Coanda Flare Jet Boundary Detection

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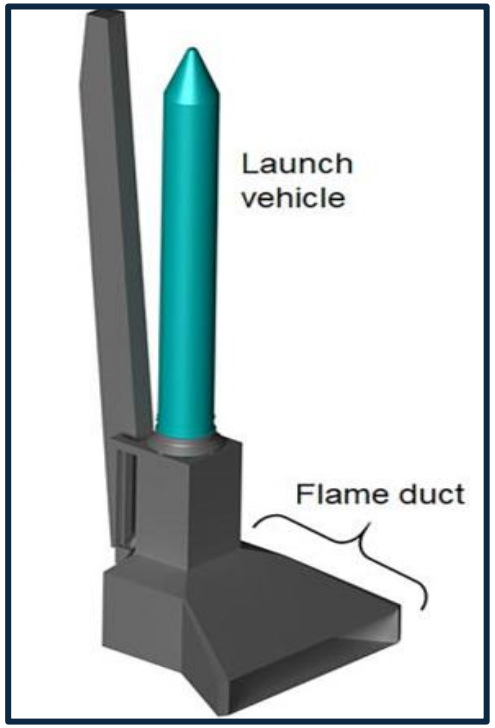
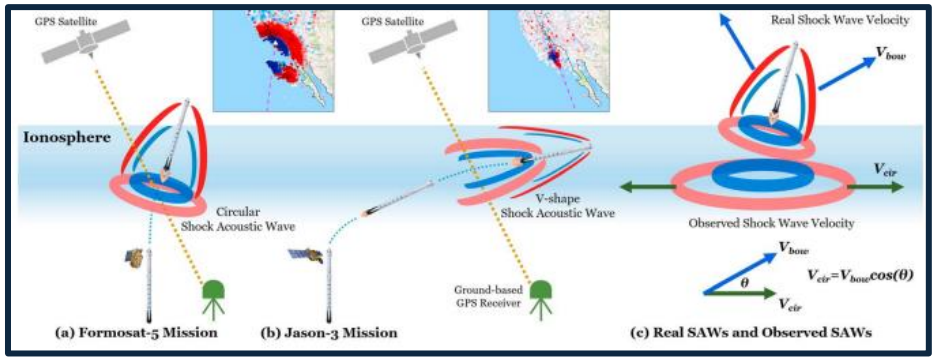
Noise generation from supersonic Coanda jets…



Damage rocket payloads
doi: 10.1121/10.0009160.



Damage the ionosphere
doi: 10.1002/2017SW001738

Produce unbearable noise
https://www.argoflares.com/design-supply/flare-tips/

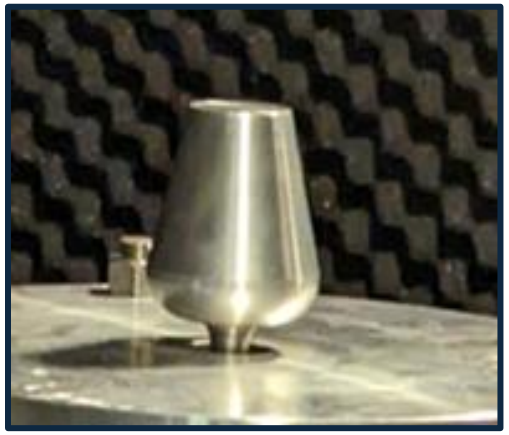
- Coanda effect = fluid follows a curved surface
- These flows haven’t been studied much

Task 1

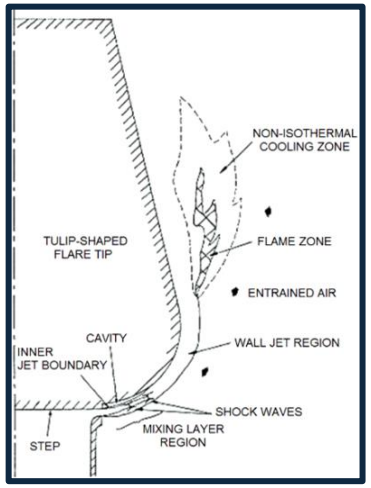
Shows what matches the slide doc template

The Data

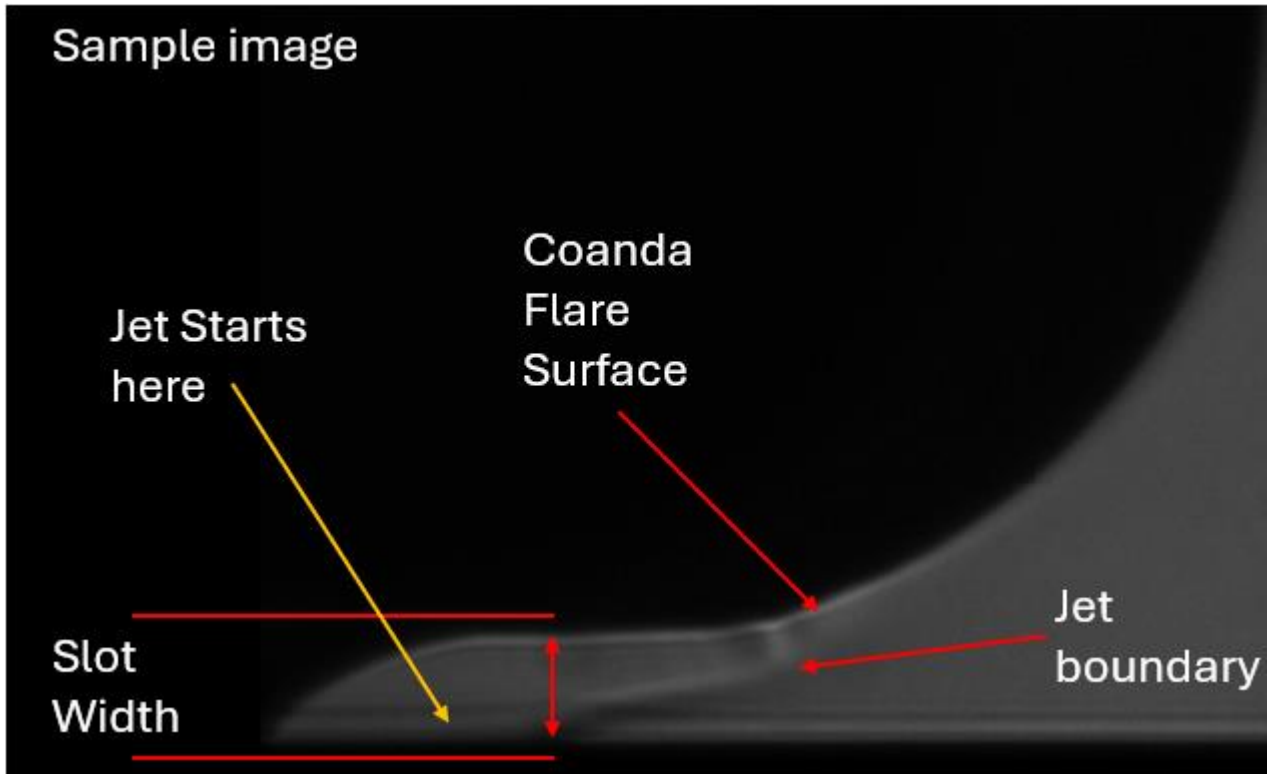
- Images of a supersonic jet of air moving over a Coanda Flare
- From Dr. Lubert's Lab at JMU
- Measured at different operating pressures and jet widths.
- This data was taken to determine a polynomial of the jet boundary and also to understand the shock cell structure.



