zipline
Insights : Zip Flights

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May, 2019
Reza Taeb

Outline

- Overview

- Dataset Info.

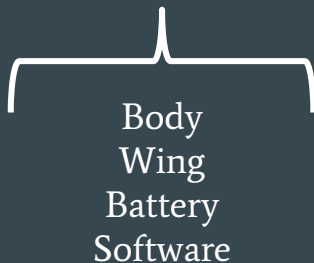- Data Exploration & Visualization

- Insights & Suggestions

Overview

In this piece, I will try to extract some actionable insights from the Zip - fully autonomous drone at Zipline Inc. - flights dataset that gathered at the Zipline distribution center in Muhanga, Rwanda.

Insights address 2 main areas :

Components and **Weather**

Body
Wing
Battery
Software

Dataset Info

Number of Flights

447

Duration

1 Month

(6th Sep to 5th Oct 2018)

Number of Bodies

15

Number of Wings

18

Number of Batteries

26

Number of Software Ver.

4

Air Temperature(Median)

24.95 (c)

Static Pressure(Median)

80445 (Pas)

Relative Humidity(Median)

56.2 (%)

Wind Magnitude(Median)

2.31 (m/s)

Wind Direction(Median)

-51.63 (0 to N)

Launch Air Speed(Median)

31.9 (m/s)

Launch Ground Speed (Median)

30.1 (m/s)
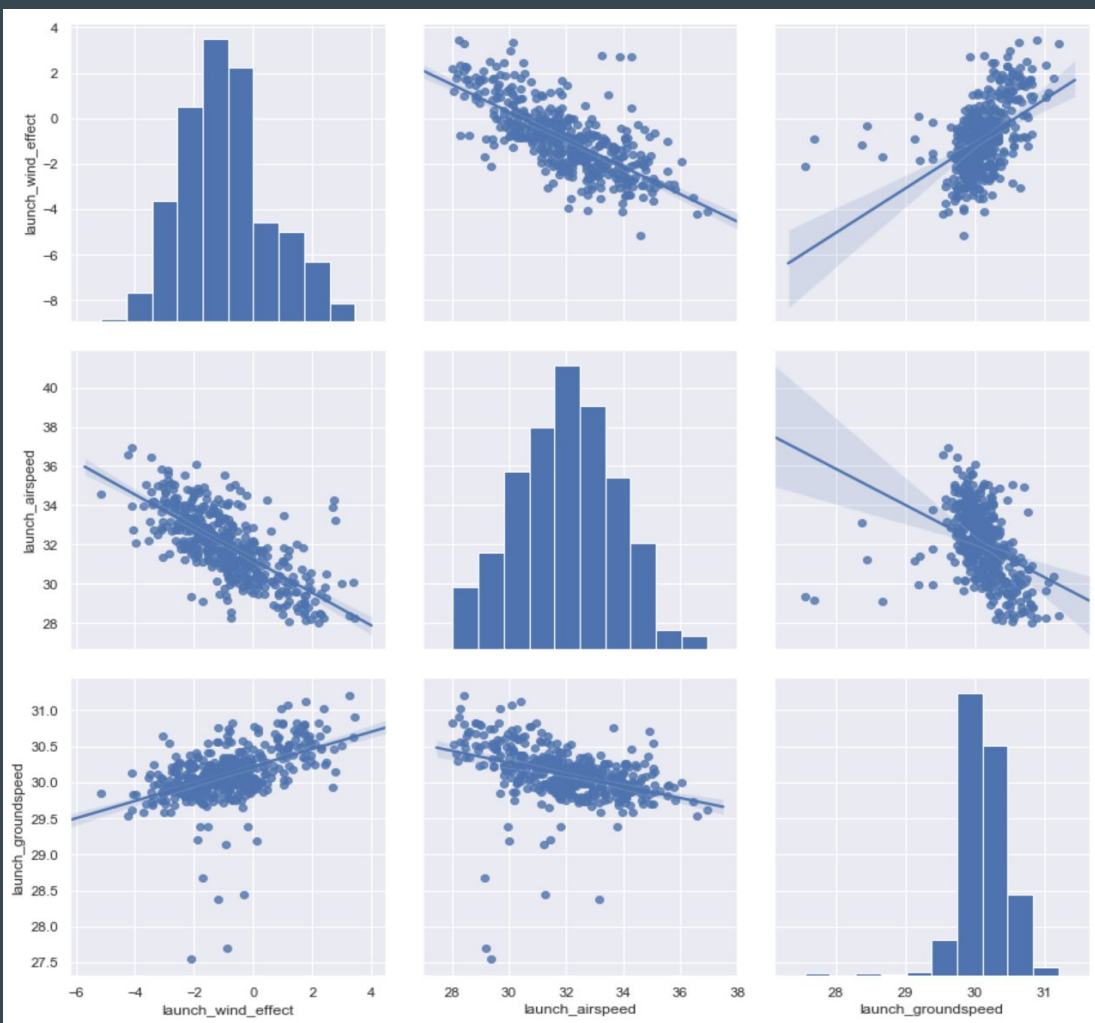
Preflight Voltage(Median)

32.19 (volt)

(16 Missing Values)

