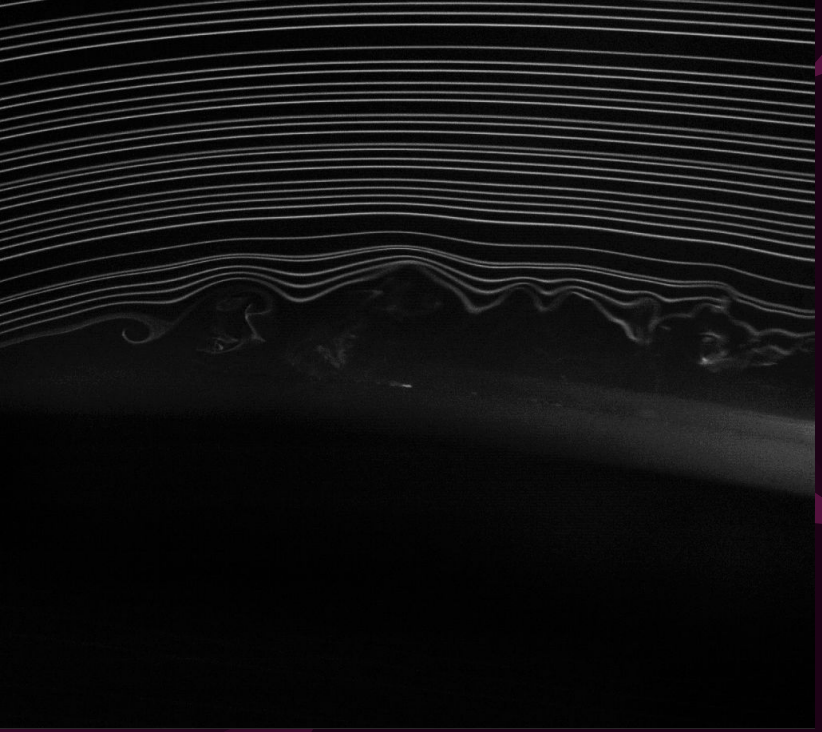


Automation of a Wind Tunnel Smoke Flow Visualization (SFV) Rig

Prepared by Daniel Asadi

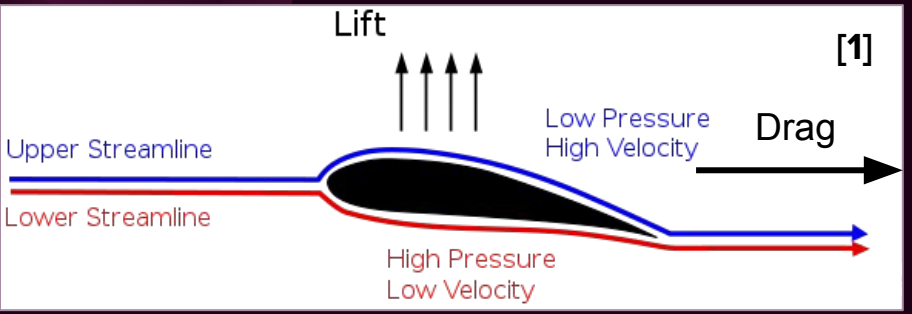
Undergraduate Engineering Research Day

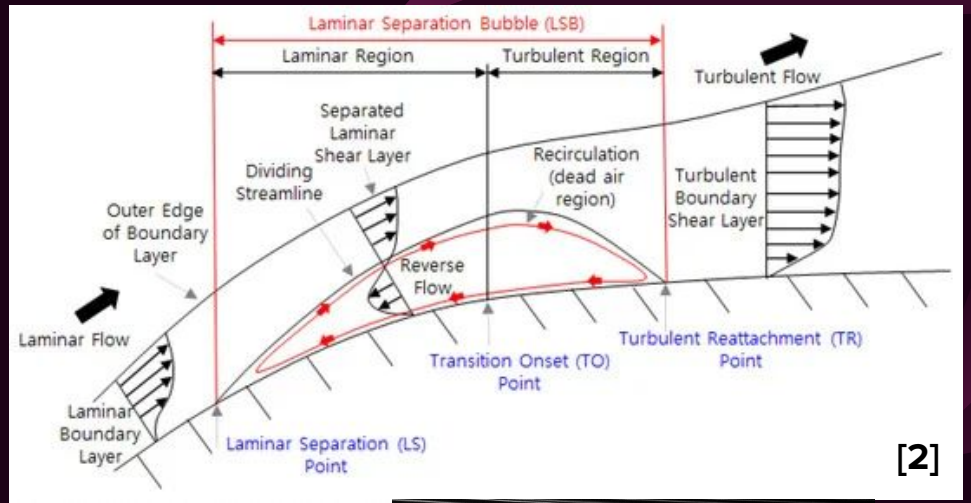
August 20th, 2021

Natural Sciences and Engineering Research Council of Canada
Conseil de recherches en sciences naturelles et en génie du Canada

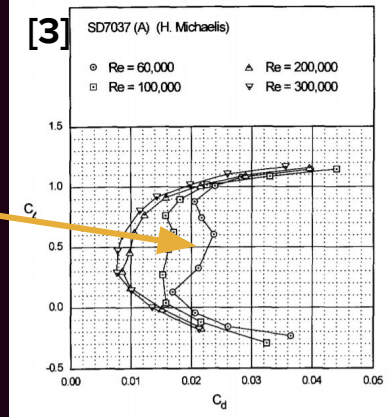
Institute for Aerospace Studies
UNIVERSITY OF TORONTO
Flow Control & Experimental Turbulence Lab

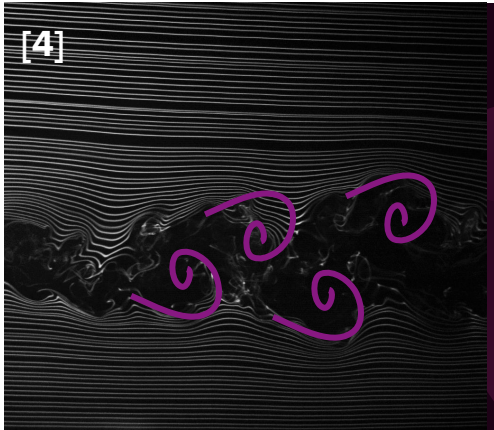
Some aerodynamics theory





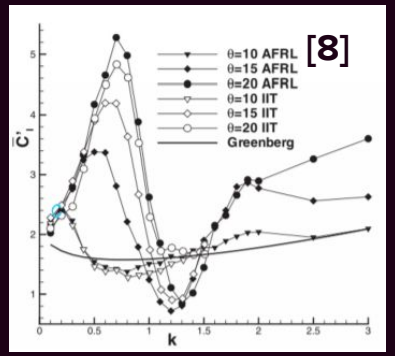
- Reynolds Number (Re) - Characteristic of flow
- Low Re -> LSB -> Increases the drag of the airfoil
- High angle of attack (AOA) -> Vortex shedding -> Lift and drag fluctuations
- Higher drag coefficient at low Re due to LSB