Coanda Flare



Coanda Flare diagram



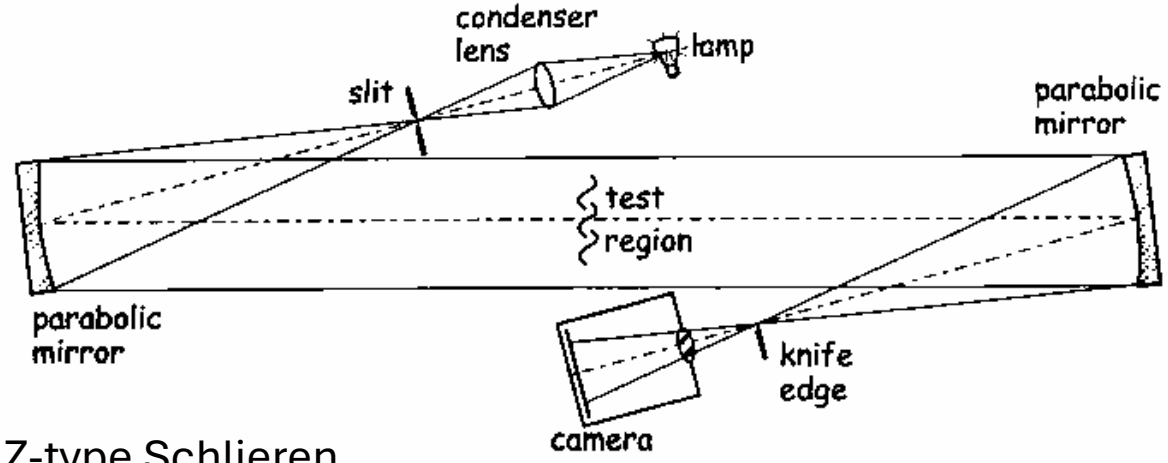
The data

https://drive.google.com/drive/u/1/folders/1i3YQtTSYGeFzxuGeiyHg8l-p9Qcb9P0h

Task 1

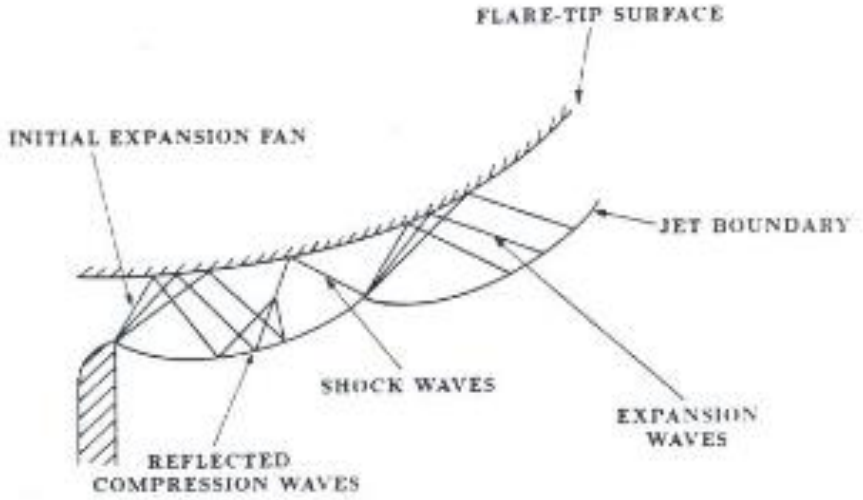
The Data: Continued

- The data was taken using a Schlieren system
- Understanding the jet boundary allows the modeling of shockwaves which enables noise-generation models (Shock Associated Noise)
- The Supersonic Turbulent Coanda Wall Jets have not really been studied so we don't know much, that's why these experiments were run



Z-type Schlieren

G. S. Settles, *Schlieren and Shadowgraph Techniques: Visualizing Phenomena in Transparent Media*. Springer Science & Business Media, 2001.



10.20855/ijav.2016.21.2413

Task 2

So,
what can we do with this data?

Task 2

Question 1: Can the Jet boundary be determined from these images with the proposed technique?

- This question is interesting because I want to see if this data set has a high enough image resolution to find the boundary and actually use the data set. In addition, I will need to see if certain parts of the data set are not usable.
- The question is inferential because this is something that can't just be answered without analyzing the data set.
- The variables of interest are going to be the difference in pixel brightness between the maximum and the average brightness

Task 2

Question 2: How does the Jet boundary change with pressure?

- The jet follows the curved surface and I am wondering if increases in pressure make the jet follow the surface better or if it causes detachment from the surface. I would also like to understand by how much it increases and if other parameter changes impact this trend.
- This is only evident by analyzing the images as one image can’t show this.
- The variables of interest are pressure and differences in pixel brightness.

Task 2

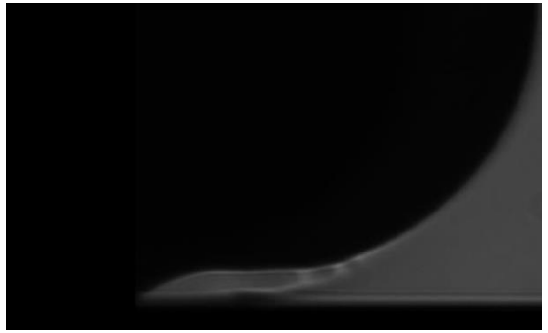
Question 3: How does the jet boundary change with slot width?

- This question is interesting because I want to know how the jet responds to changes in width. Clearly, the jet will be larger, but will it contract faster, and will it detach from the surface sooner? If so by how much?
- This is an inferential question because one has to carefully look through hundreds of images and take measurements to fully understand what is going on here.
- The variables of interest are slotwidth and differences in pixel brightness.

Task 2

Question 4: How does the shock cell structure change with pressure changes?

- The jet boundary changes with pressure but so does the shock cell structure. The shock cell structure appears as lines in the flow that occur because the flow is supersonic. How does the pattern of shock waves change when we change pressure and by how much?
- This is an inferential question because one has to carefully look through hundreds of images and take measurements to fully understand what is going on here.
- These shock cells are important be cause they directly determine noise generation.



Task 2

Question 5: How does shock cell structure change with slot width?

- The jet boundary changes with slot width but so does the shock cell structure. How does the pattern of shock waves change when we change slot width and by how much?
- This is an inferential question because one has to carefully look through hundreds of images and take measurements to fully understand what is going on here.
- This is important because noise generation is determined directly by the shock cell structure

Task 3

Choosing Question to approach

Question	Data of interest	Does the data have the potential to answer the question?
Can the Jet boundary be determined from these images with the proposed technique?	Pixel brightness	yes
How does the Jet boundary change with pressure?	Jet boundary width across different pressures	Yes
How does the jet boundary change with slot width?	Jet boundary width across different slotwidths	Yes
How does the shock cell structure change with pressure changes?	Shock cell locations across different pressures	No, too hard to make them out in most images
How does shock cell structure change with slot width?	Shock cell locations across different slot widths	No, too hard to make them out in most images

Task 3

Q1: Can the Jet Boundary be extracted?