Data Exploration 01
Launch Airseed, Groundspeed, Wind Effect

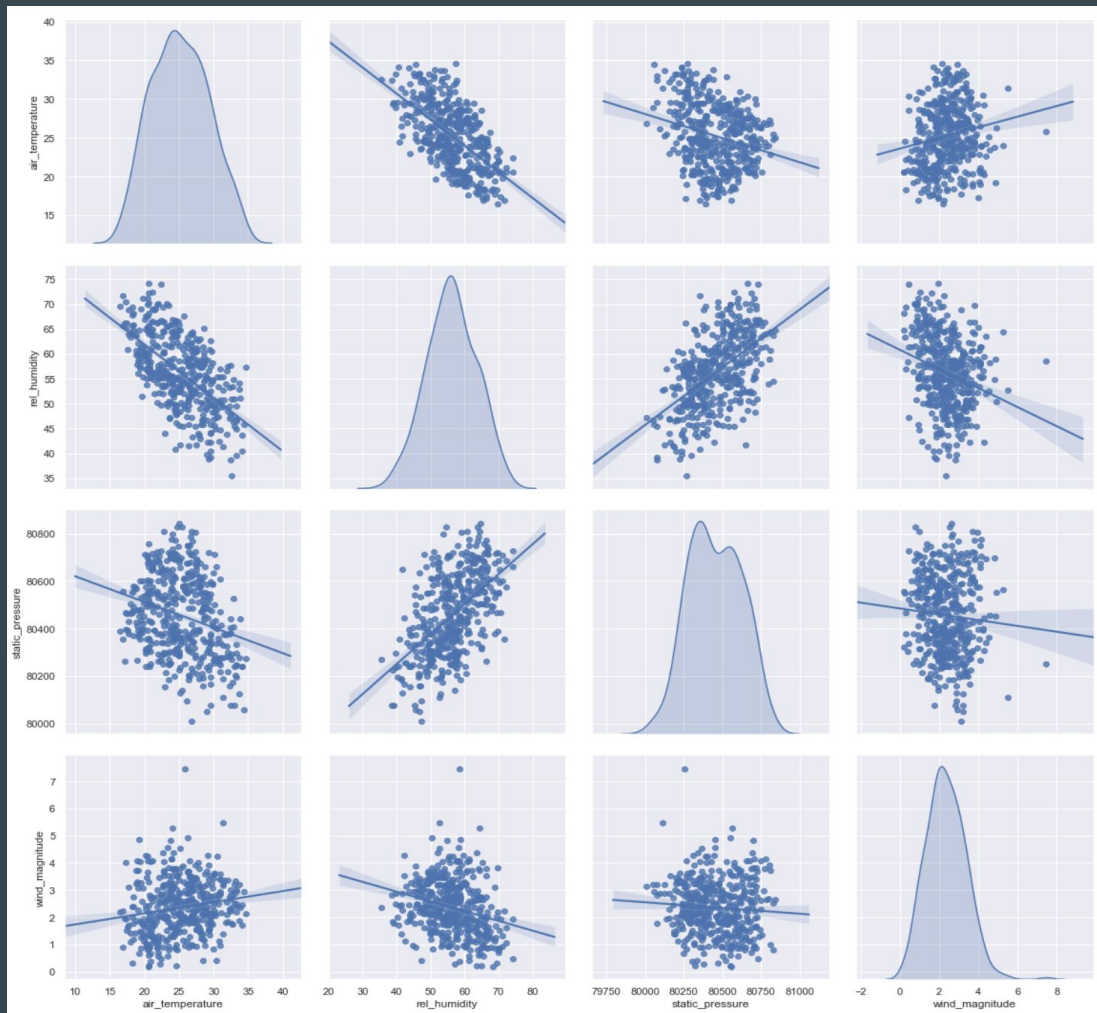- Launch air speed shows slightly negative correlation with launch ground speed, and highly negative with wind effect.

