Workshop on Collision Avoidance Challenge Results

Introduction

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ESA, 23/04/2021

Welcome

https://kelvins.esa.int/collision-avoidance-challenge/

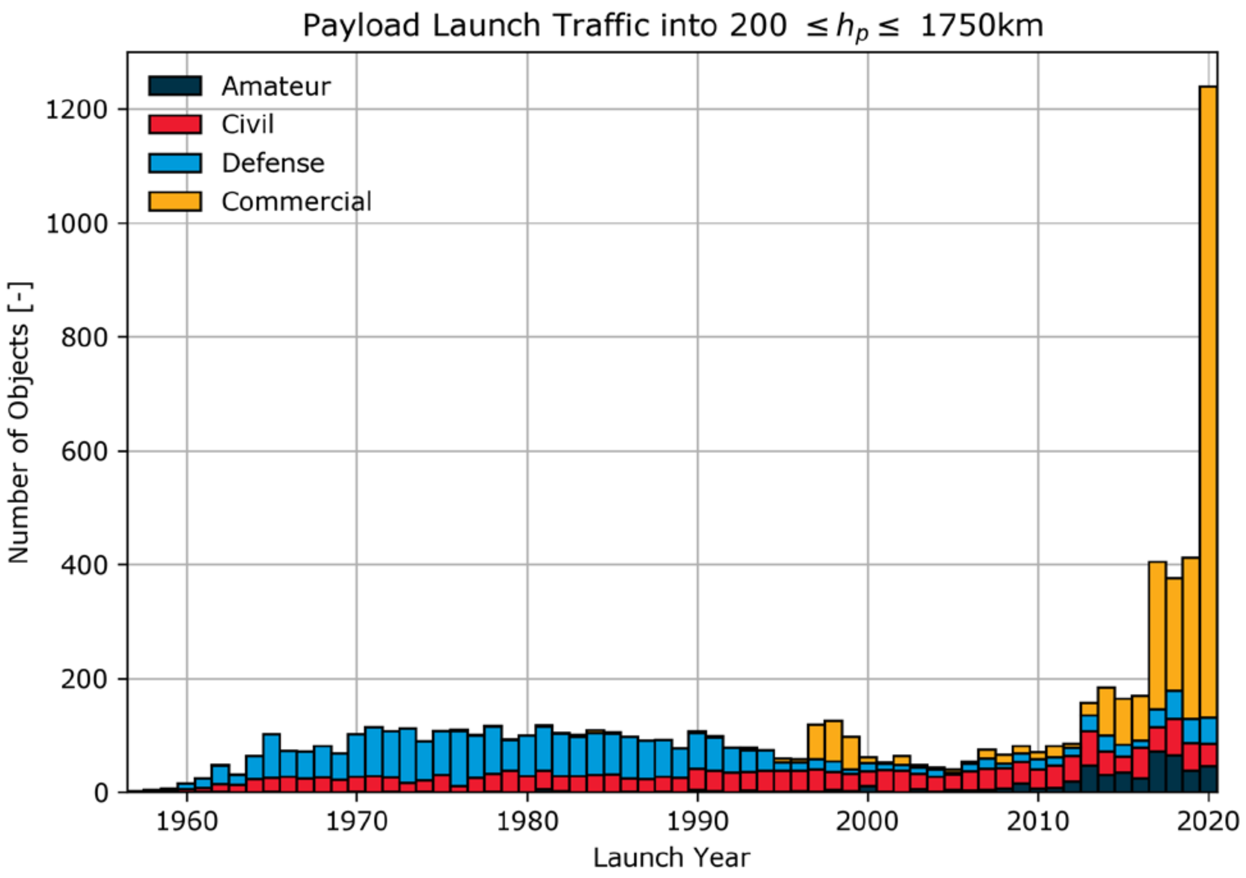
Motivation

Recap Challenge

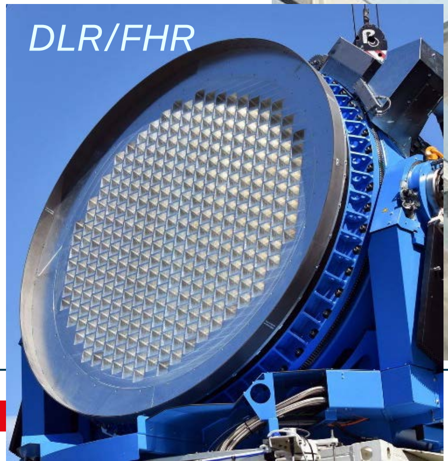
Challenge Preparation