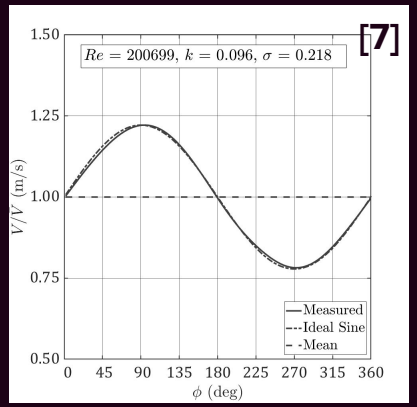


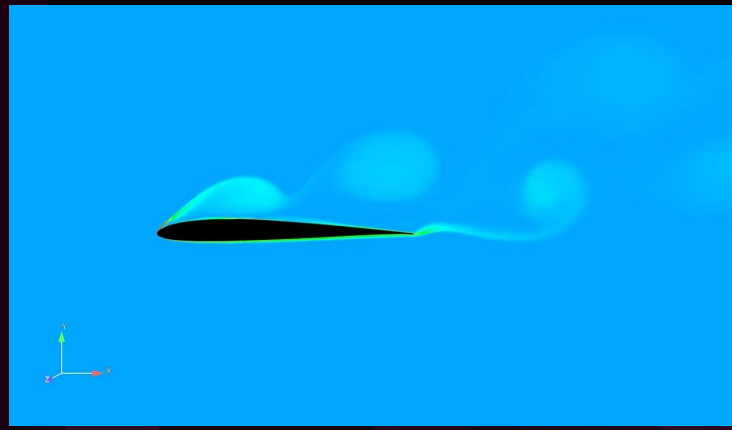


Unsteady aerodynamics

- Active grid -> Simulates real-life wind gusts by varying flow velocity periodically [5]
- Gusts cause significant changes in the mean forces and the amplitude of the unsteady forces on the wing
- Creates new flow structures - leading-edge vortices
- Bigger periodic variations in lift
- Unconventional effects



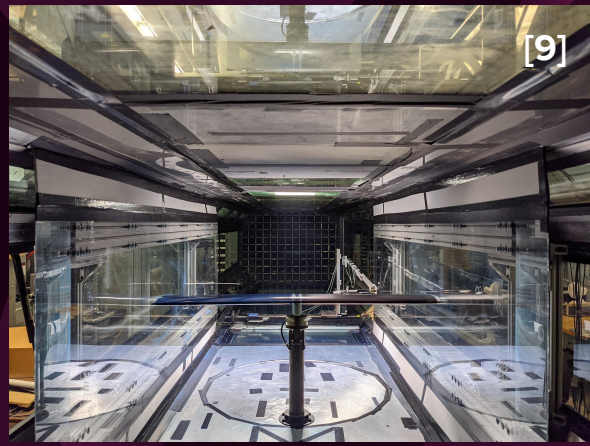




Creation of a leading-edge vortex [6]

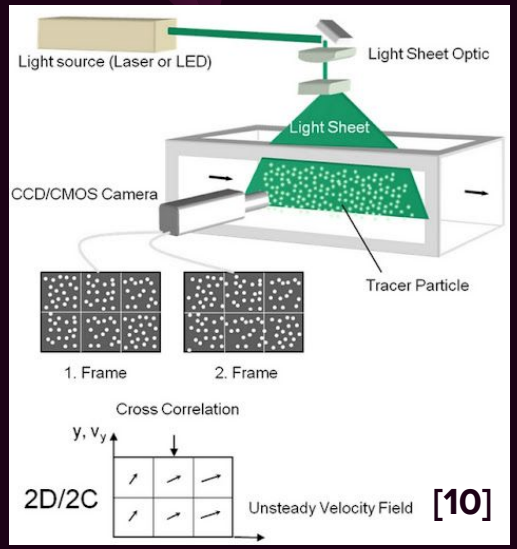
Why do we need to study this?

- Design airfoil to minimize the effect of the LSB
- Reduce drag -> Increase fuel efficiency of aircraft
- Vortex shedding -> fluctuations cause vibration and higher structural loading
- Gusts change performance of airfoils, cause vibrations, increases loading, can lead to unstable flight controllers in small aircraft
- Test different many parameters and study the structures and effects present

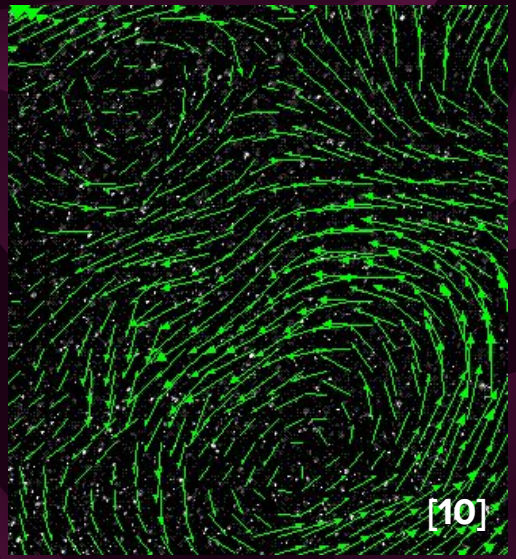


Experimental flow analysis methods

Particle image velocimetry (PIV)



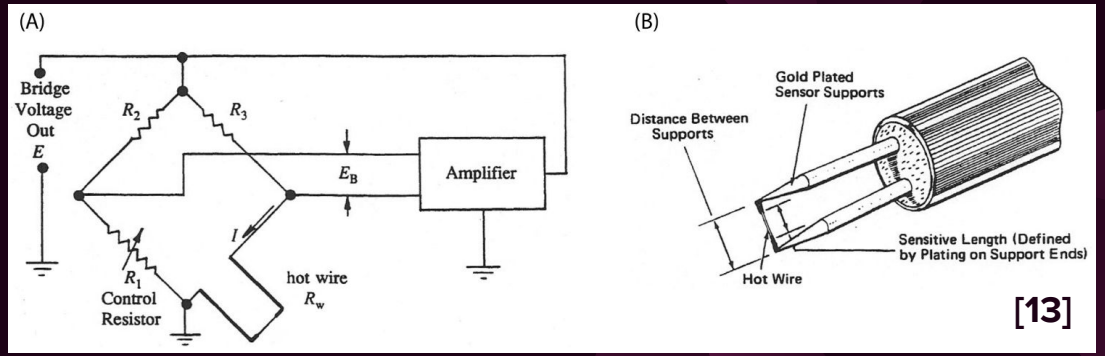
- Quantitative flow field mapping technique
- The velocity field of an entire region within the flow is measured simultaneously [11]
- Time consuming setup
- Expensive
- Large amount of data to process/compute