  Wind effect : wind magnitude * $\cos(\theta)$

Data Exploration 02
Weather Factors

- Humidity shows negative correlation with air temperature and positive correlation with static pressure.
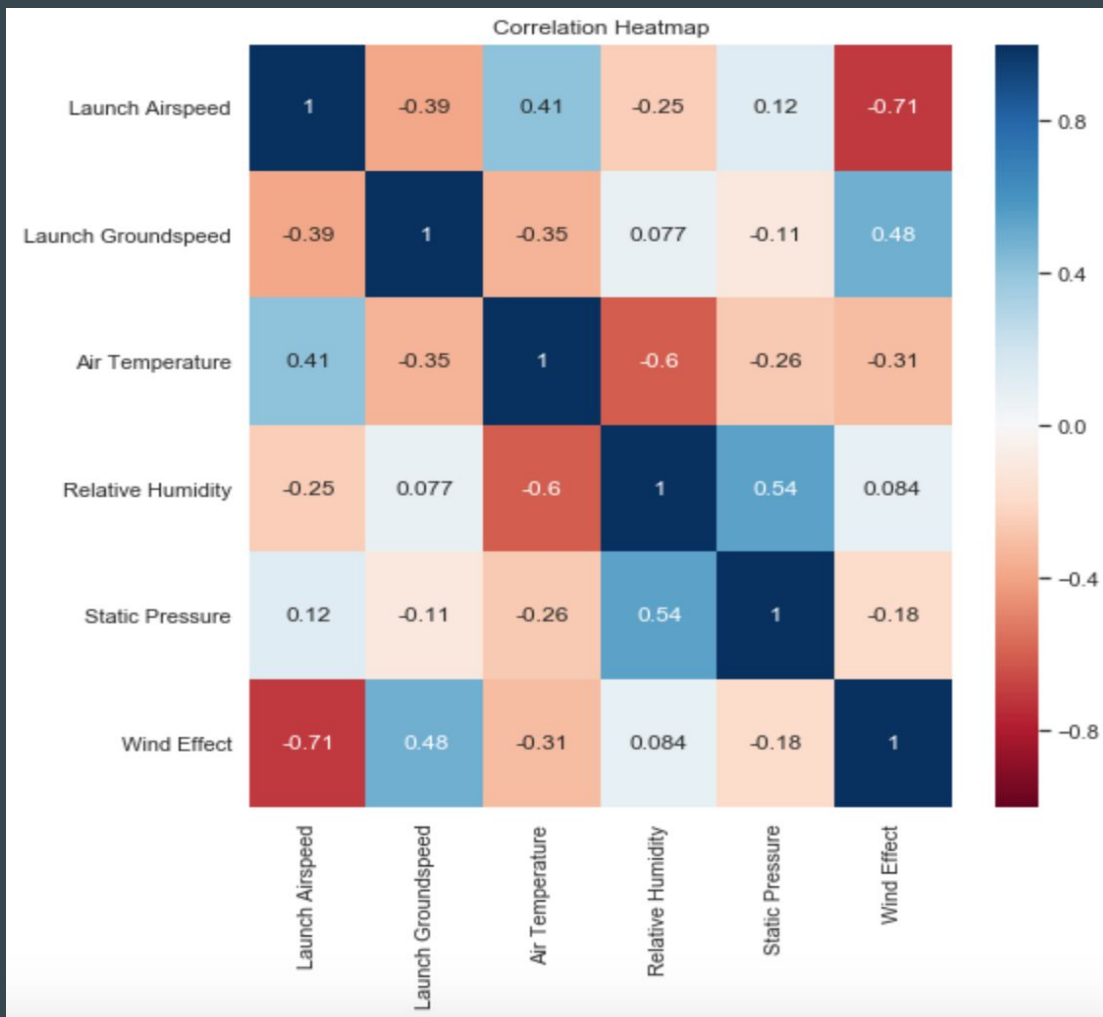
Data Exploration 03
Correlation Between All Factors

- The highest level of correlation   (+ or -) between factors are :

Launch Airspeed	-0.71	Wind Effect
Rel. Humidity	-0.6	Air Temp.
Rel. Humidity	0.54	Static Pres.

Correlation Heatmap

Data Exploration 04
## Airspeed, Groundspeed and Wind effect

- **Airspeed** and **groundspeed** are the important quantities in generating lift power of drone and its flight. These two quantities can be checked as indices to recognize patterns, anomalies and defective components.

Airspeed= Ground Speed - Wind Effect

- In most flights **(82%)** :

> launch airspeed > launch groundspeed

This can be explained by having negative 'wind effect' in these cases.

- **Attention!**
  Orange points above 45 degree line and blue points below this line are not aligned with aerospace concept (relationship between airspd, groundspd, and wind eff.)
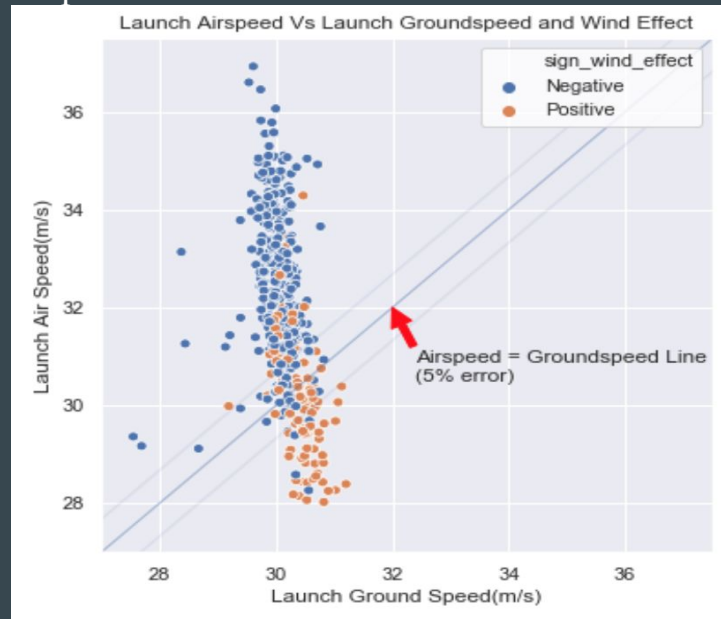
Data Exploration 05