Motivation

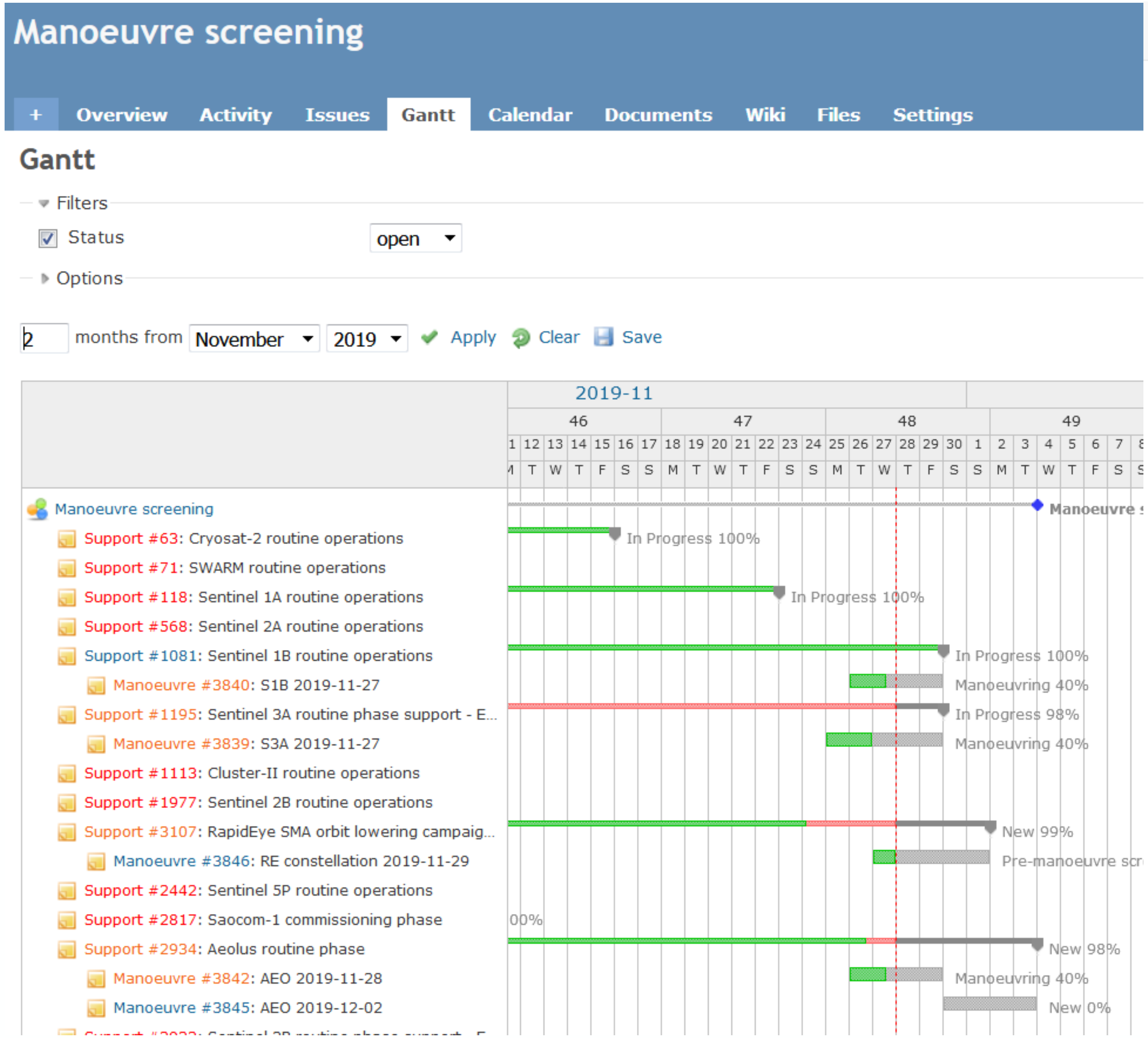
increased launch traffic

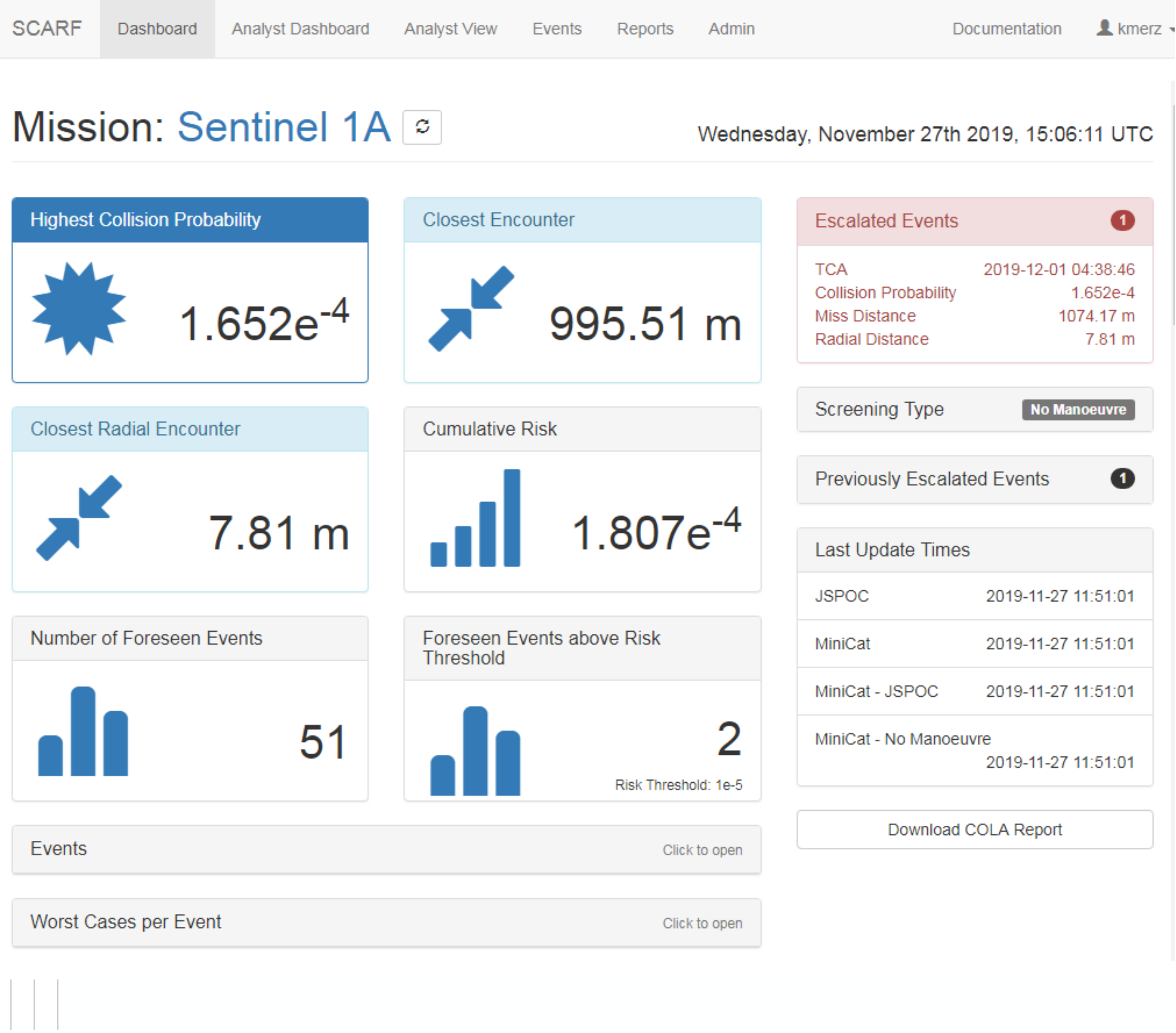


increased sensor performance



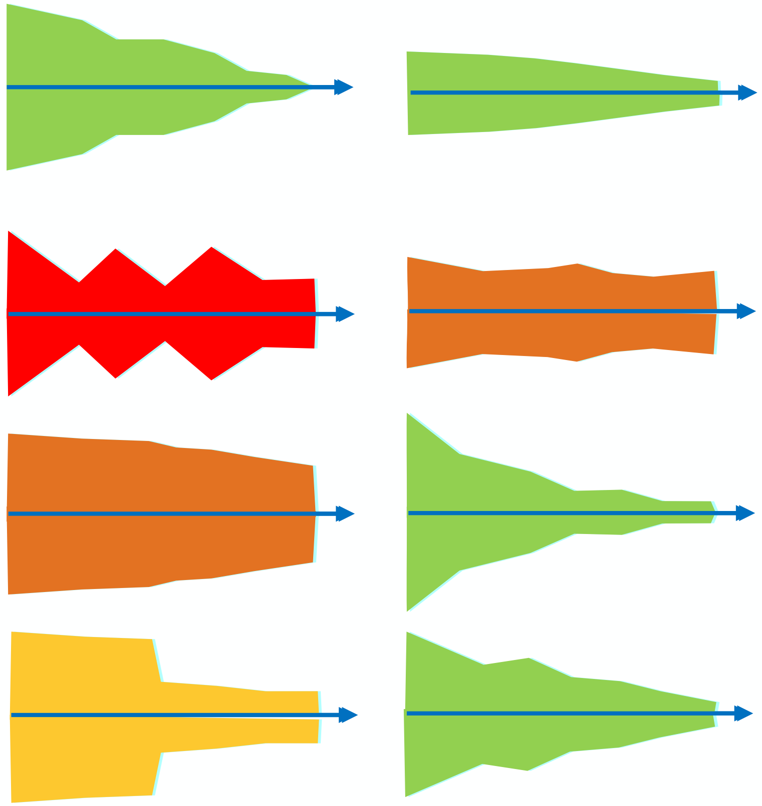
From manual expert work….





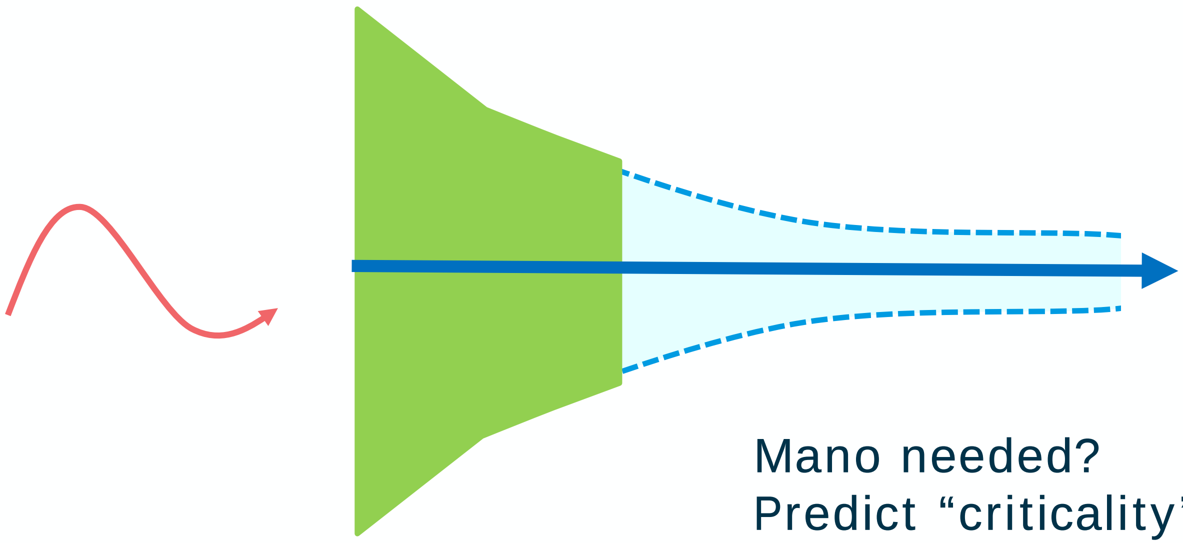
… to machine learning

Training data