Experimental flow analysis methods

Hot wire anemometry

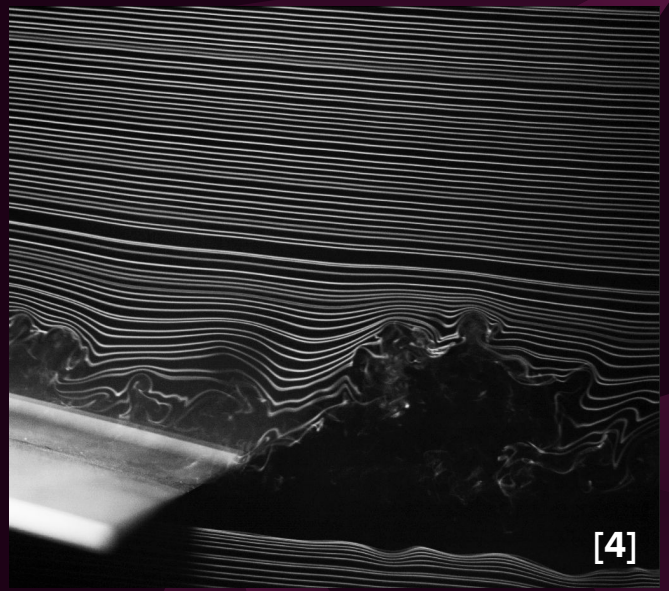
- Measures instantaneous flow velocity at a single point
- Very high spatial resolution [12]
- Excellent frequency response characteristics
- Intrusive measurement



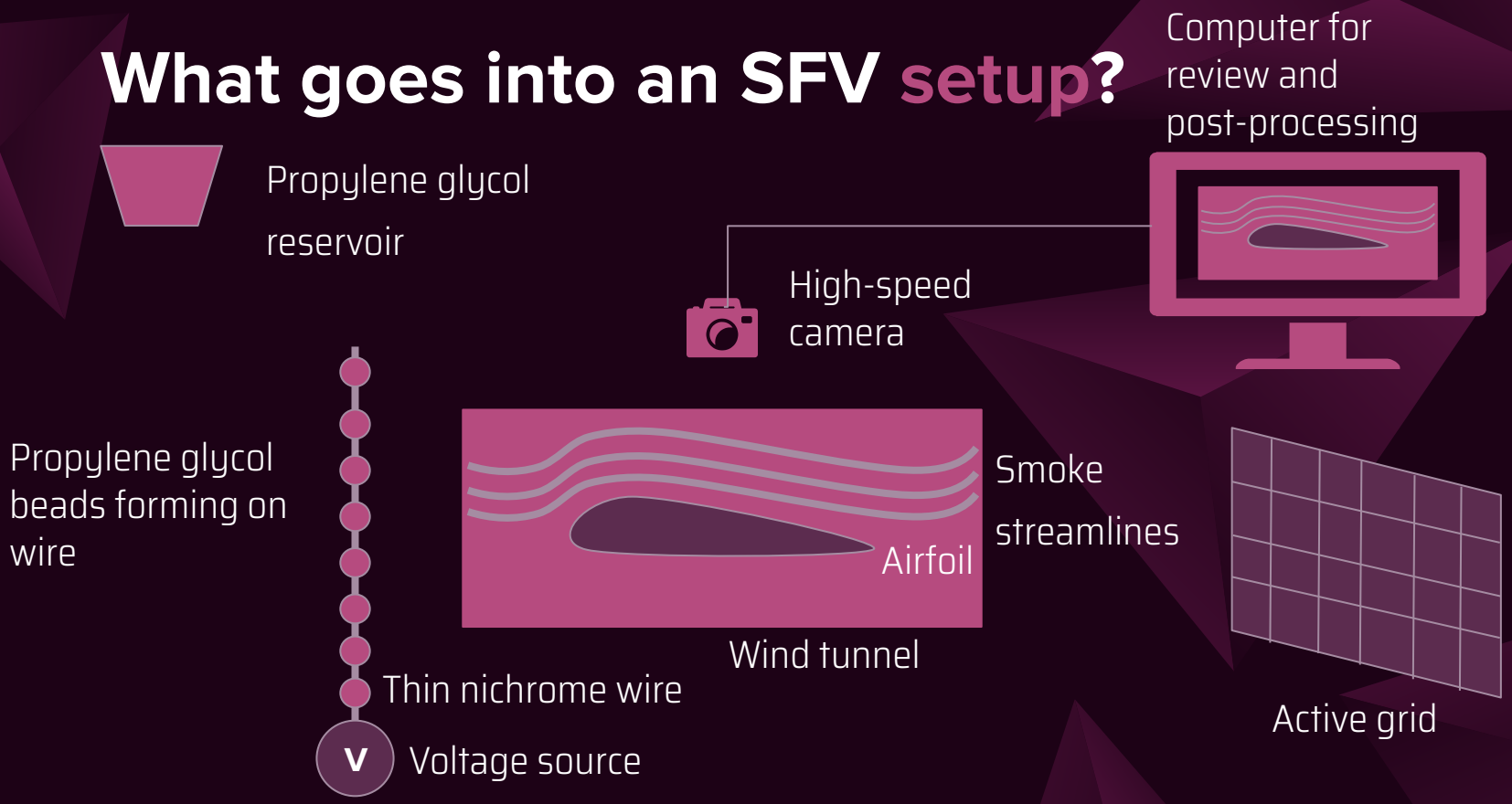
Experimental flow analysis methods

Smoke Flow Visualization (SFV)

- Qualitative, macroscopic view of the overall flow field from smoke streamlines [14]
- Allows for the identification of key flow structures
- Less time-consuming and less complicated setup



What goes into an SFV setup?