Launch Groundspeed

- All drone flights should have approximately similar launches. The outliers can be related to anomalies of some working components such as launching rail, actuator motor, and ...
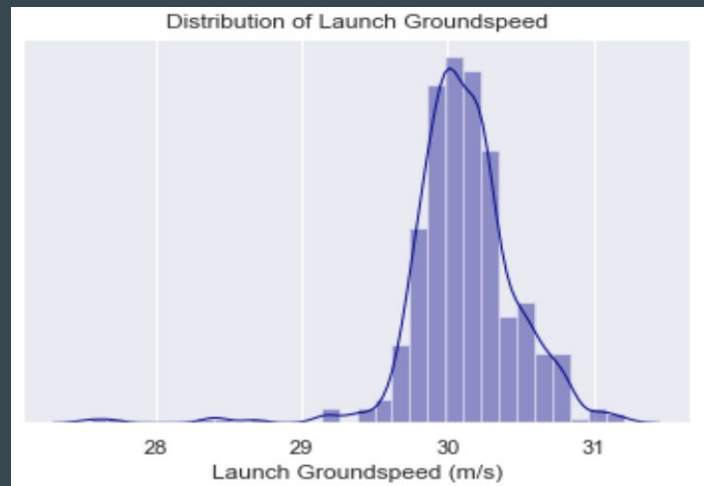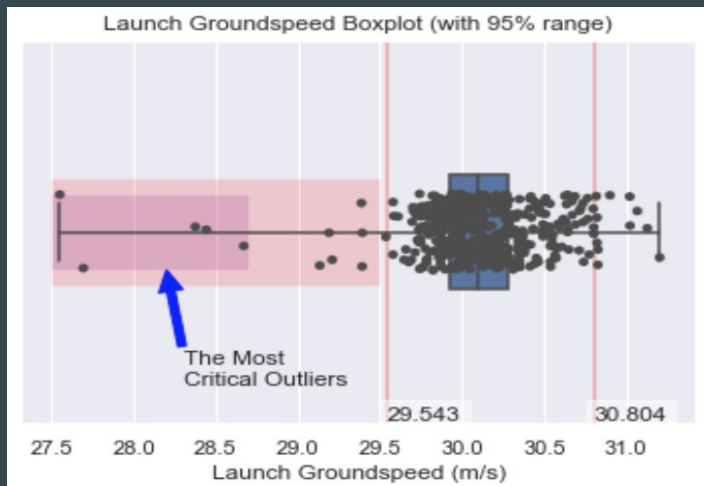

- The above figure shows that **lower bound** of launch ground speed have extreme outliers. These points should be investigated more in depth. According to plots of few slides ago, these points do not show any specific correlation with wind, and launch air speed.

Data Exploration 06

Launch Groundspeed

- Extreme outliers (and in general, all groundspeed outliers) did not occur in very specific bodies, wings, batteries, and do not show correlation with preflight voltage of batteries.
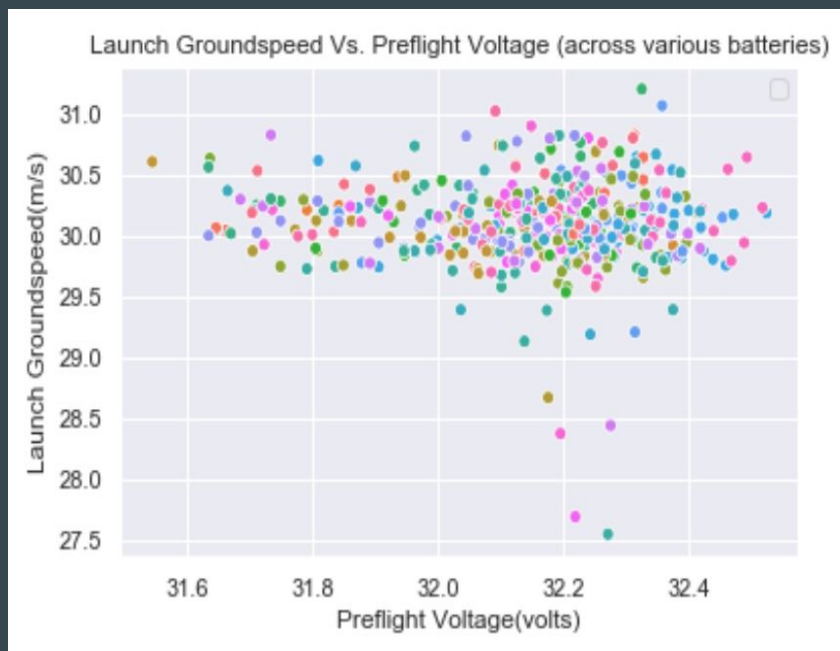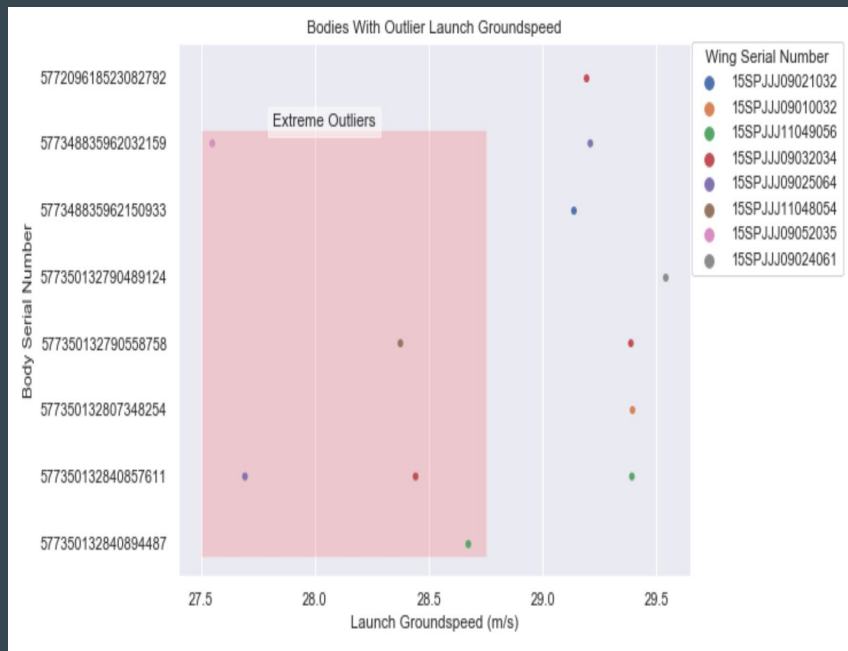
Data Exploration 07
Launch Groundspeed