ESOC: database of > 250 000 close approach events

Classification *Prediction*



Mano needed?
Predict “criticality”, e.g. final risk, uncertainty, separation, mimic past decisions

The Challenge

Public challenge held late 2019 running 2 months

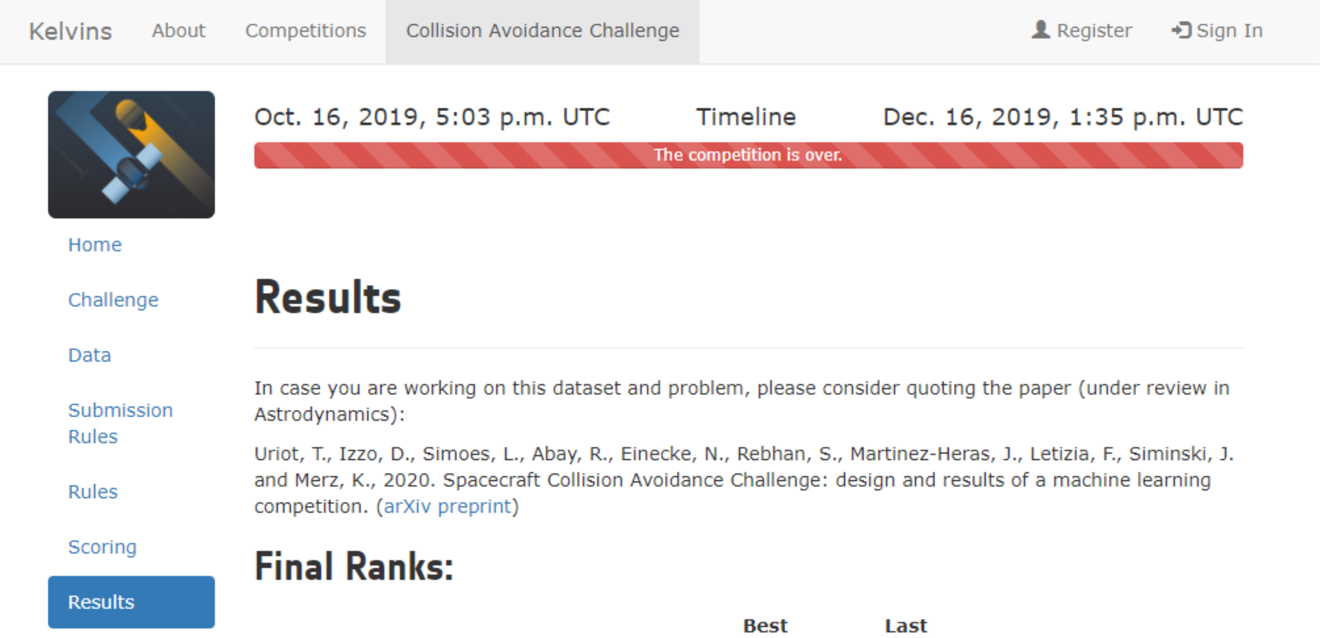
First ever public release of a large set of CDMs