Current problems with experimental setup

- Each instrument in the setup is controlled manually
- Only effective for flow speeds under 5 m/s
- Not a streamlined process
- Limited precision of equipment usage
- Cannot study unsteady flow conditions

Main goals of the project

Efficiency of consecutive uses

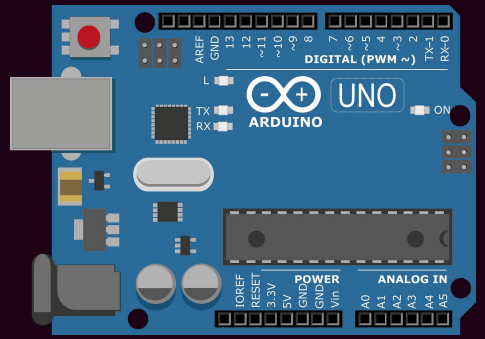
Precision of manual/automated I/O

Versatility for different cases

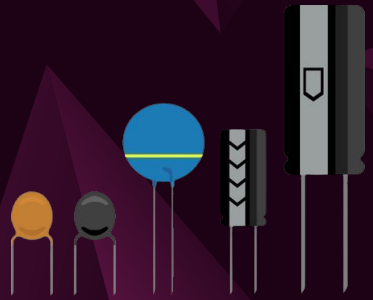
Simple usability

Proposed improvements to set up

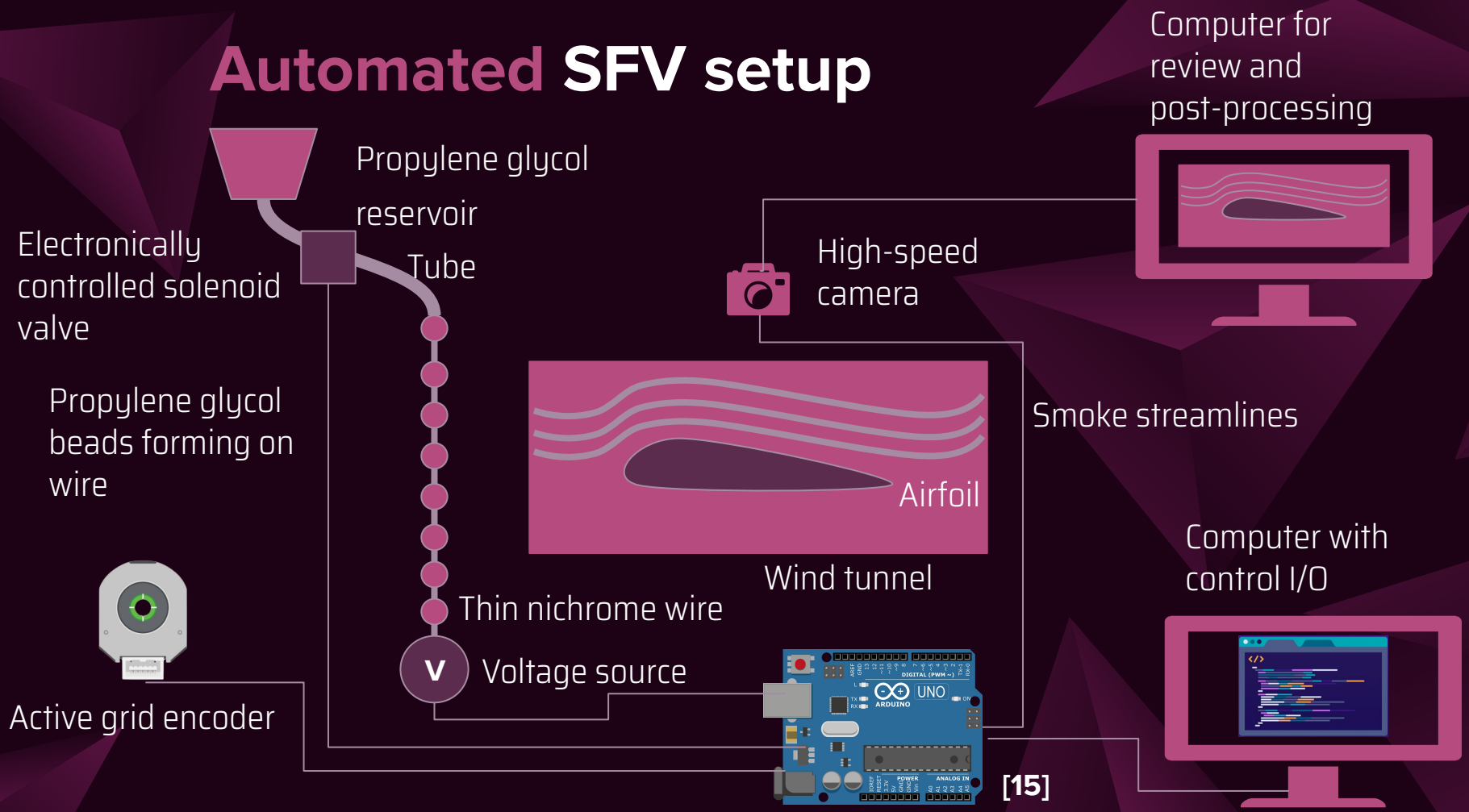
- Mount an encoder to an active grid motor
- Connect all SFV components to a microcontroller to automate the process
- Implement capacitors to rapidly discharge high levels of current for usage above 5 m/s



[15]