- How I thought I could do it…
- This demonstrates that one can see the jet boundary in the brightness data in the plot below.
- I expect to find that the jet boundary can be resolved easily from this graph.
- The final peak is due to an unwanted effect at the bottom that can be ignored. The boundary can be defined at where the brightness decreases to a little above the average brightness of the ambient air.

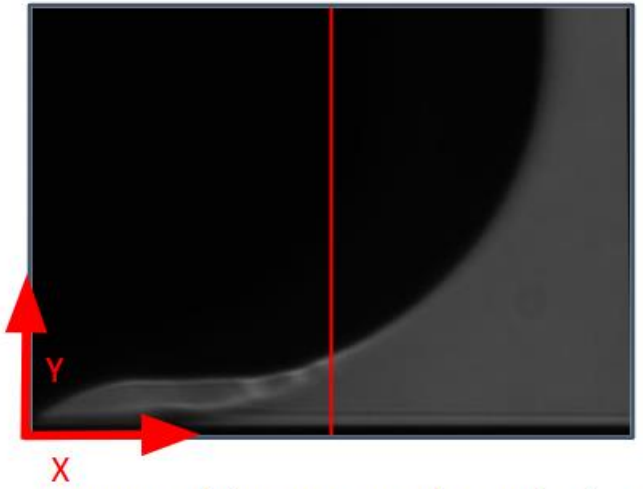
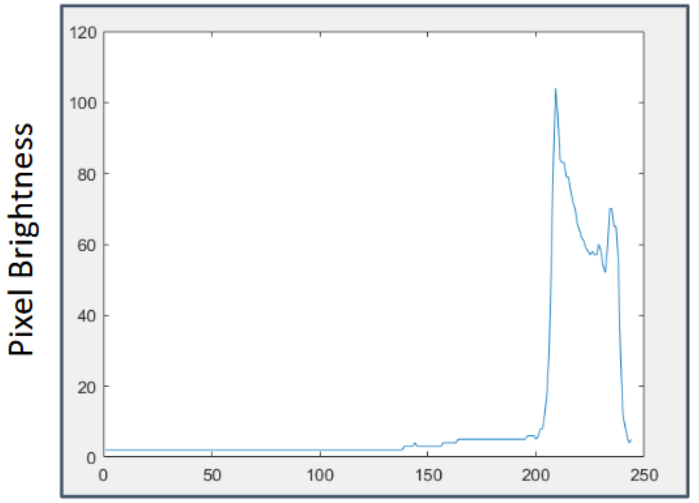


Figure 9. Schlieren Image of Coanda Flare

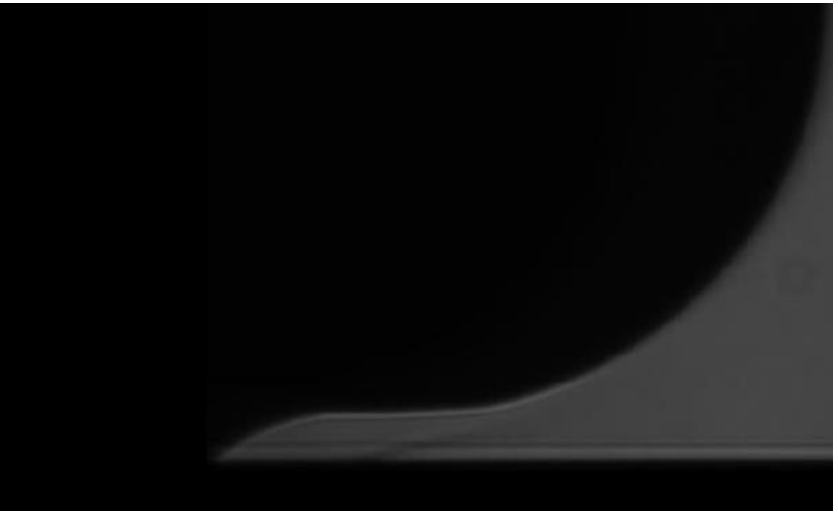
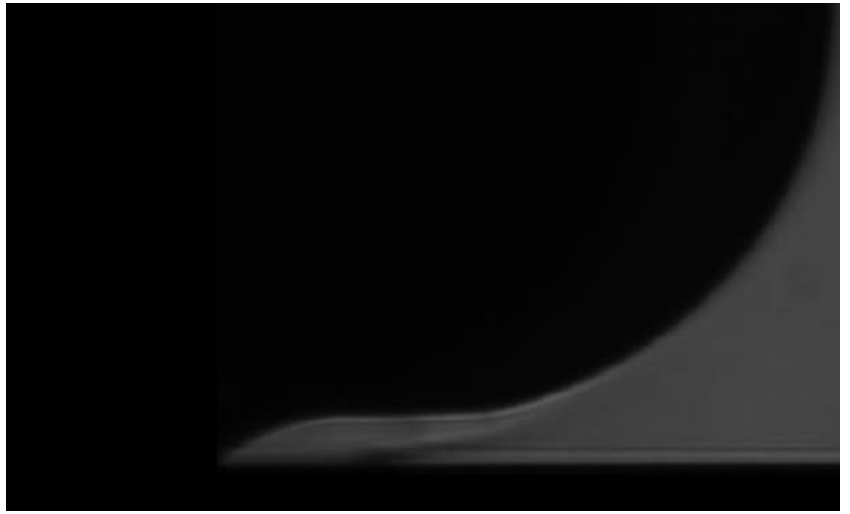
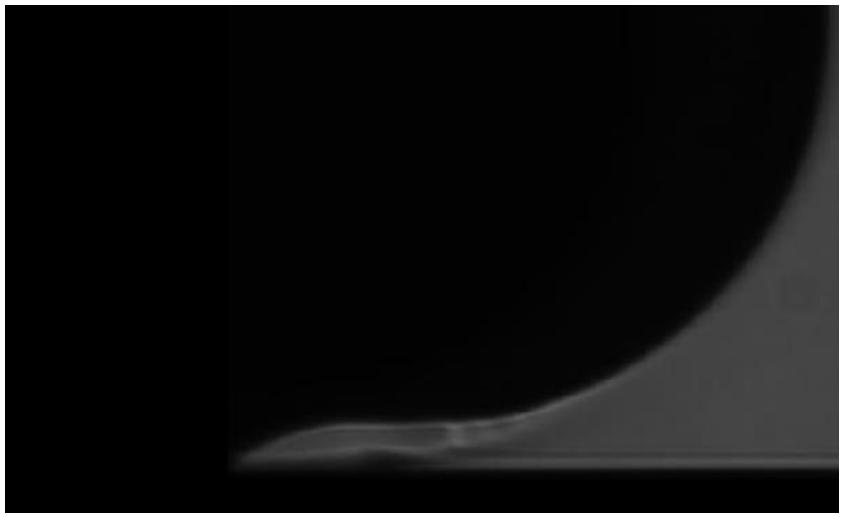