- Only mildly anonymised

Pilot to assess whether ML can help assessing conjunctions

- Engage/attract data scientists
- (i.e. not necessarily experts in debris / flight dynamics)

96 participants, 862 submissions

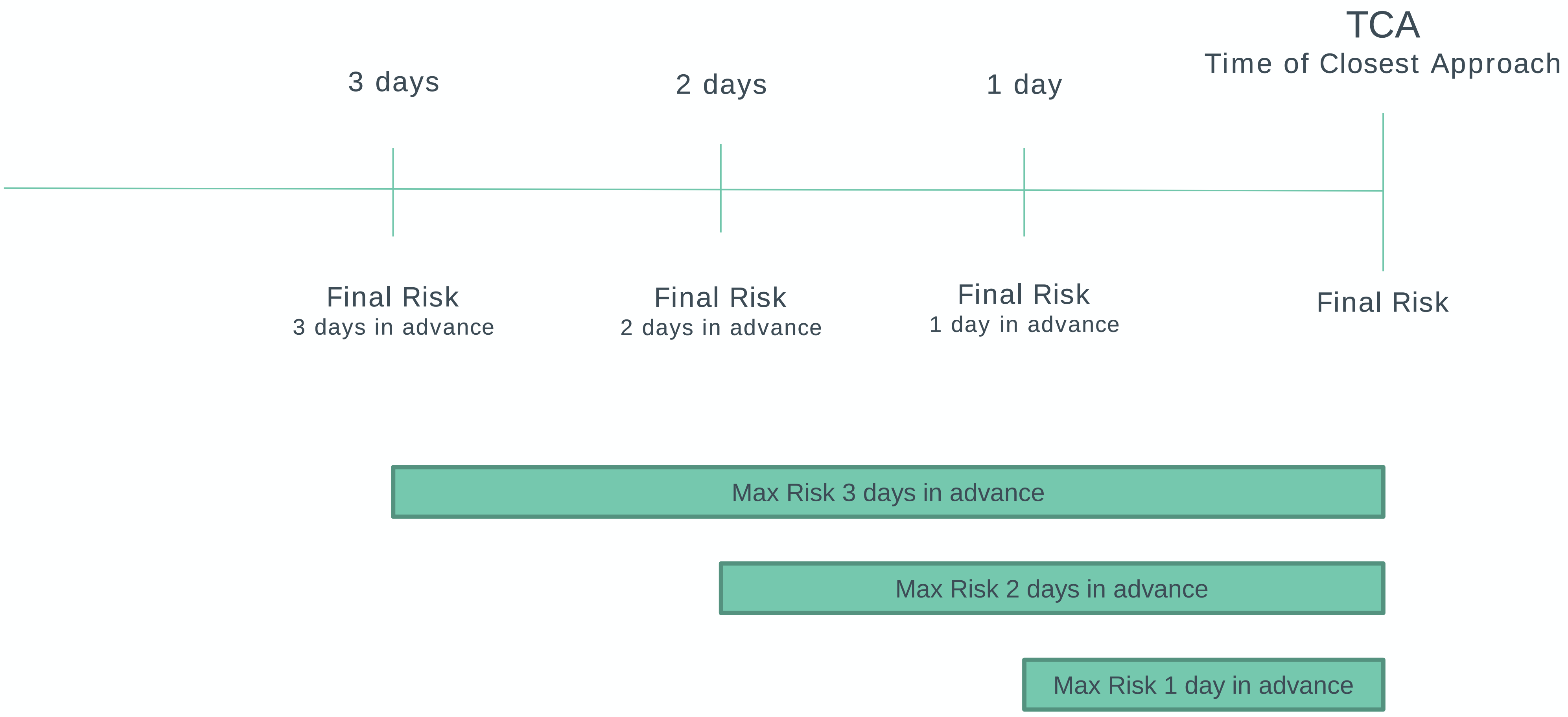


Challenge Preparation

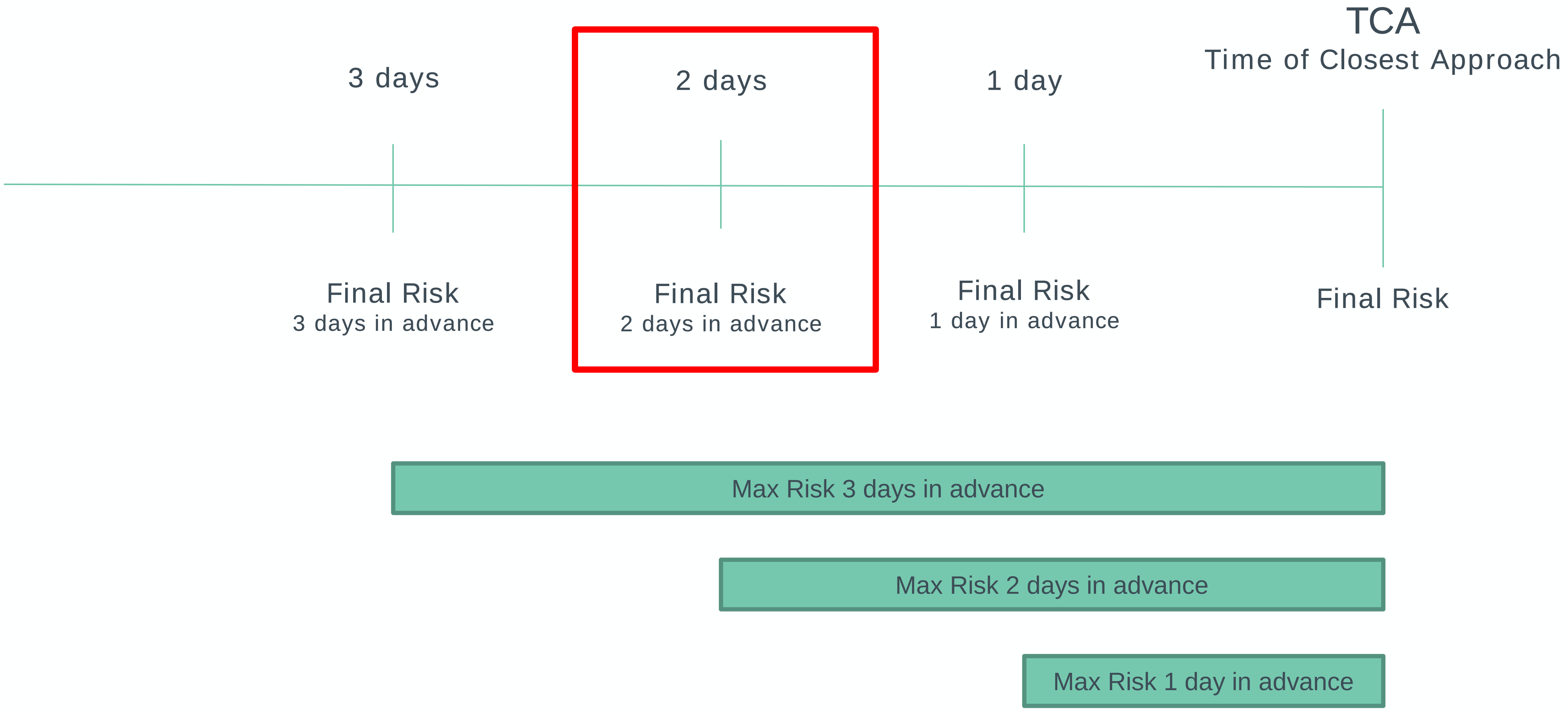
How data looks like?

event_id	time_to_tca	mission_id	risk	max_risk_estimate	max_risk_scaling	miss_distance	relative_speed	relative_position_r	relative_position_t	relative_position_n	relative_velocity_r	relative_velocity_t	relative_velocity_n	t_tim
0	1.566798229	5	-10.205	-7.83476	8.602100967	14923	13792	453.8	5976.6	-13666.8	-7.2	-12637	-5525.9	
0	1.207493507	5	-10.3558	-7.84894	8.956373809	14544	13792	474.3	5821.2	-13319.8	-7	-12637	-5525.9	
0	0.952192743	5	-10.3456	-7.84741	8.932195119	14475	13792	474.6	5796.2	-13256.1	-7	-12637	-5525.9	
0	0.579669363	5	-10.3378	-7.84588	8.913444064	14579	13792	472.7	5838.9	-13350.7	-7	-12637	-5525.9	
0	0.257806042	5	-10.3913	-7.85294	9.036838245	14510	13792	478.7	5811.1	-13288	-7	-12637	-5525.9	
1	6.530455104	5	-7.5613	-7.2543	2.746781823	2392	3434	74.3	2317.1	-589.4	25.9	-847.8	-3328.2	
1	5.561646088	5	-9.31569	-7.4689	7.223137485	3587	3434	99	3475.4	-885.1	24.7	-847.8	-3328.2	
1	5.226503738	5	-7.42251	-7.051	2.956639138	7882	3434	-50	-7638.3	1945.7	36.8	-847.7	-3328.2	
1	3.570013079	5	-9.24811	-7.32753	7.425994268	26899	3434	-82	-26067	6638.2	56.8	-847.8	-3328.2	
2	6.983473519	2	-10.8162	-6.60171	13.29315867	22902	14348	-1157.6	-6306.2	21986.3	15.8	-13792	-3957.1	
2	6.691610521	2	-10.8505	-6.60345	13.3742415	22966	14348	-1161.1	-6330.2	22046.3	15.8	-13792	-3957.1	
2	6.269979225	2	-30	-6.21796	426.8085319	18785	14347	-698.8	-5176.4	18044.8	14.4	-13791.4	-3957.2	