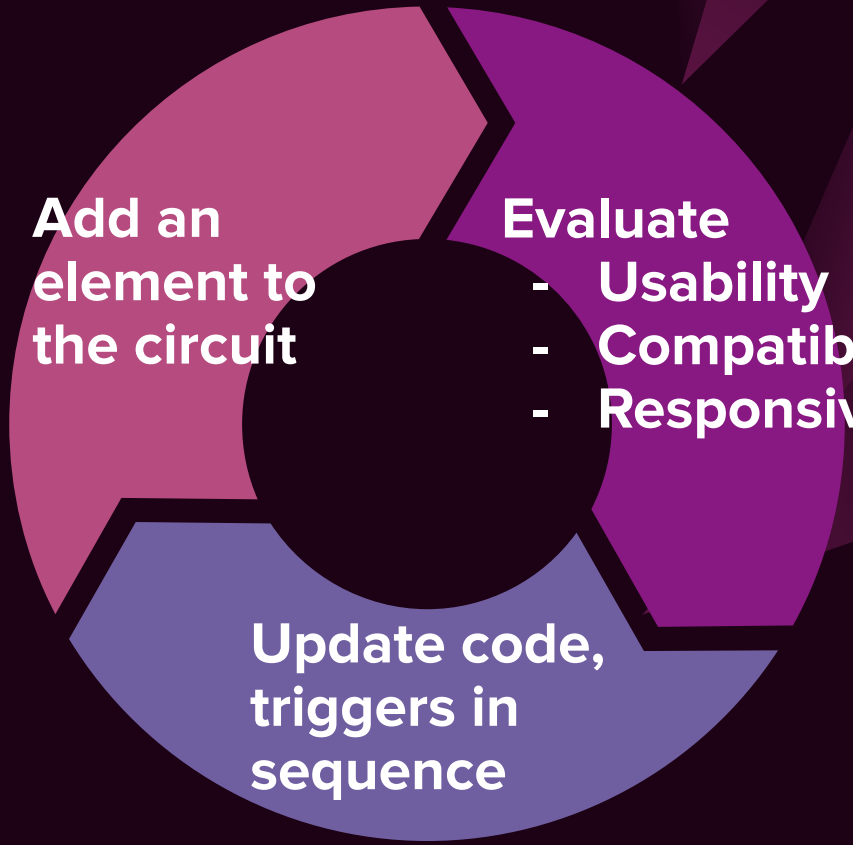


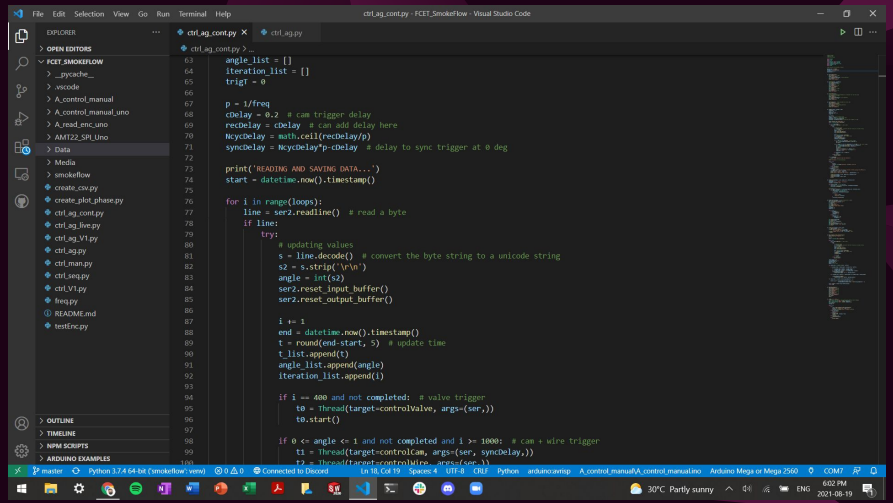
Automated SFV setup

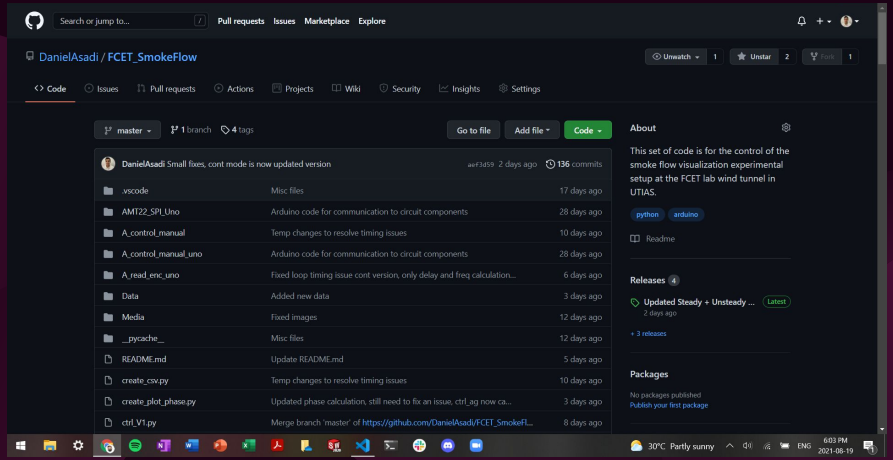


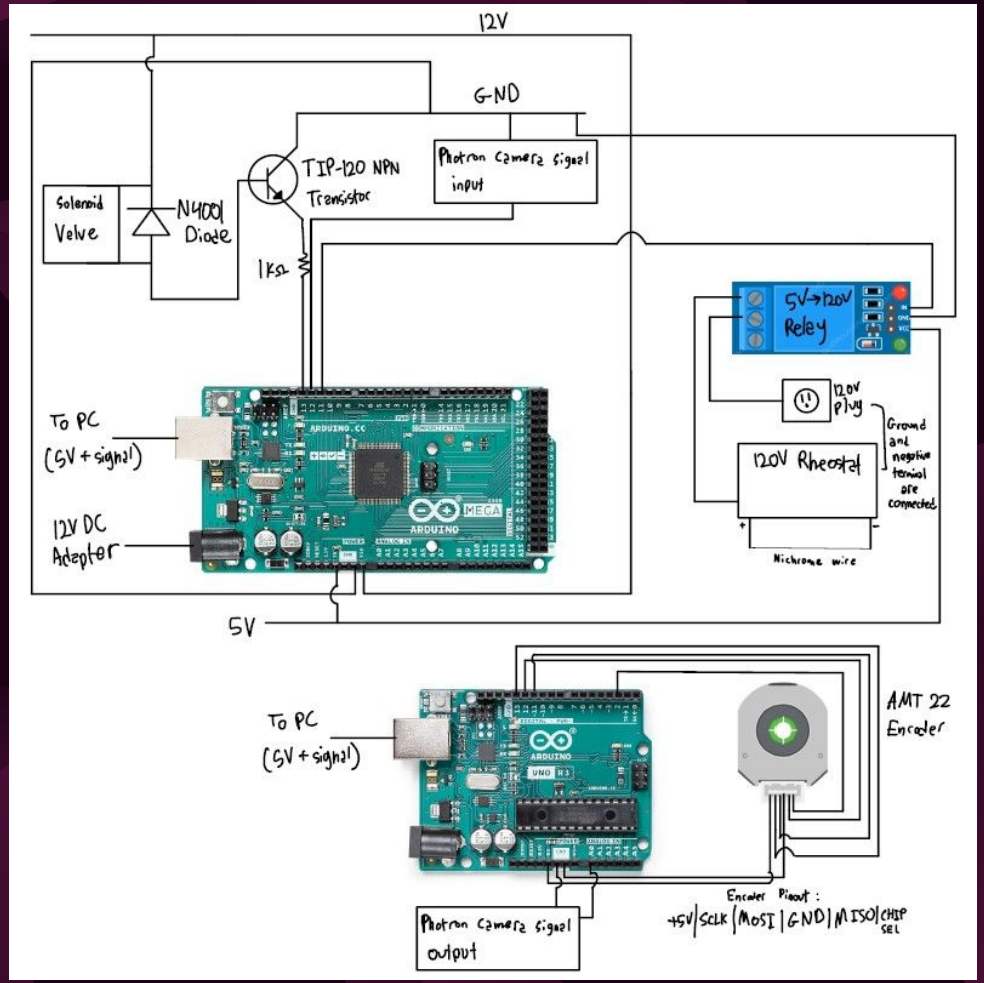
[15]