Problem #1: Yes That's MATLAB

Task 3

Q2: What is the impact of pressure on the Jet Boundary

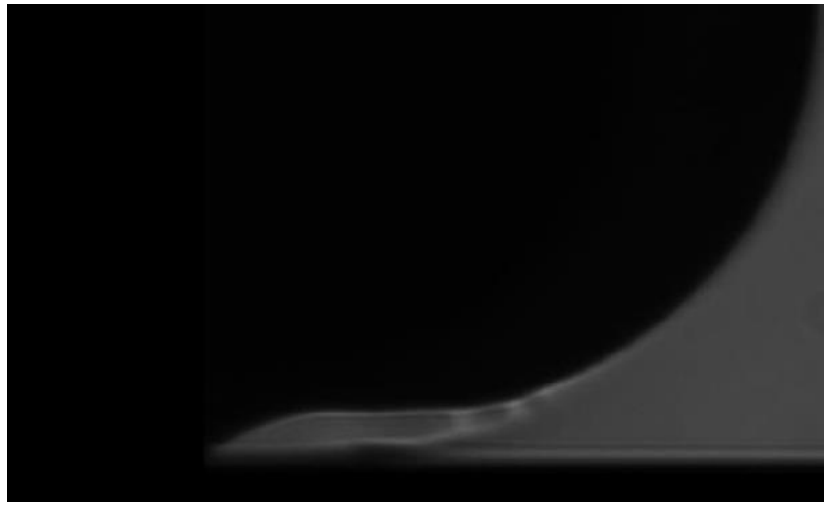
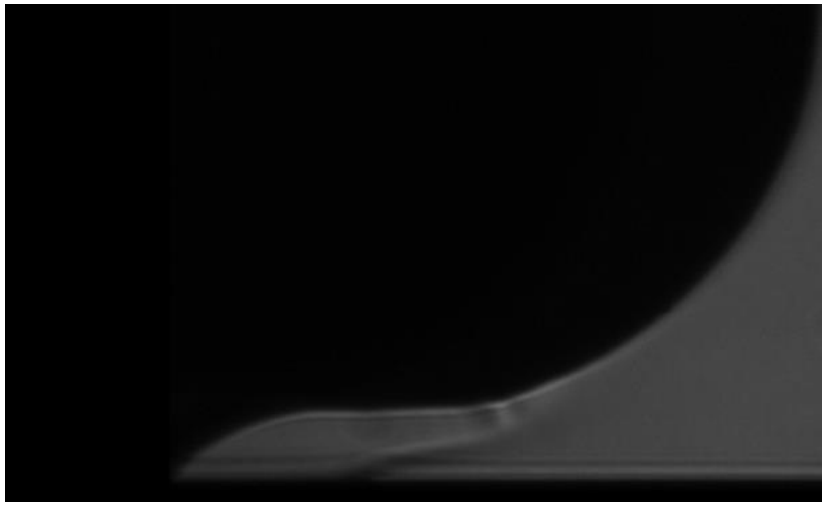
- The jet boundary can be seen to change with different pressure levels. These images all have the same slot width
- I expect to find that increasing pressure makes the jet boundary more compact from this initial analysis.

Task 3

Q3: What is the impact of slot width on the Jet Boundary

- The jet boundary can be seen to change with different slot widths. These images all have the same pressure.
- I expect to find that increasing slot width makes the jet boundary larger from this initial look

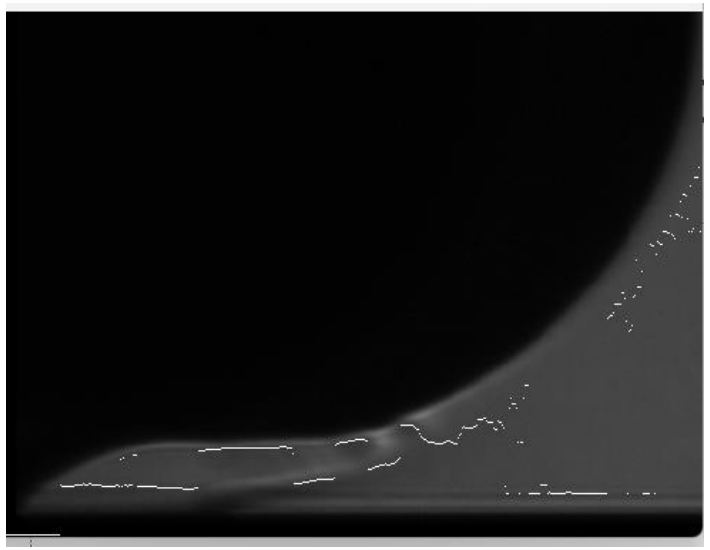

Task 4

The Approach

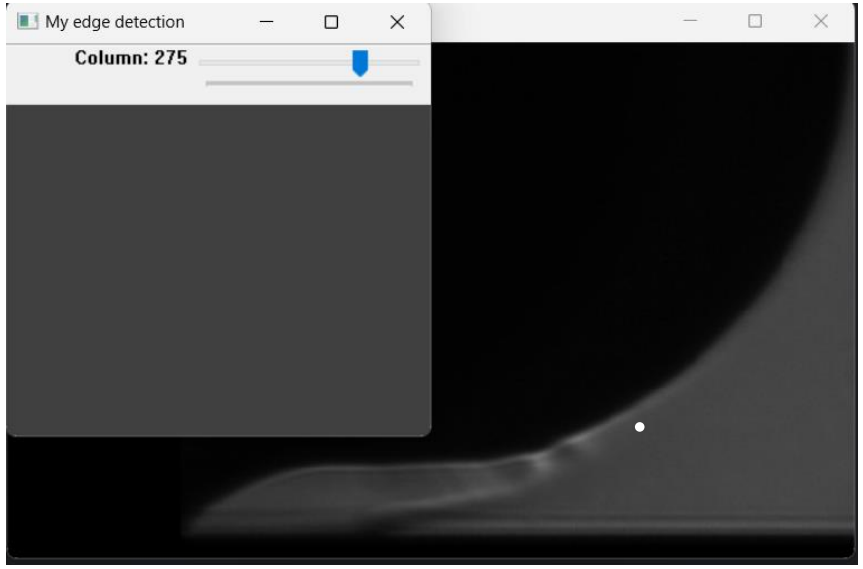
- Calculated Metrics
  - Question 1: jet boundary edge points
  - Questions 2&3: Lines of best fit
- Additional Software
  - Image processing in ImageJ
  - OpenCV for image manipulation and Canney Edge detection
- Visualization of final results
  - Question 1: Plot of successful edge detection
  - Question 2&3: Show lines of best fit on the same plot