- All 5 flights with extremely low launch ground speed (<29 (m/s)):

 *Same* Day: **2018-09-11**

  Same Software Ver.:   **5c504d9a16**

Launch Groundspeed Through Time (across Software Versions)

commit
- 5c504d9a16
- 4d9468bd3c
- 38bf99b15a
- 1ecbc27833
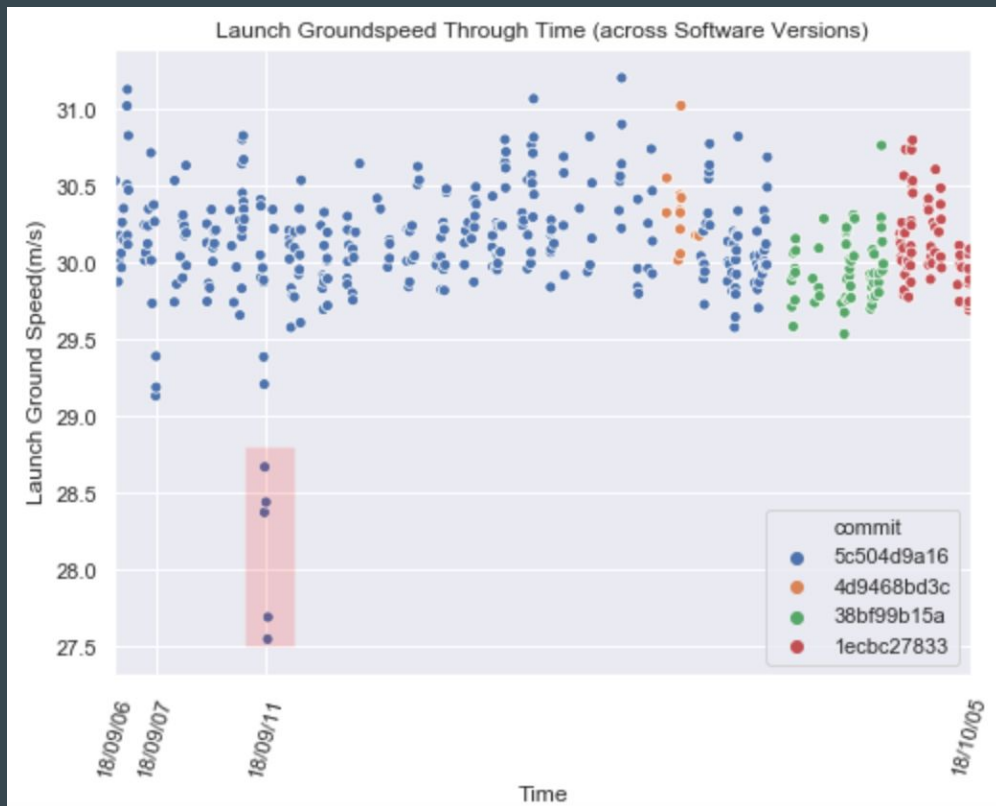
Data Exploration 08

Launch Airspeed

- I assume that **95%** A of our flights have launch airspeed within the acceptable range and any case with launch airspeed out of this range should be investigated more in depth.

Launch Airspeed Boxplot (and 95% range)

28.474   35.102

Launch Airspeed (m/s)

Distribution of Launch Airspeed
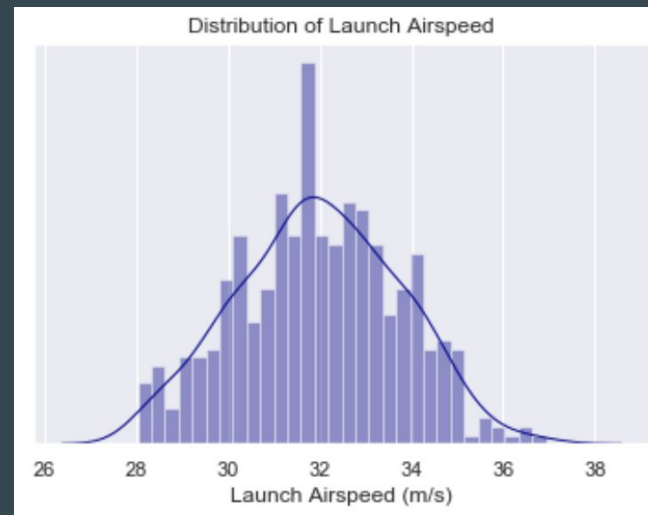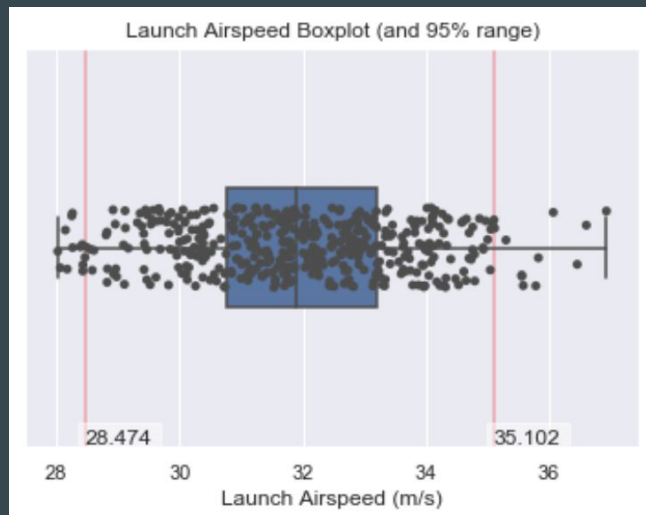
Launch Airspeed (m/s)

