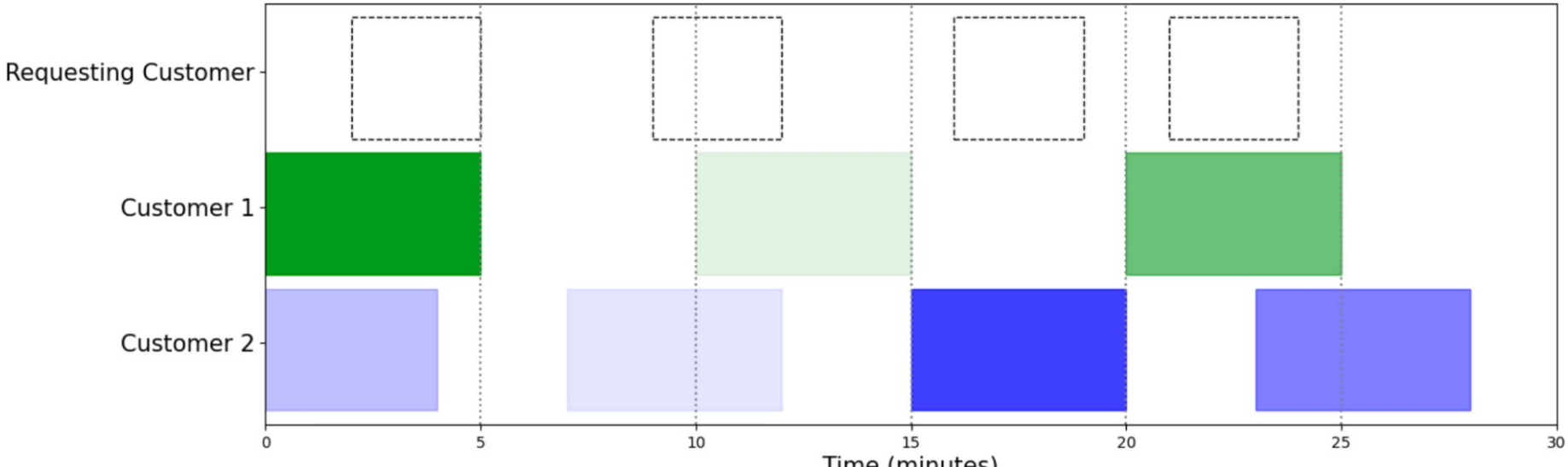
- Scheduling requests are on-demand
- Acceptance is near real time
- Undesirable bias towards early booking customers; Bumped Tasks can occur

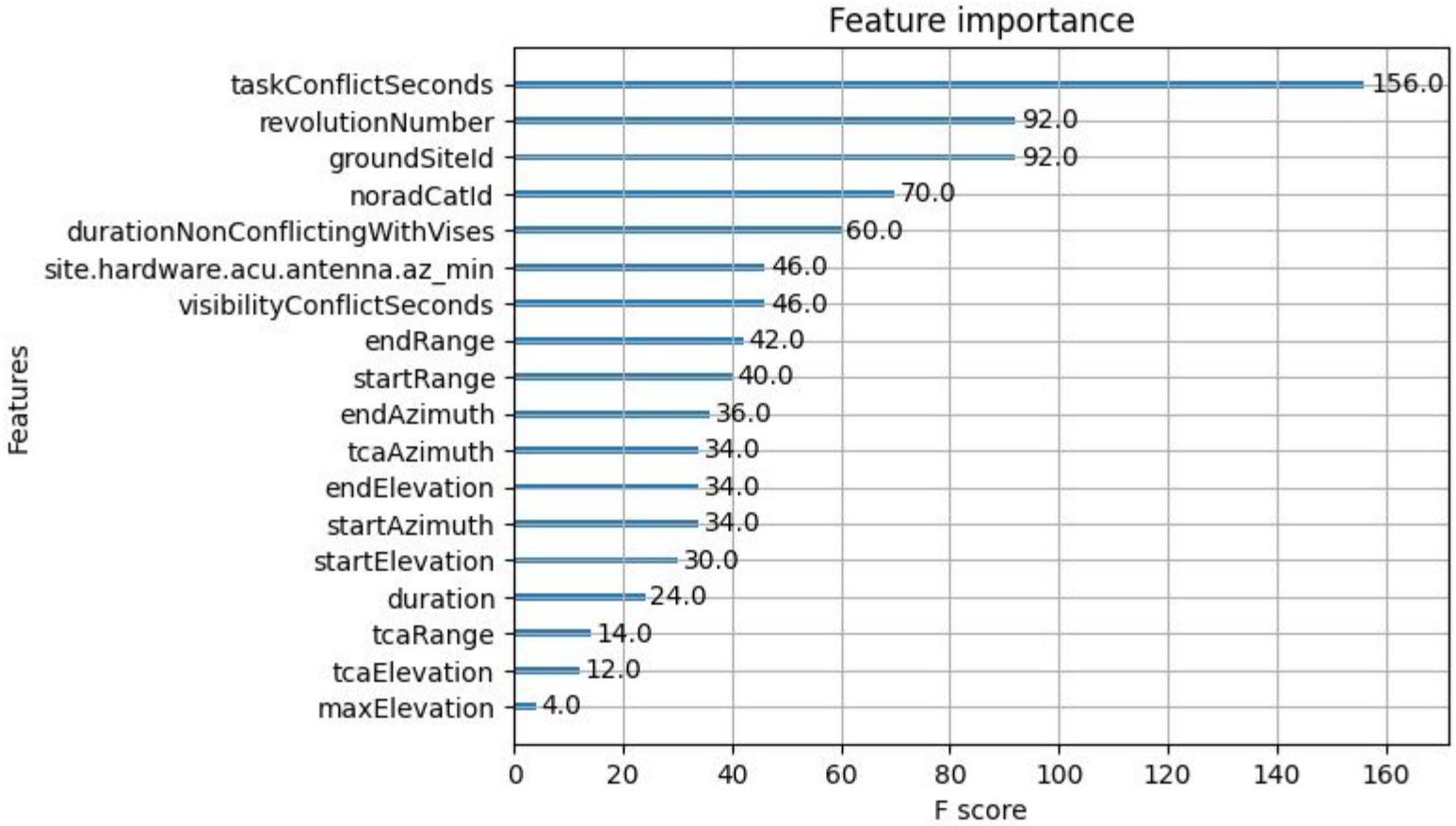
Full real world example



Visibility Prediction Problem

Can we predict
if a future **Task Request**
will target a particular **Visibility**?




Feature importance
taskConflictSeconds
revolutionNumber
groundSiteId
noradCatId
durationNonConflictingWithVises
site.hardware.acu.antenna.az_min
visibilityConflictSeconds
endRange
startRange
endAzimuth
tcaAzimuth
endElevation
startAzimuth
startElevation
duration
tcaRange
tcaElevation
maxElevation
156.0
92.0
92.0
70.0
60.0
46.0
46.0
42.0
40.0
36.0
34.0
34.0
34.0
30.0
24.0
14.0
12.0
4.0
Features
0
20
40
60
80
100
120
140
160
F score

Current / Future work

- Operational integrations
- Failure detection
- Automated recovery from failure
- Predictive maintenance
- Cognitive scheduling
- Anomaly detection with human feedback
- Chat GPT on JIRA tickets

Thank you!

kyle@dataskeptic.com