Task 5

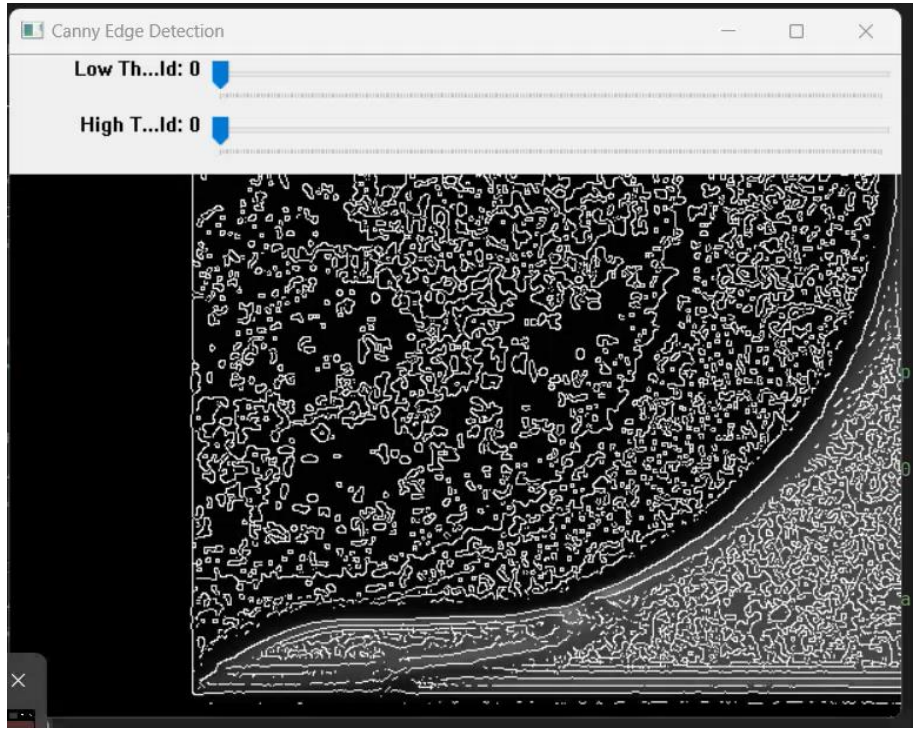
Question 1: Attempts



Attempt 1: vertical scanning



Attempt 2: horizontal scanning

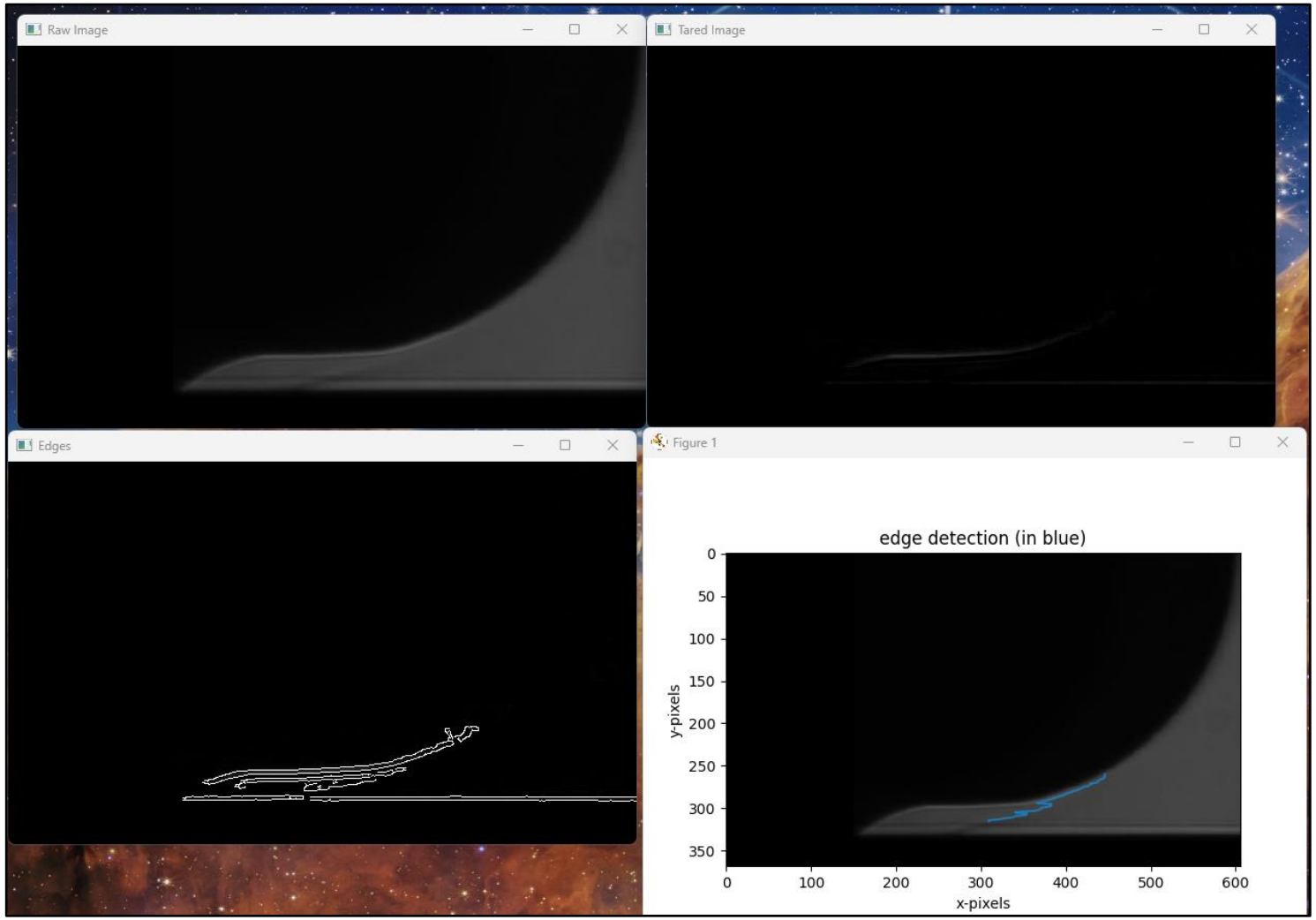


Attempt 3: Canney Edge detection

Task 5

Question 1: Results

- Edge detection successful
- Required image subtraction to make it repeatable
- Q1 shows the process and results
- I subtracted the images in ImageJ



Task 5

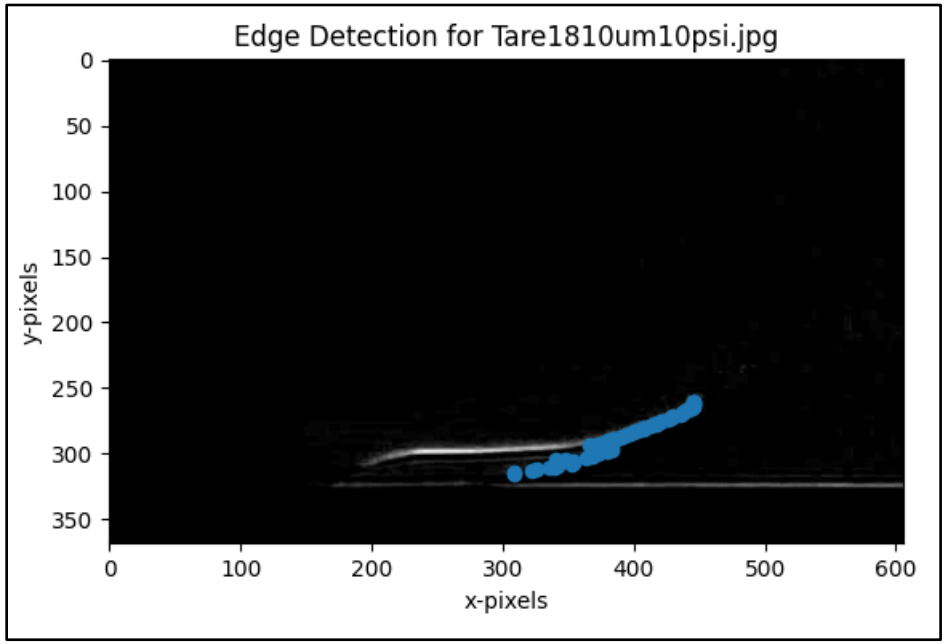
Question 1: Results

- We didn't need it, but we have a printout...