A- In real world, acceptable range should be calculated and confirmed in collaboration with engineering and safety departments.

Data Exploration

Launch Airspeed

- At the *first glance* the specific **body** <u>577209618523082792</u> shows more than *30%* of all flights with launch airspeed out of normal range.

- Extreme Launch Airspeed Outliers do not show any unusual relationship with weather factors.
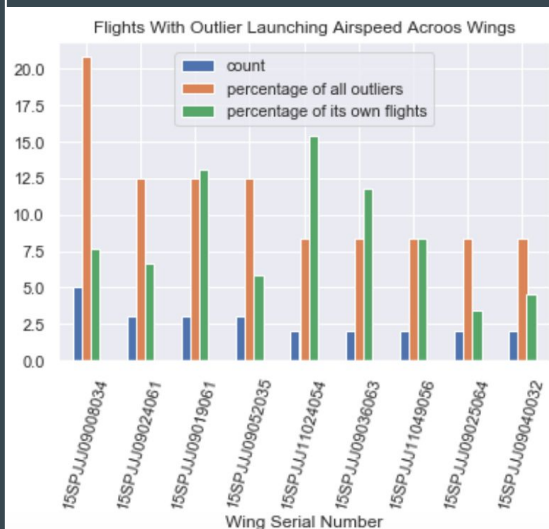(in general, launch airspeed just has relationship with wind effect)

Bodies With Outlier Launch Airspeed
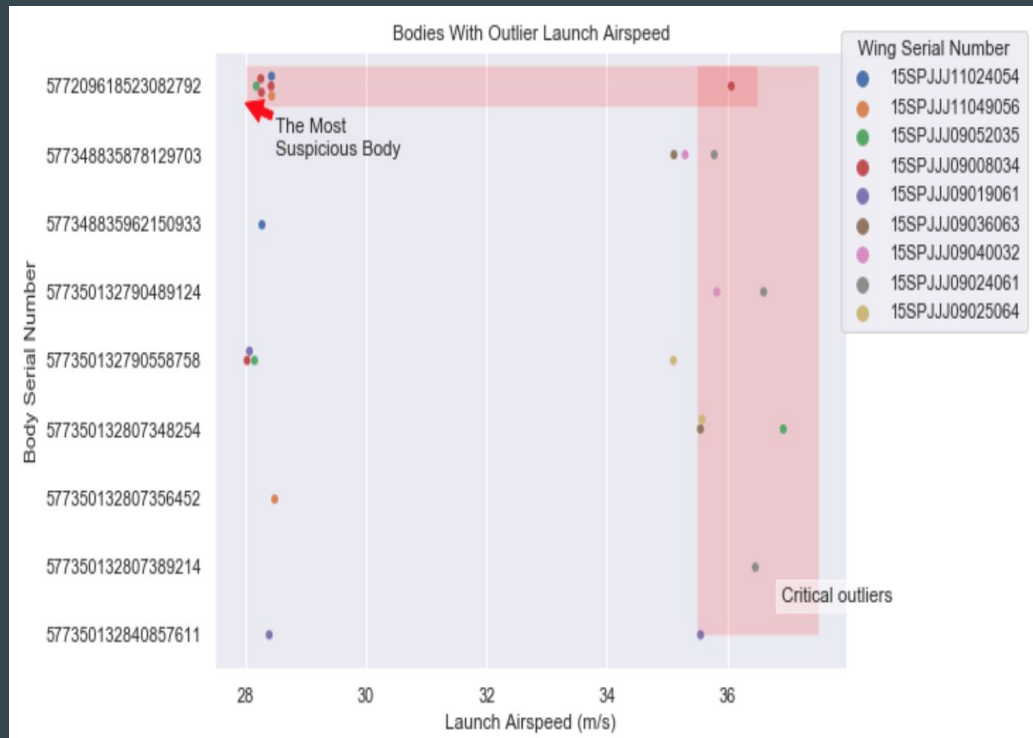
Data Exploration 10