Iterative design process

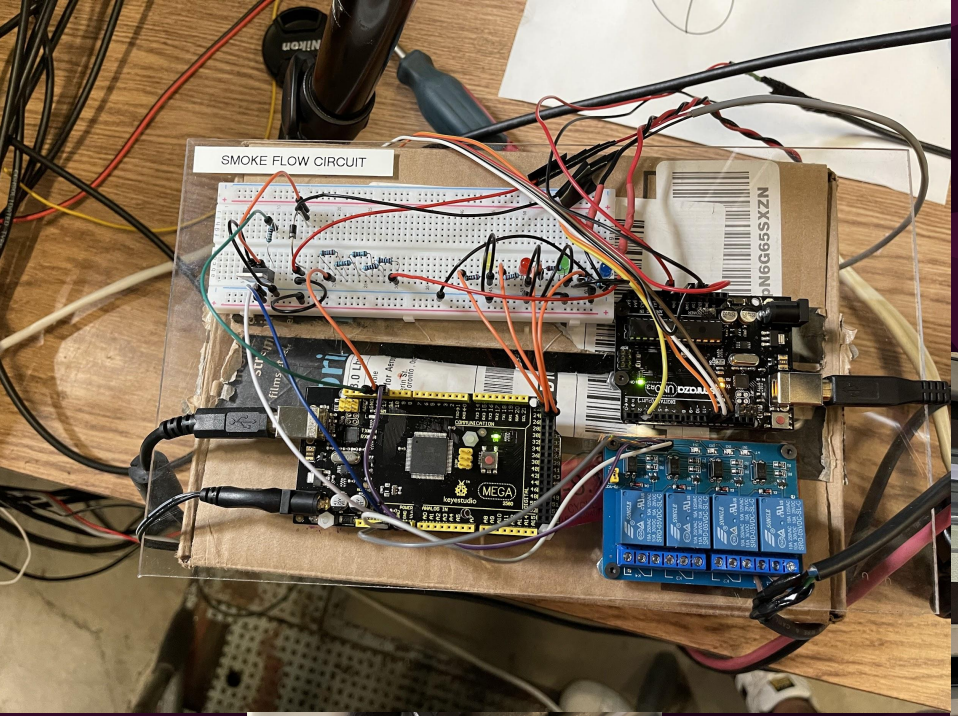


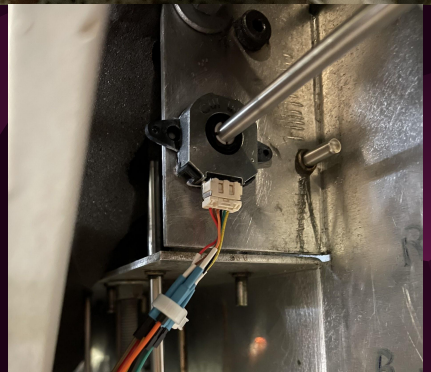

ctrl_ag_cont.py - FCET_SmokeFlow - Visual Studio Code
EXPLORER
OPEN EDITORS
FCET_SMOKEFLOW
__pycache__
.vscode
A_control_manual
A_control_manual_uno
A_read_enc_uno
AMT22_SPI_Uno
Data
Media
smokeflow
create_csv.py
create_plot_phase.py
ctrl_ag_cont.py
ctrl_ag_live.py
ctrl_ag_V1.py
ctrl_ag.py
ctrl_man.py
ctrl_seq.py
ctrl_V1.py
freq.py
README.md
testEnc.py
OUTLINE
TIMELINE
NPM SCRIPTS
ARDUINO EXAMPLES
ctrl_ag_cont.py
ctrl_ag.py
angle_list = []
iteration_list = []
trigT = 0
p = 1/freq
cDelay = 0.2 # cam trigger delay
recDelay = cDelay # can add delay here
NcycDelay = math.ceil(recDelay/p)
syncDelay = NcycDelay*p-cDelay # delay to sync trigger at 0 deg
print('READING AND SAVING DATA...')
start = datetime.now().timestamp()
for i in range(loops):
line = ser2.readline() # read a byte
if line:
try:
# updating values
s = line.decode() # convert the byte string to a unicode string
s2 = s.strip('\r\n')
angle = int(s2)
ser2.reset_input_buffer()
ser2.reset_output_buffer()
i += 1
end = datetime.now().timestamp()
t = round(end-start, 5) # update time
t_list.append(t)
angle_list.append(angle)
iteration_list.append(i)
if i == 400 and not completed: # valve trigger
t0 = Thread(target=controlValve, args=(ser,))
t0.start()
if 0 <= angle <= 1 and not completed and i >= 1000: # cam + wire trigger
t1 = Thread(target=controlCam, args=(ser, syncDelay,))
t2 = Thread(target=controlWire, args=(ser,))
Python 3.7.4 64-bit ('smokeflow': venv)
Connected to Discord
Ln 18, Col 19
Spaces: 4
UTF-8
CRLF
Python
arduino.ino
A_control_manual\A_control_manual.ino
Arduino Mega or Mega 2560
COM7
30°C Partly sunny
ENG
6:02 PM
2021-08-19