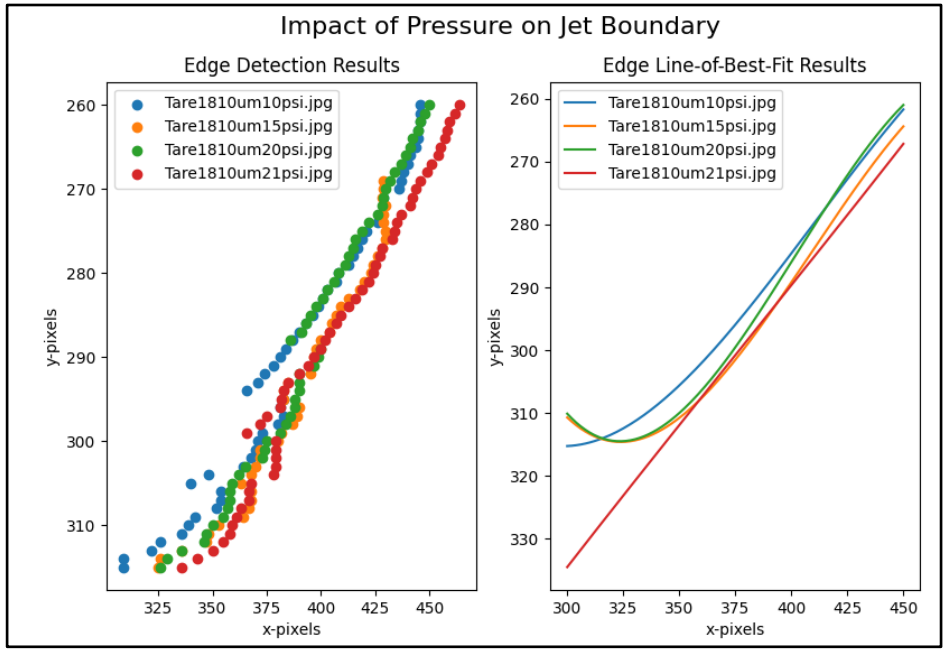
```
Hey look! Some wild metrics have appeared! Its the-edge-points-I-detected
the X coordinates [446, 446, 446, 445, 445, 444, 441, 440, 438, 437, 436, 429, 429, 428, 426, 421, 419,
the Y coordinates [260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276,
417, 415, 413, 408, 407, 403, 401, 399, 396, 393, 390, 387, 384, 381, 378, 374, 371, 366, 383, 381, 383, 380, 373, 371, 370, 368, 364, 348, 340, 354, 354, 352, 342, 339, 336,
277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311,
326, 322, 309, 309]
312, 313, 314, 315]
```

Task 5

Question 2: Results



- For each file the user can see how the edges are detected



- Plots showing the edge detection results and lines of best fit

Task 5

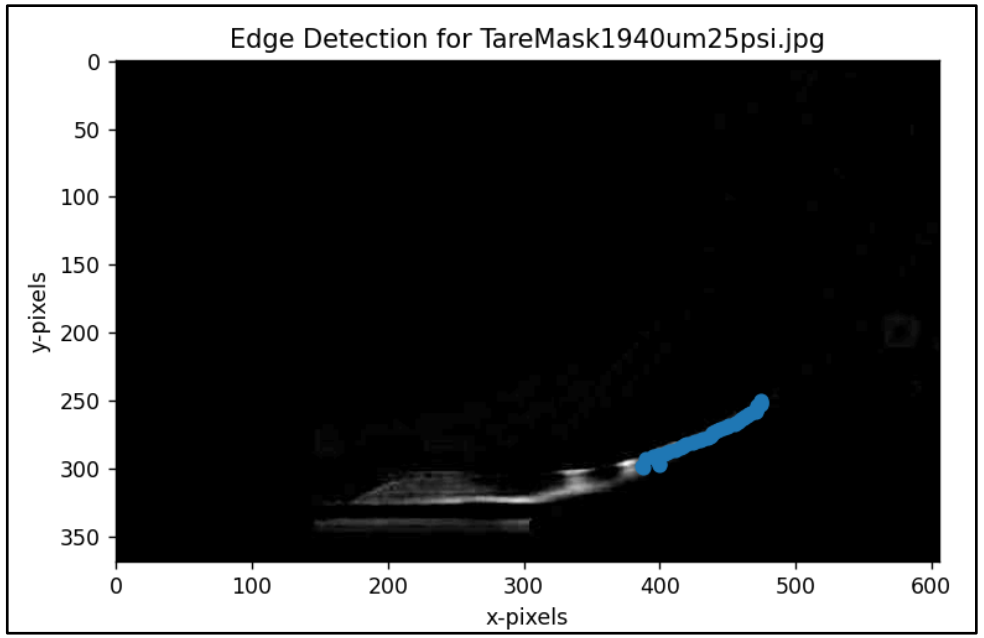
Question 2: Results

```
Best fit for Tare1810um10psi.jpg is:
           3           2
1.262e-05 x - 0.01553 x + 5.893 x - 395.9
Best fit for Tare1810um15psi.jpg is:
           3           2
2.453e-05 x - 0.03009 x + 11.77 x - 1175
Best fit for Tare1810um20psi.jpg is:
           3           2
3.057e-05 x - 0.03689 x + 14.27 x - 1476
Best fit for Tare1810um21psi.jpg is:
            3             2
-7.947e-07 x + 0.0009013 x - 0.7853 x + 510.5
```

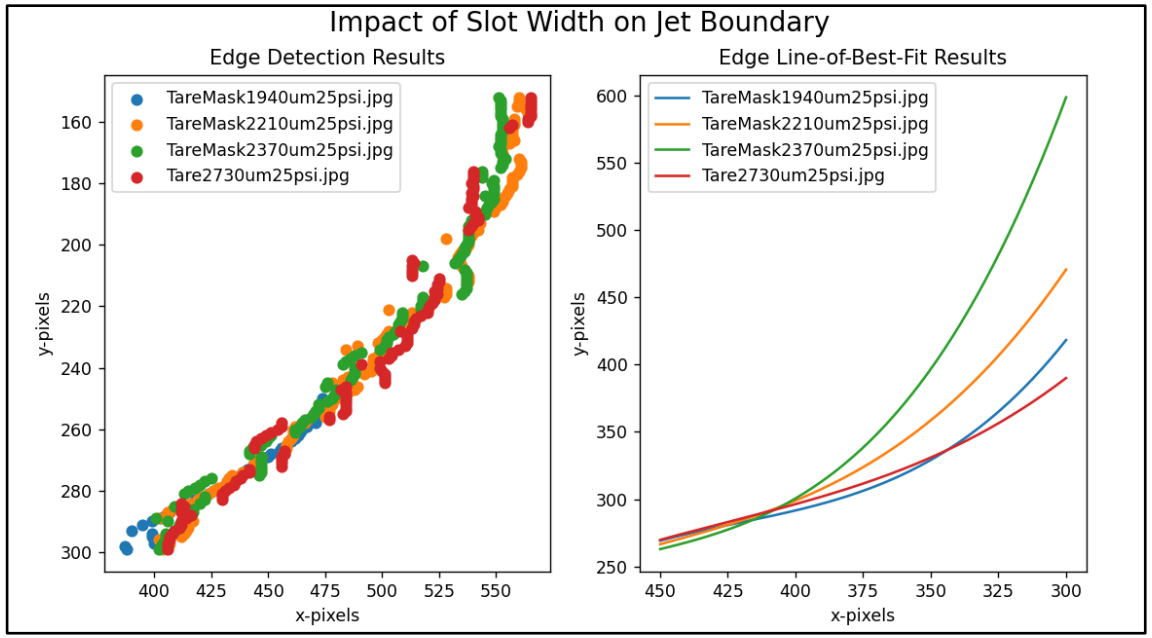
- Print of lines of best fit for each file