Launch Airspeed - Physical Component Exploration
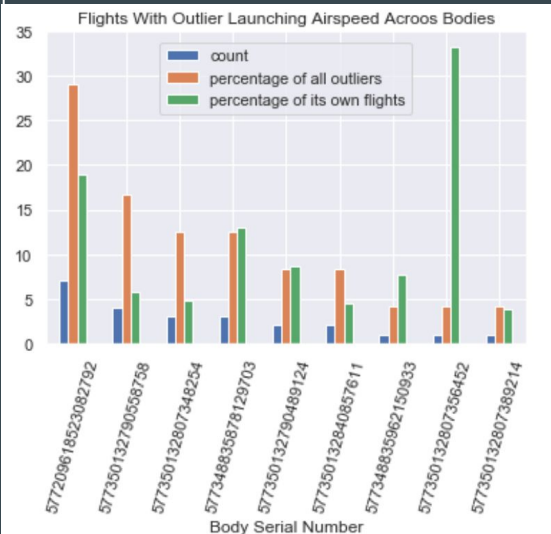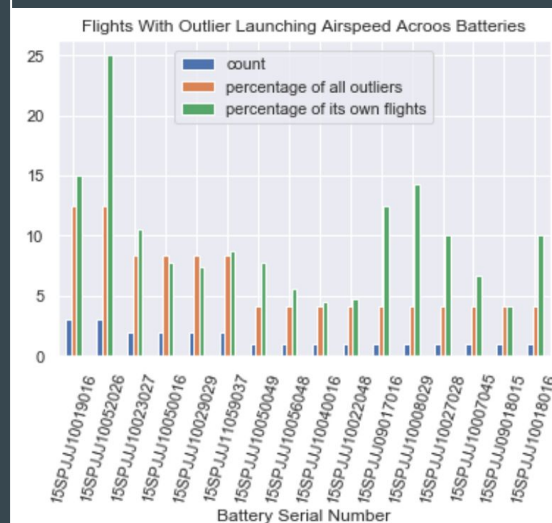
Data Exploration 11

Launch Airspeed - Software Exploration

- Here is the list of bodies, wings, batteries and software versions that show extreme launch airspeed in more than 10% of their flights or all outlier launch airspeed:

Body	Wing	Battery	Software
577209618523082792	15SPJJJ09008034	15SPJJJ10019016	5c504d9a16
577350132790558758	15SPJJJ09024061	15SPJJJ10052026	38b199b15a
577350132807348254	15SPJJJ09019061		
577348835878129703	15SPJJJ09052035		
577350132807356452	15SPJJJ11024054		
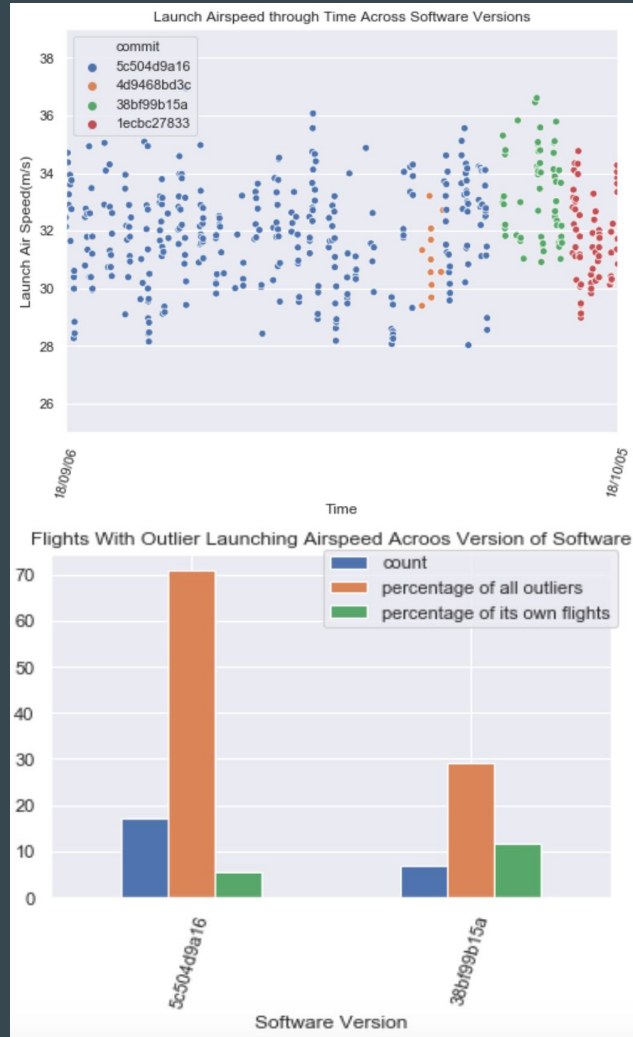
Data Exploration 12

Flights Outliers - Motion Attributes

- All motion attributes were investigated <u>flight by flight</u>. The below table shows flight ID <u>extreme outliers</u> in each category:

Motion Attribute		Flight IDs
Position to Fixed Reference	in North D.	17176, 17188,17476,17585
	In East D.	17176, 17188,17476,17585
	In Down D.	17160,17266,17580
Velocity	in North D.	17176,17188,17476,17585
	In East D.	17176,17188,17476,17585
	In Down D.	__
Acceleration	in North D.	__
	In East D.	17619
	In Down D.	17568

Motion Attribute		Flight IDs
Euler	Roll	__
	Pitch	__
	Yaw	17176,17188,17476,17585
Angular Velocity	Forward D.	__
	Right D.	__
	Down D.	17735
Standard Error of Position	in Noth D.	17603
	In East D.	17035,17326,17361
	In Down D.	17035,17076,17160,17266,17603

Data Exploration 13

Flights Outliers - Motion Attributes

- Checking outlier flights across bodies, wings, and batteries. There is no very unusual behavior among any of the component just 1 Wing, and 2 Bodies show more than 2 motion attribute outliers.