2	6.04235213	2	-30	-6.27108	181.4967781	18842	14347	-700	-5192.1	18099.4	14.4	-13791.4	-3957.2	
2	5.711715972	2	-30	-6.27745	187.5253596	19015	14347	-709.9	-5242.1	18264.8	14.5	-13791.4	-3957.2	
2	5.377642257	2	-30	-6.27827	190.0905681	19137	14347	-710.3	-5273.6	18382.8	14.5	-13791.4	-3957.2	
2	5.02891463	2	-30	-6.28325	188.2700588	18918	14347	-714.8	-5213.9	18172	14.5	-13791.4	-3957.2	
2	4.724354919	2	-30	-6.28358	192.1005632	19152	14347	-717.5	-5277.4	18397.2	14.5	-13791.4	-3957.2	
2	4.334353623	2	-30	-6.52462	1984.965171	18635	14347	-704.3	-5134.8	17900	14.4	-13791.4	-3957.2	
2	4.055291782	2	-30	-6.27051	404.8873209	18789	14347	-700.7	-5177.3	18048.3	14.4	-13791.4	-3957.2	
2	3.692814988	2	-30	-6.27165	408.1050061	18826	14347	-698.8	-5187.4	18084.4	14.4	-13791.4	-3957.2	
2	3.358613426	2	-30	-6.26313	393.7434614	18715	14347	-690.8	-5155.7	17978.5	14.4	-13791.4	-3957.2	
2	2.886460741	2	-30	-6.26344	397.1047409	18748	14347	-686.8	-5171.4	18008.5	14.4	-13791.4	-3957.2	
2	2.340627465	2	-30	-6.26624	401.442549	18763	14347	-692.9	-5175.6	18022.2	14.4	-13791.4	-3957.2	
2	1.883868252	2	-30	-6.26809	403.494416	18753	14347	-700.1	-5172.4	18012.1	14.4	-13791.4	-3957.2	
2	1.68578941	2	-30	-6.26737	399.2433736	18709	14347	-703	-5160.9	17970	14.4	-13791.4	-3957.2	
2	1.363231435	2	-30	-7.1943	6711.316427	18686	14347	-733.1	-5153.3	17947	14.4	-13791.4	-3957.2	
2	1.042884213	2	-30	-7.19017	6592.133467	18666	14347	-732.2	-5146.1	17928.3	14.4	-13791.4	-3957.2	
2	0.602016169	2	-30	-7.19736	6804.742777	18692	14347	-727	-5148.4	17954.6	14.4	-13791.4	-3957.2	
2	0.40194684	2	-30	-7.44928	37296.16821	18708	14347	-717.9	-5159	17968.9	14.4	-13791.4	-3957.2	