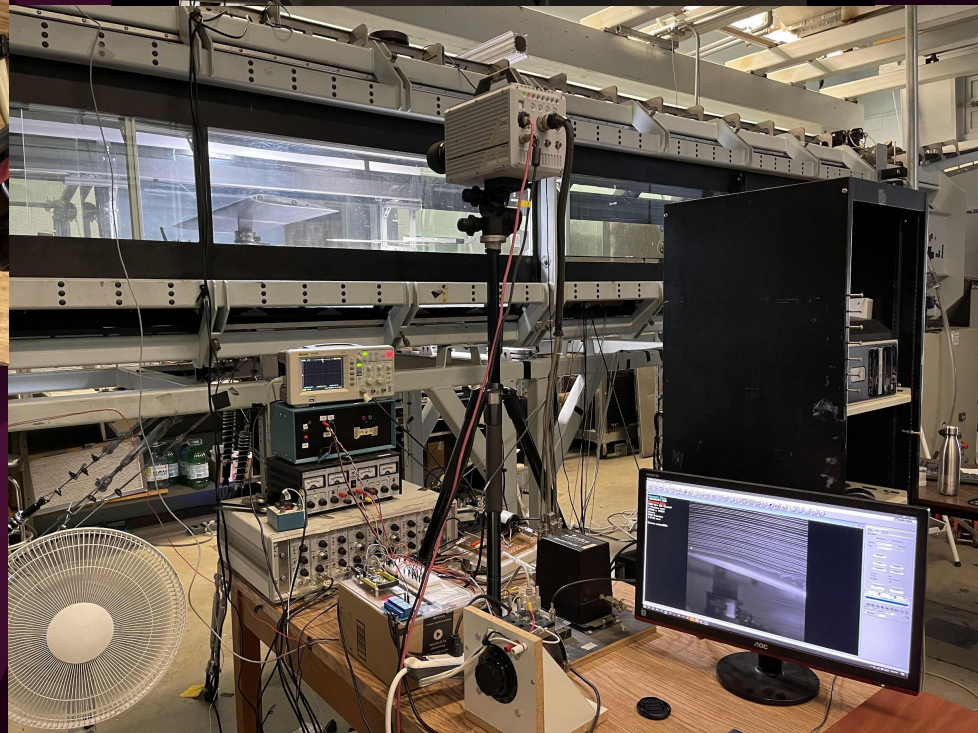

Search or jump to...
Pull requests
Issues
Marketplace
Explore
DanielAsadi / FCET_SmokeFlow
Unwatch 1
Unstar 2
Fork 1
Code
Issues
Pull requests
Actions
Projects
Wiki
Security
Insights
Settings
master
1 branch
4 tags
Go to file
Add file
Code
DanielAsadi Small fixes, cont mode is now updated version
ae43d59 2 days ago
136 commits
.vscode Misc files 17 days ago
AMT22_SPI_Uno Arduino code for communication to circuit components 28 days ago
A_control_manual Temp changes to resolve timing issues 10 days ago
A_control_manual_uno Arduino code for communication to circuit components 28 days ago
A_read_enc_uno Fixed loop timing issue cont version, only delay and freq calculation... 6 days ago
Data Added new data 3 days ago
Media Fixed images 12 days ago
__pycache__ Misc files 12 days ago
README.md Update README.md 5 days ago
create_csv.py Temp changes to resolve timing issues 10 days ago
create_plot_phase.py Updated phase calculation, still need to fix an issue, ctrl_ag now ca... 3 days ago
ctrl_V1.py Merge branch 'master' of https://github.com/DanielAsadi/FCET_SmokeFl... 8 days ago
About
This set of code is for the control of the smoke flow visualization experimental setup at the FCET lab wind tunnel in UTIAS.
python
arduino
Readme
Releases 4
Updated Steady + Unsteady ...
Latest
2 days ago
+ 3 releases
Packages
No packages published
Publish your first package
30°C Partly sunny
ENG
6:03 PM
2021-08-19


12V
G-ND
TIP-120 NPN Transistor
Photron Camera signal input
Solenoid Valve
N4001 Diode
1kΩ
5V→120V Relay
120V plug
Ground and negative terminal are connected
120V Rheostat
Nichrome wire
To PC (5V + signal)
12V DC Adapter
5V
To PC (5V + signal)
AMT 22 Encoder
Photron Camera signal output
Encoder Pinout :
+5V | SCLK | MOSI | GND | MISO | CHIP SEL

[4]

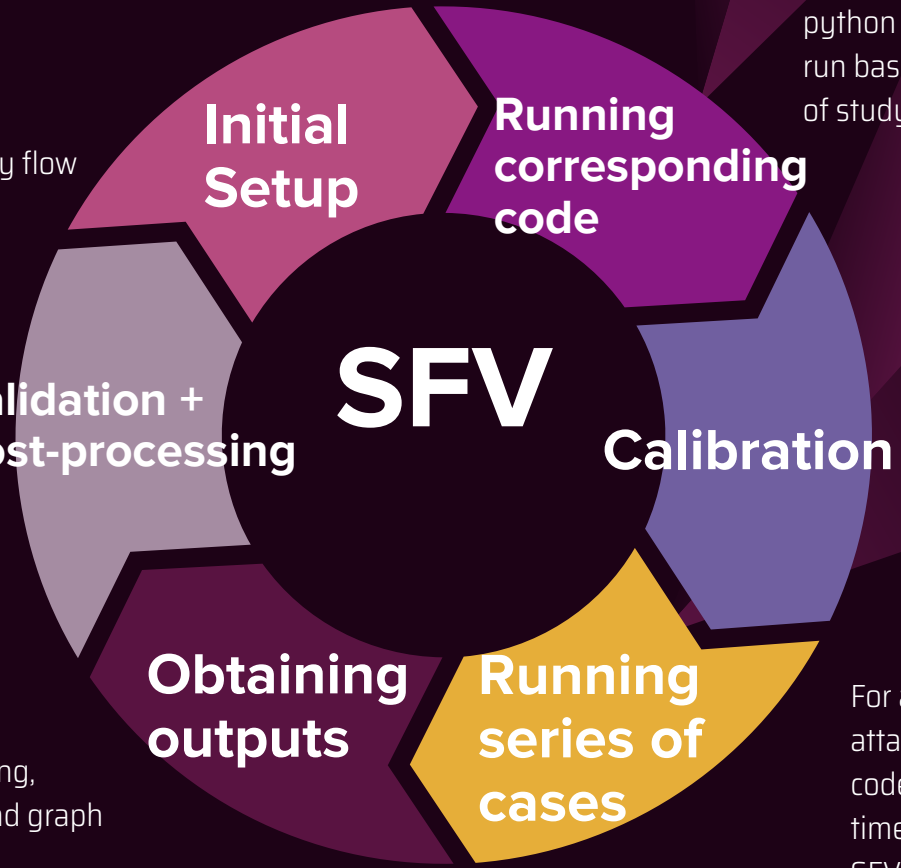






[4]

Streamlined workflow



Set wind tunnel properties, steady/unsteady flow

Select one of many python programs to run based on the case of study

Calibrate camera view, code parameters

For a set angle of attack/flow speed, the code outputs precise, timed controls to the SFV elements

Camera recording, encoder CSV and graph files, frequency

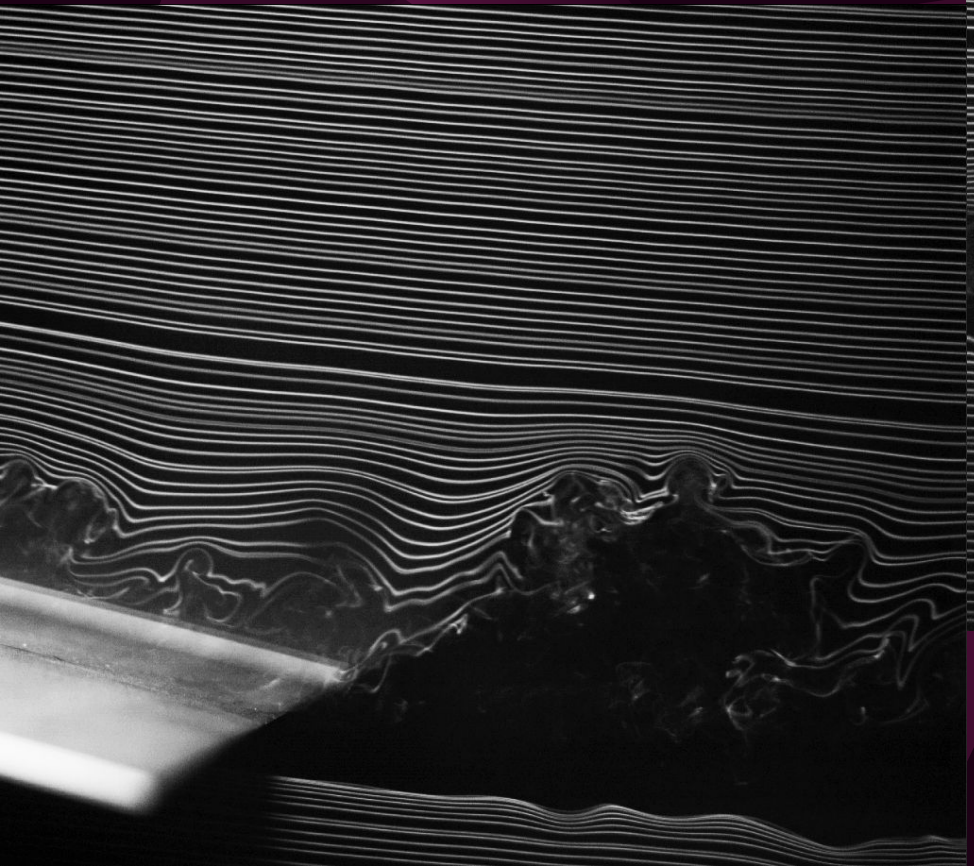
Review and edit video for smoke quality and double check data