Body Serial Number	577348835962032159	577350132790558758
Wing Serial Number	15SPJJJ09052035	
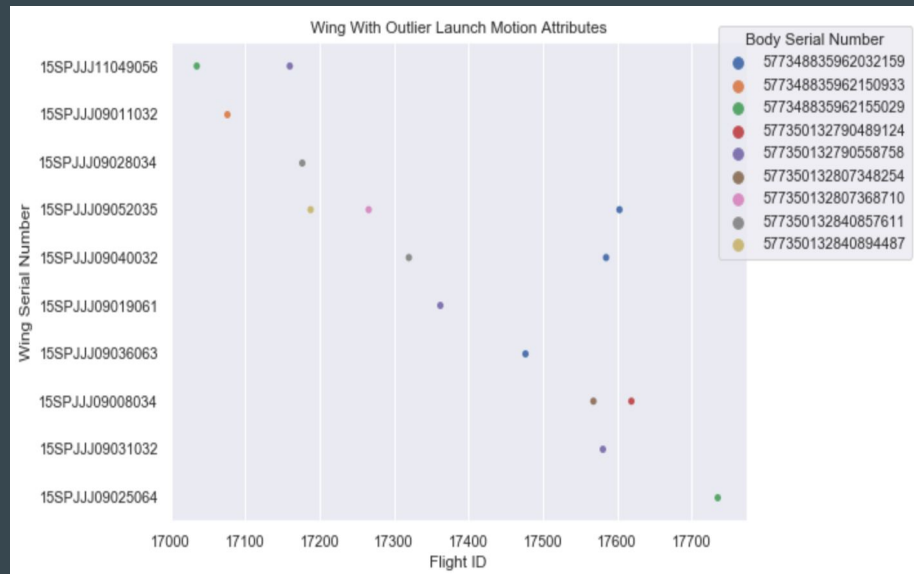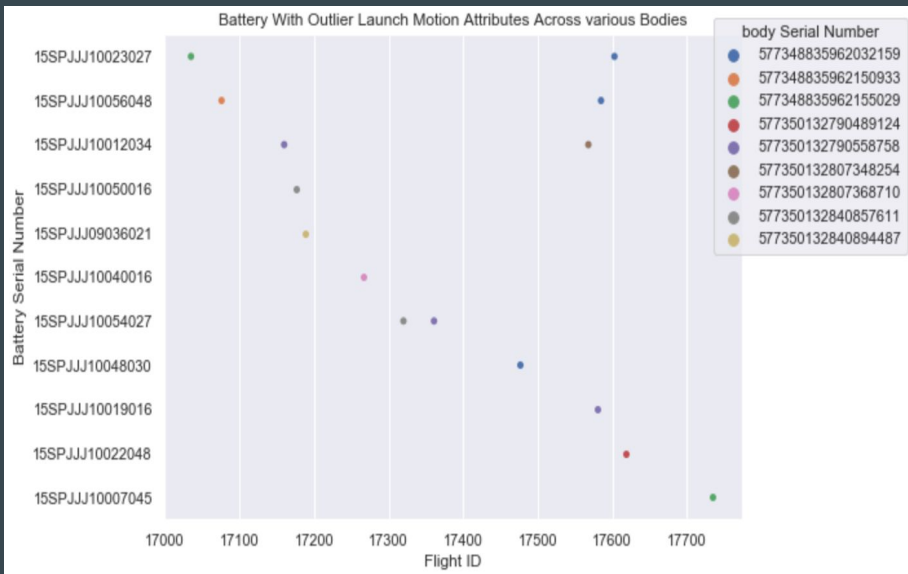
Insights & Suggestions 01

- Air speed is one of the important factors to generate lift power. Launch airspeed has negative relationship with wind effect. So, we can set up the adjustable launching rail so we can use wind effect and decrease the essential ground speed (lowering the load on actuator motor).

- Relative humidity increases by having lower air temperature and increases by having higher static pressure.

- Very low air temperature may lead to low launch ground speed which may not be enough to generate enough airspeed. So we need to take some actions (like using some covers around launching rail or heater) to prevent possible flaw in flights during very cold days.

- According to the plot in DExp-04 slide (Airspd. Vs. Grspd.), there is a small percentage of unusual flights above and under 45 degree line. These flights are not aligned with the aerospace concept (relationship between airspeed, groundspeed, and wind effect).Maybe we had some dysfunctionality in our speed indicator sensors. Anyway we need more   investigations.

- Very extreme wind magnitude leads to extreme launch air speed. However there is just one point with extreme wind magnitude,   so   we   can   not   generalize   any   theory.

Insights & Suggestions

- Very extreme low launch ground speed (*less than 29 mps)*, all occured at the same date (**11th Sep 2018**) and by using the same version of software (**5c504d9a16**) . The data (body,wing,or weather condition) does not show any unusual behavior in other attributes in these specific 5 flights. However the report of that day should be investigated more in depth.

- Specific body (serial No. : **577209618523082792**) shows around *30%* of flights with launch airspeed out of normal range (95% range). This body needs to be checked more carefully.

- Extreme Launch Airspeed Outliers do not show any unusual relationship with weather factors.

- In terms of anomalies in motion attributes of each flight, 1 wing (**15SPJJJ09052035**) and 2 bodies (**577348835962032159** & **577350132790558758**) show 3 outliers and should be checked by engineers.

- Other physical components and software versions which is better to get checked are mentioned in the table of slide DExp-12.

Thank You