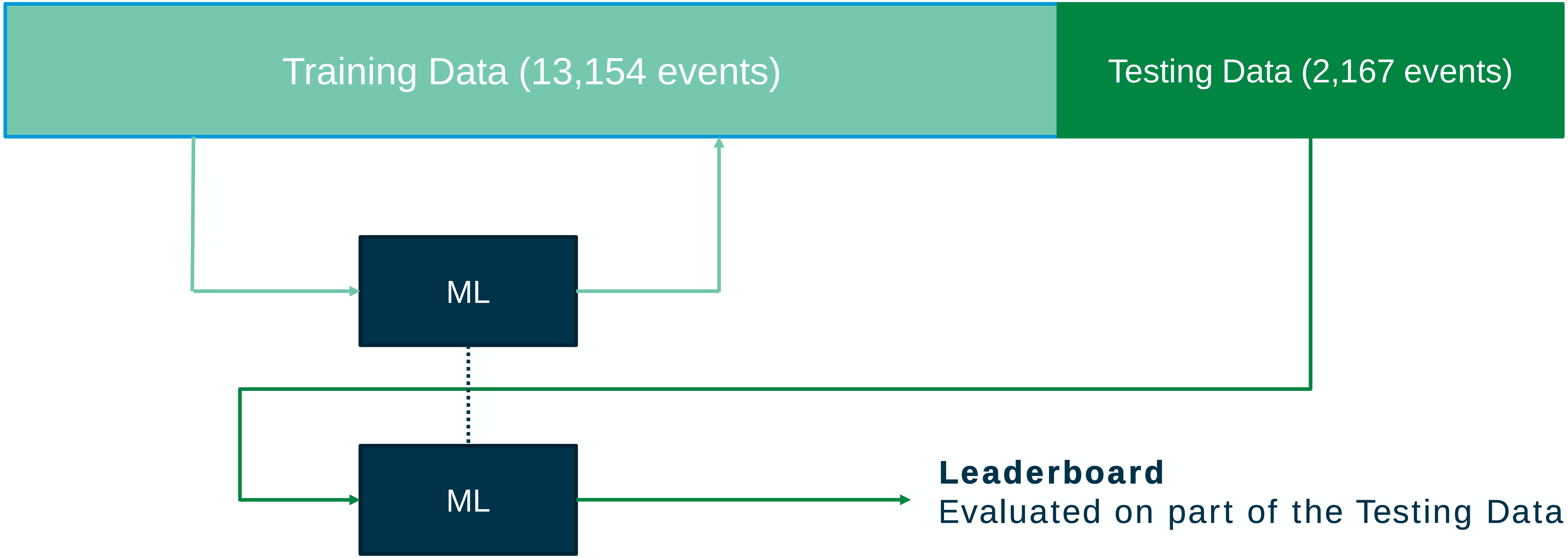
What do we want to predict?



What do we want to predict?



How are we Scoring submissions?