Task 5

Question 3: Results



- For each file the user can see how the edges are detected



- Plots showing the edge detection results and lines of best fit

Task 5

Question 3: Results

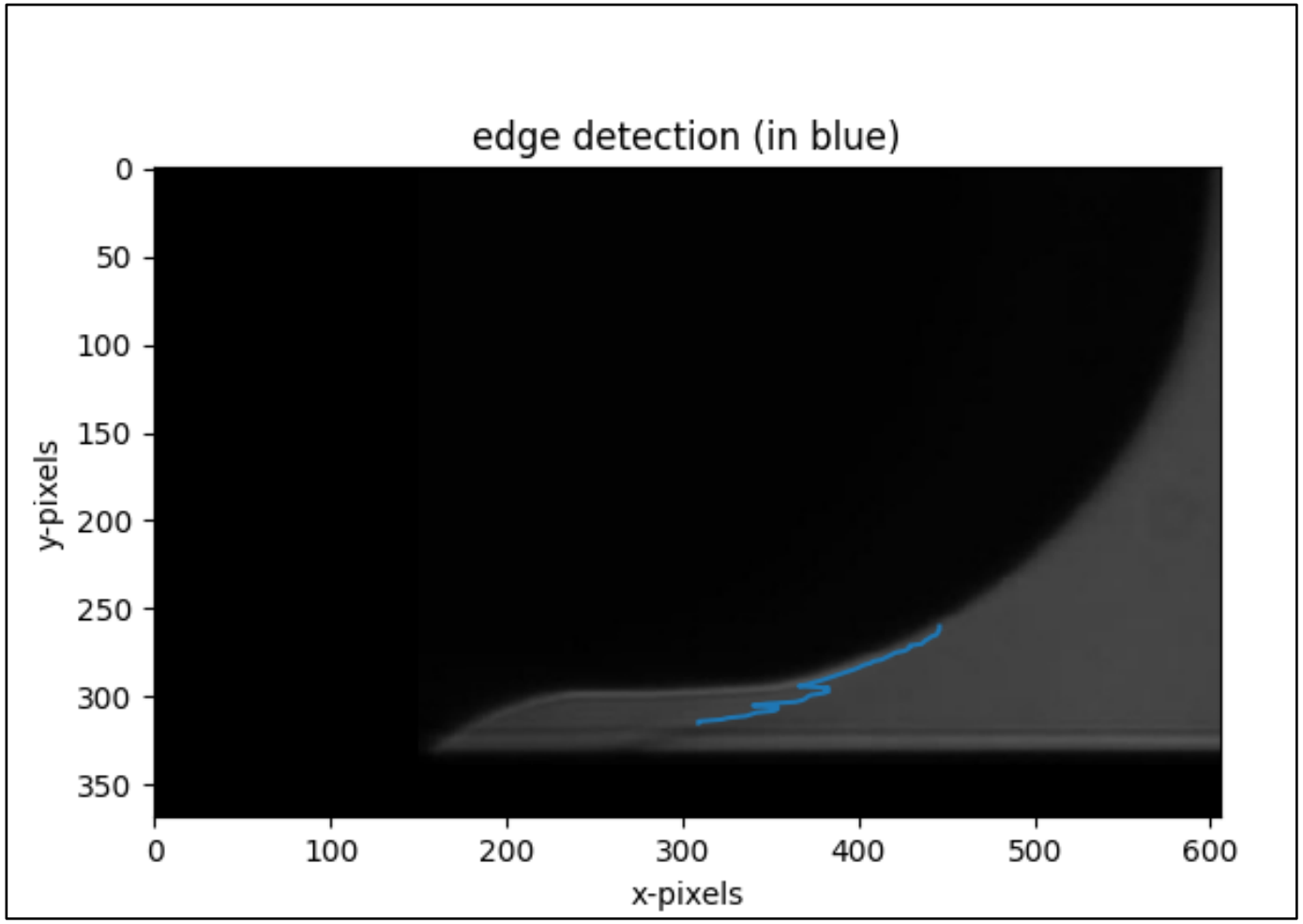
```
Best fit for TareMask1940um25psi.jpg is:
            3           2
-4.869e-05 x + 0.06144 x - 26.26 x + 4081
Best fit for TareMask2210um25psi.jpg is:
            3           2
-3.367e-05 x + 0.04584 x - 21.35 x + 3659
Best fit for TareMask2370um25psi.jpg is:
            3           2
-6.308e-05 x + 0.08739 x - 40.81 x + 6681
Best fit for Tare2730um25psi.jpg is:
            3           2
-2.175e-05 x + 0.02772 x - 12.29 x + 2171
```

- Print of lines of best fit for each file

Task 6

Question 1: Decisions

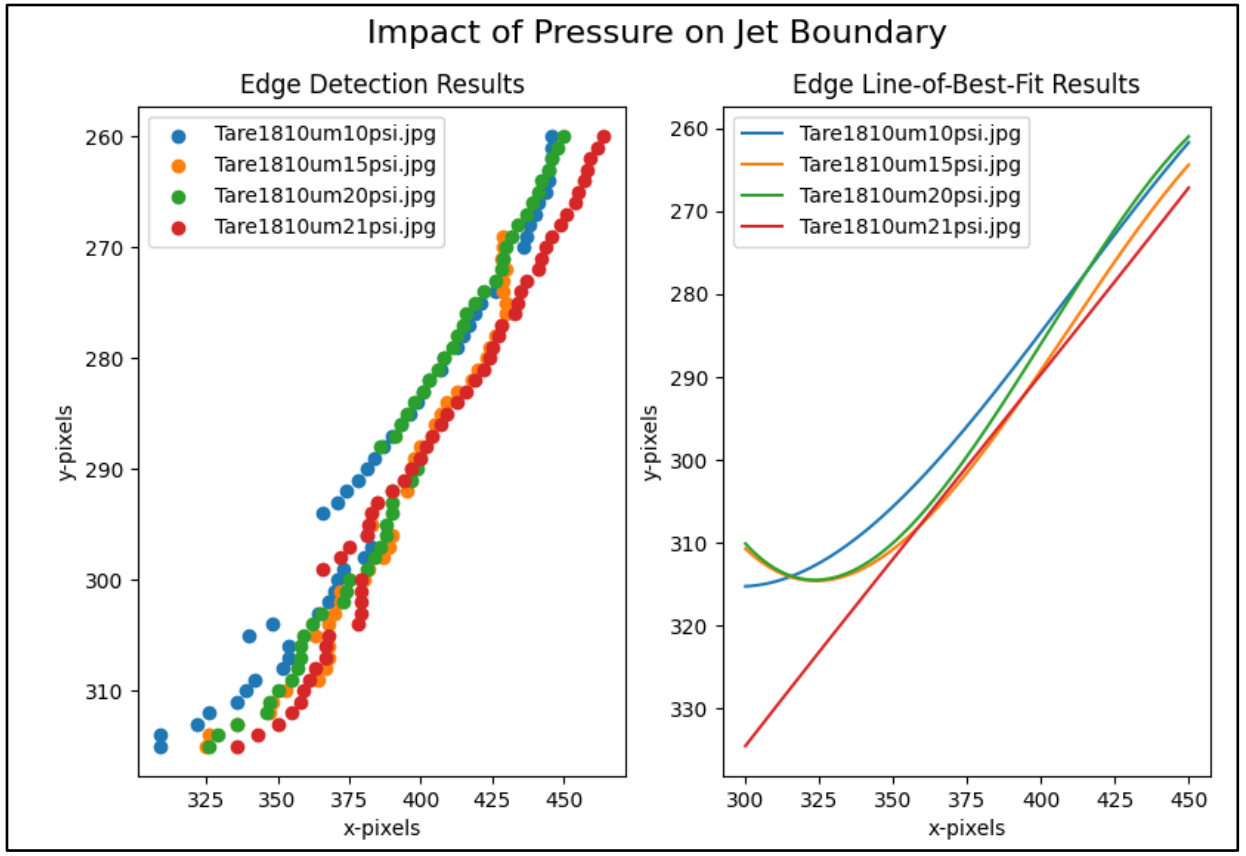
- Edge detection successful as expected
- Personally, I thought it would be easier
- It’s not perfect, but its honest work
- Further calibration and iteration are likely necessary (we will see this is true in Q2&3)



Task 6

Question 2: Decisions

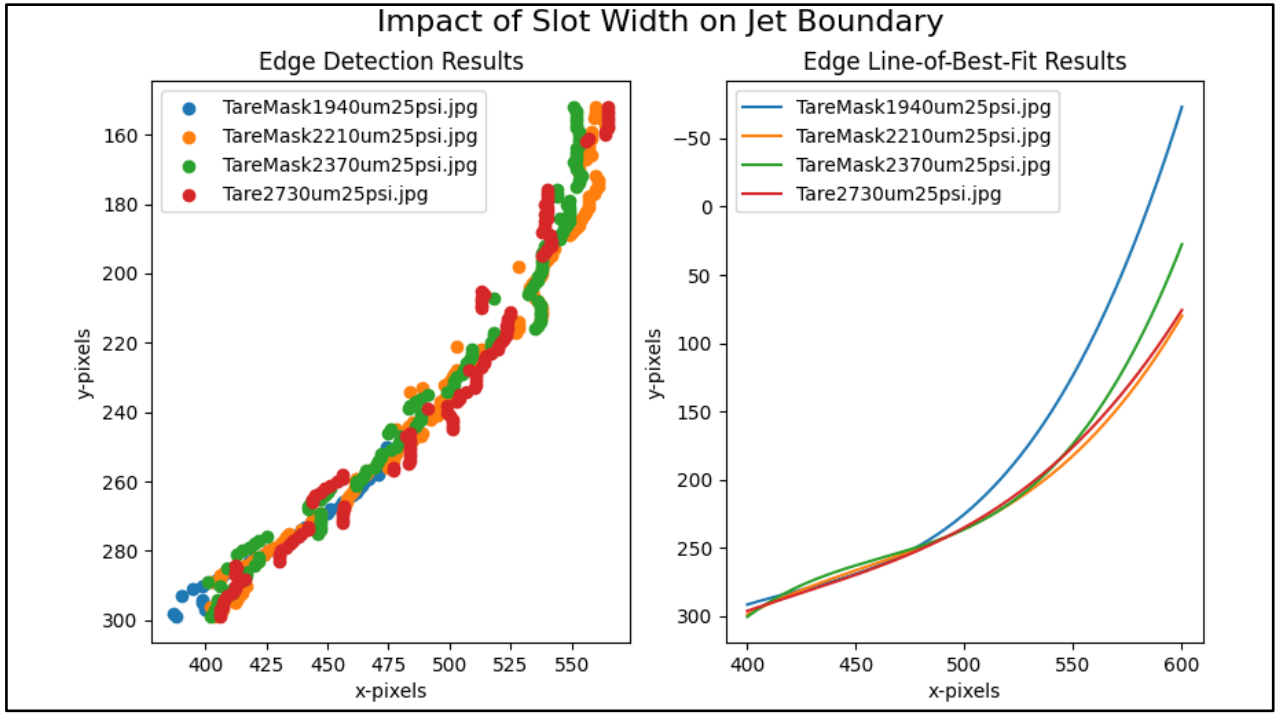
- My expectation:
  I expect to find that increasing pressure makes the jet boundary more compact from this initial analysis.
- As pressure increases the jet boundary seems to move outward
- Edge detection results aren't clean enough here for a decent comparison because the green line doesn't follow the trend.
- I would need to measure larger changes and calibrate the edge detection algorithm more



Task 6

Question 3: Decisions

- Expectation:
  I expect to find that increasing slot width makes the jet boundary larger
- As slot width increases, the edges get somewhat flatter, but the trend is unclear because the orange edge doesn't follow the trend
- I would need to measure larger changes and calibrate the edge detection algorithm more



Task 7

Reflection: Assignment Level

- How do you feel about the process?
  - Happy it went well, excited for where it could go
- What surprised you along the way?
  - It was far more difficult to get edge detection going than I expected but now I want to try some other methods.
- What did you learn about the questions asked, the data, and this approach to answer those questions?
  - I learned about computer vision, the importance of image subtraction, types of image filters and more
  - For future experiments I will make sure to recommend a no-flow image
  - I learned that bad data is hard to work with and that machine learning might be the answer
- If you had to do it again, what would you do differently?
  - I would just choose an easier challenge
  - Otherwise, I would have just started with image subtraction sooner
- I am convinced there are discoverable trends and that with further work (and a lot of it) this data analysis process alone would be easily publishable.

Task 7

Reflection: Course Level

- Reflect on your growth so far. How does this make you feel? Do you feel better about your skills?
  - I have become more confident in my coding and data analysis skills. I at least know what tools are available and how to find more tools.
- How about your study/work habits? Have they improved (or not) over the semester?
  - Actually yes. I've learned not to put off coding projects.
- What feedback do you have for the instructors on this assignment and the lectures/labs/assignments we provided to prepare you for this?
  - Potentially a rubric for this assignment or at least expectations (or textually communicated lack-thereof) would be nice