Score

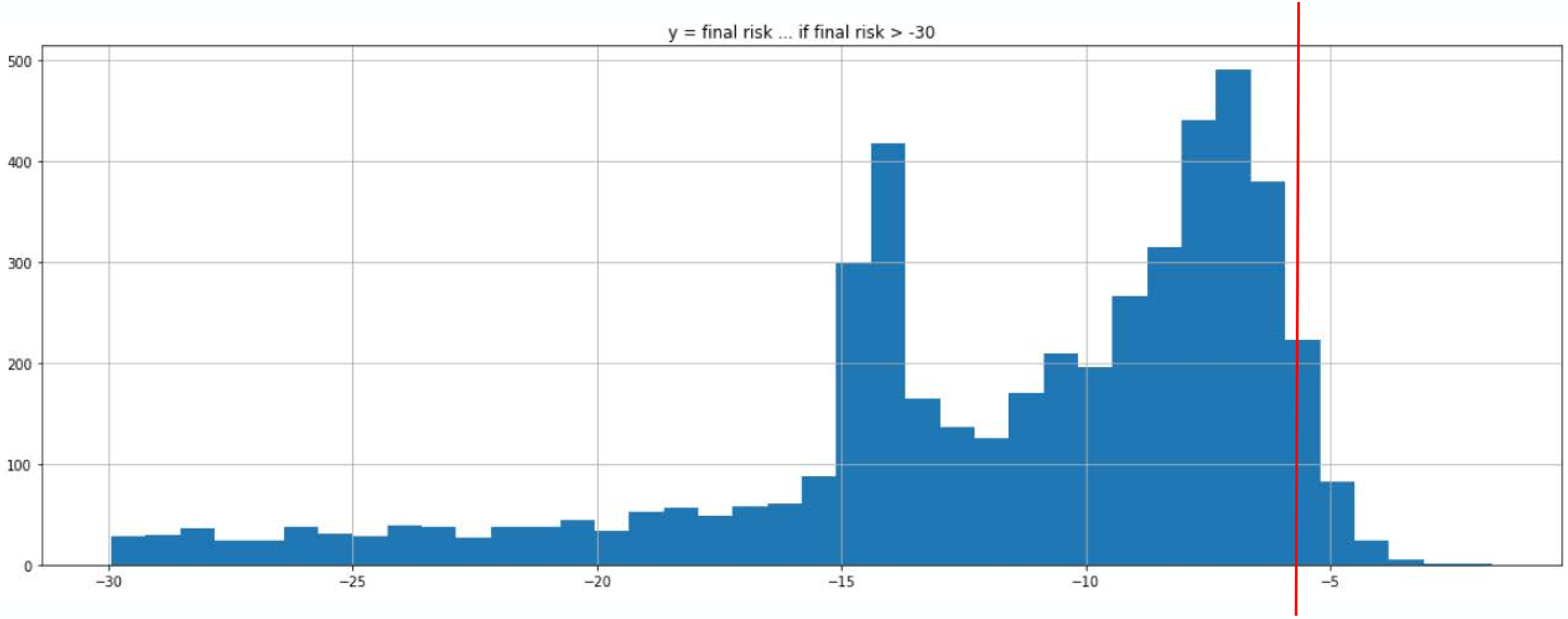
How we came up with …

$$scoring = \frac{MSE}{F2}$$

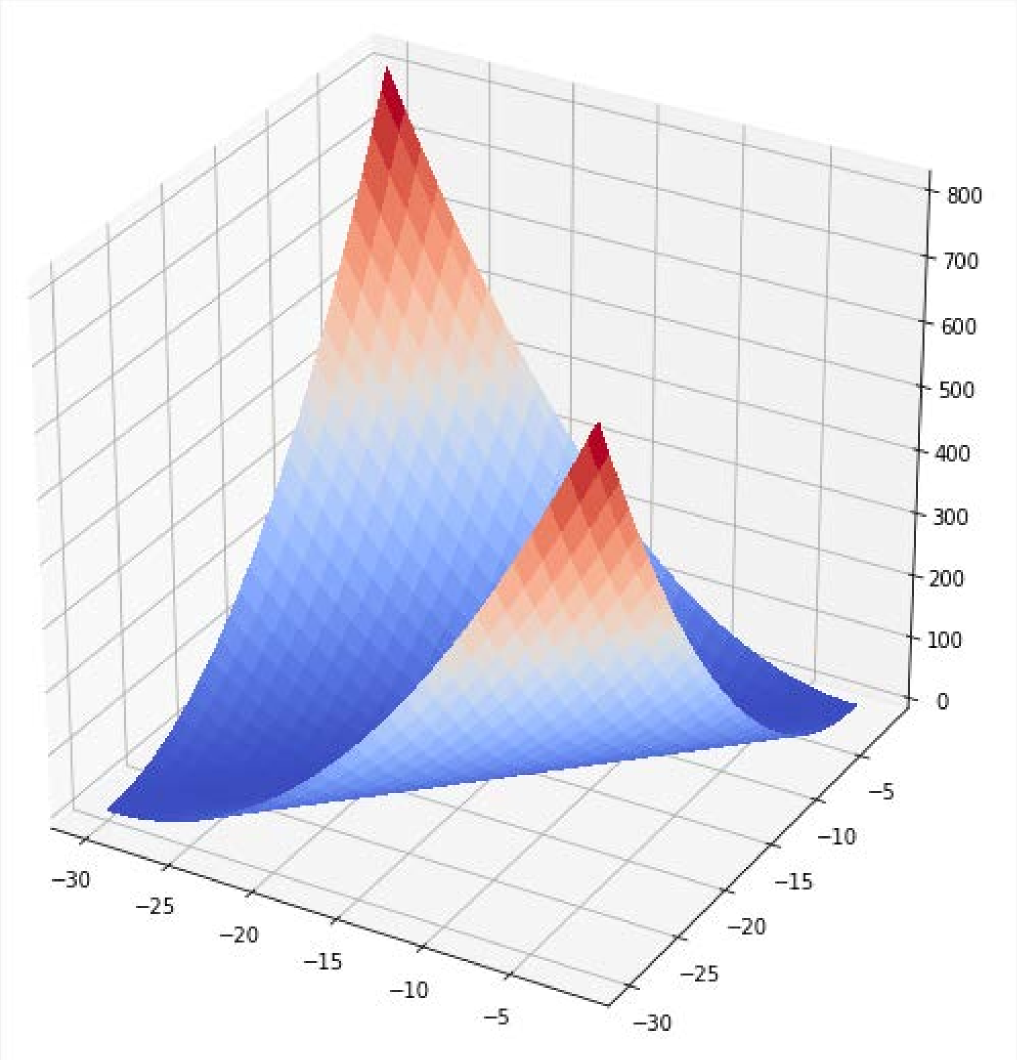
- Classification: probability above or below 10^{-6}: F2 value
- Regression for those above 10^{-6}: MSE

Long story short: it took us 5 iterations

Log10(risk) … if log10(risk) > -30



Scoring Function (I)

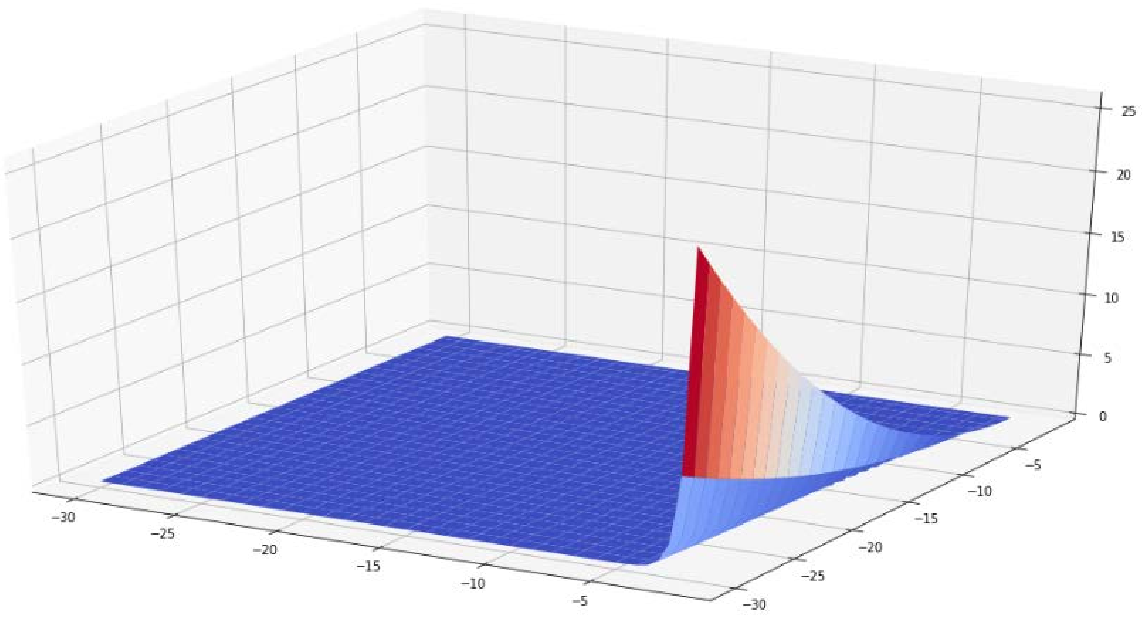


MSE(log(risk)): Mean Squared Error

Issues

- All errors are equally important
- -6 → -3 >>> -26 → -23

Scoring Function (II)



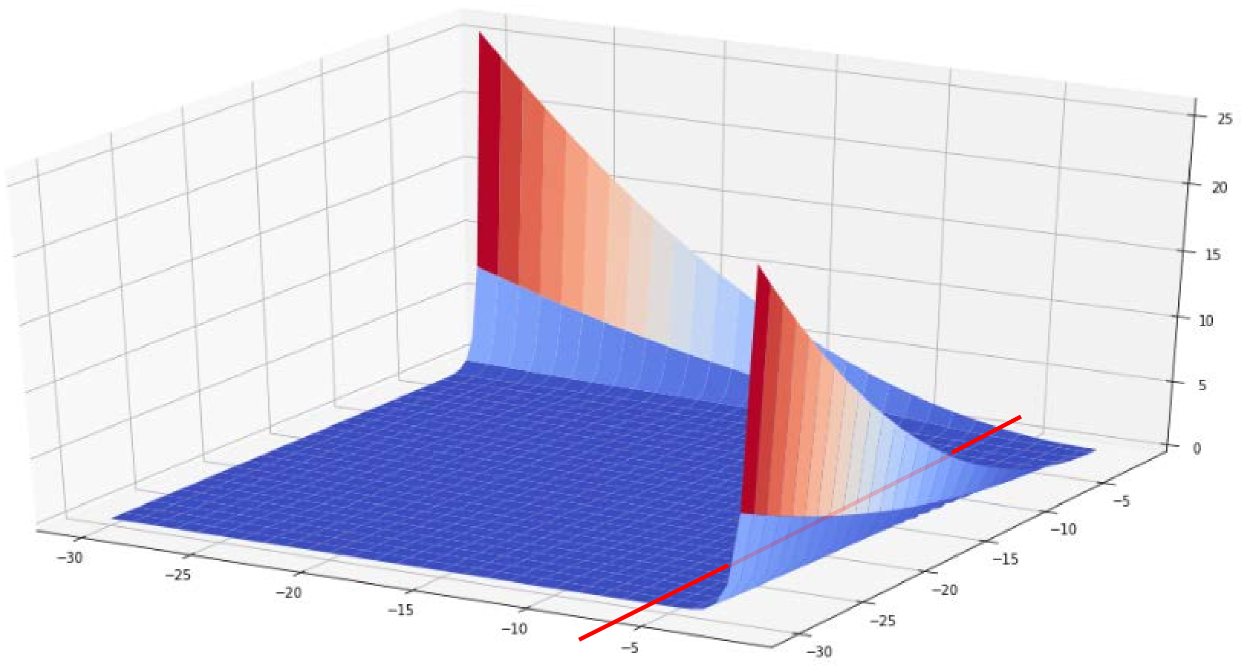
MSE * true_risk

Higher risk events are more important

Issues

- candidates could always predict high risk and not being penalized appropriately
- Would lead to false alarms

Scoring Function (III)



MSE * max(true_risk, pred_risk)

Higher risk events are more important

Properly penalizes false alarms

Issues

- Risk = -7 gives a very good scoring

Scoring Function (IV)

- Need to know how bad it can get
    - Only for high risk events (e.g. > 1e-6)

Regression

MSE

- Need to tell the difference between:
    - High risk events (risk > 1e-6)
    - Low risk events (risk < 1e-6)

Classification

F1

Scoring Function (IV)

$$scoring = \frac{MSE}{F1}$$

But ... F1 gives equal importance to False Positive & False Negatives

For collision avoidance we can accept false positives but don’t want to miss potential risks

Scoring Function (V)

$$scoring = \frac{MSE}{F2}$$

F2 penalises (more than F1) the false negatives

Details see also https://link.springer.com/article/10.1007/s42064-021-0101-5

There is more to it …

- Lots of data preparation (data cleaning, missing data, deciding which data …)
- Data Anonymization
- Code / Version control (gitlab.esa.int)
- Permissions to release the data
- Meetings / Telecons / presentations / mails
- Media outreach

https://www.meetup.com/FrankfurtDataScience/events/255952732/

ENABLING & SUPPORT

AI challenged to stave off collisions in space

https://www.esa.int/Enabling_Support/Space_Engineering_Technology/AI_challenged_to_stave_off_collisions_in_space

ESA Operations
@esaoperations

Interested in taking part in a rubbish challenge?

To manoeuvre or not to manoeuvre... that's the question posed by ESA's #SpaceDebris Office and Advanced Concepts Team.

Find out more: esa.int/Our_Activities...

#MachineLearning
#AI
@ESAcleanspace

5:03 PM · Oct 9, 2019 · Twitter Web App

Team Work

Space Debris Office

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Daniel Scuka

Sean Blair

Artificial Intelligence & Operations Innovation

Jose Martinez Heras

https://kelvins.esa.int/collision-avoidance-challenge/

16:30 → 16:50 **Introduction (ESA)**

16:50 → 17:10 **Engineered Decision Tree for Judging Spacecraft Collision Risks, Sven Rehban (Honda Research Institute Europe)**

17:10 → 17:30 **Learning from an imbalanced dataset of conjunction data messages, Rasit Abay (NeuraSpace)**

17:30 → 17:50 **Machine learning-powered algorithms for predicting the risk of satellite collisions, Michal Myller (KP Labs)**

17:50 → 18:10 **Outlook (ESA)**