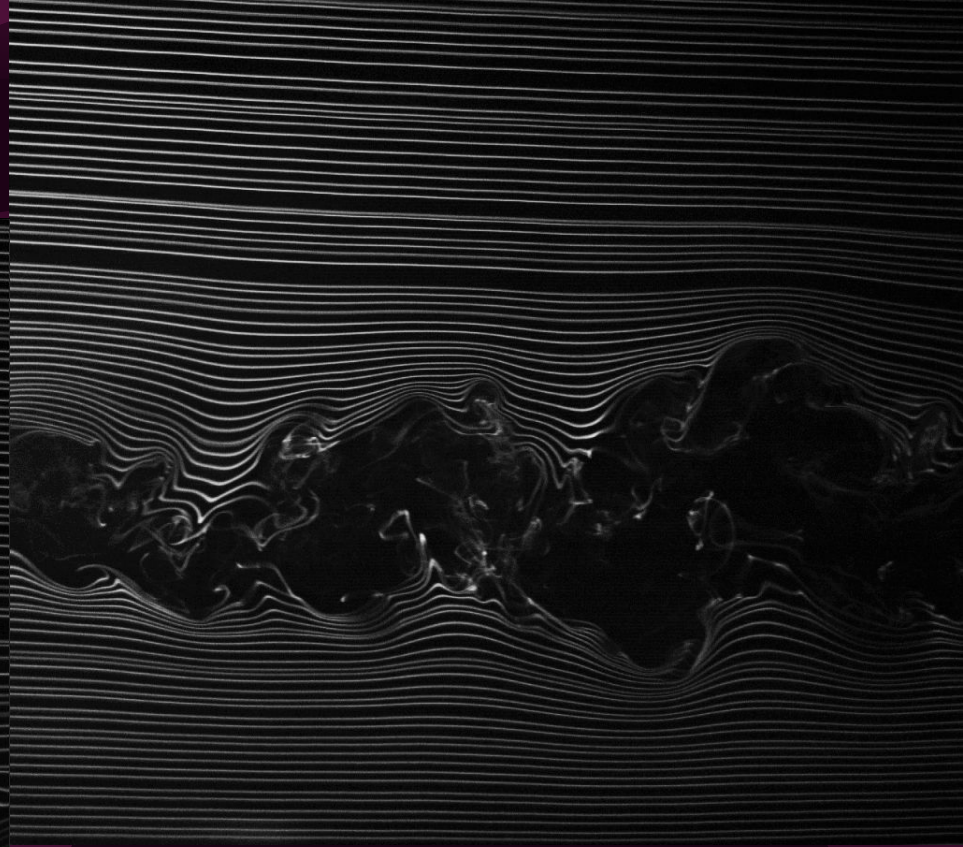
New capabilities of the setup

- User selects between
  - Manual control mode
  - Automated trigger mode
  - Trigger from encoder output for unsteady cases
- Saves encoder data and syncs with recording
- Can be used completely remotely

RESULTS

Wake effects

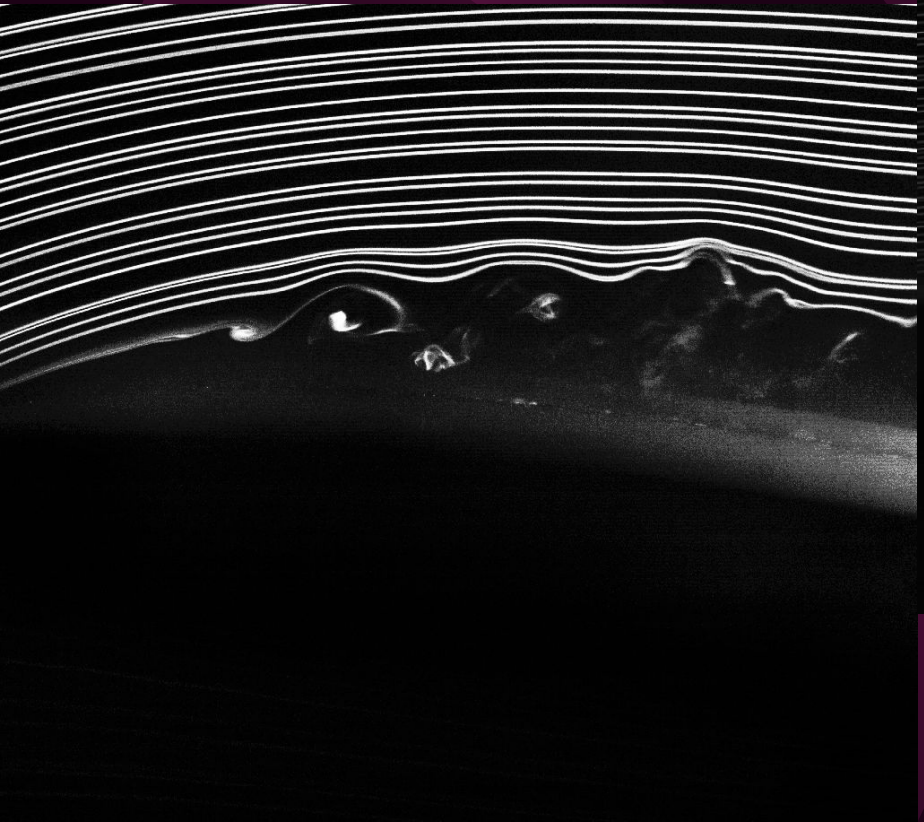


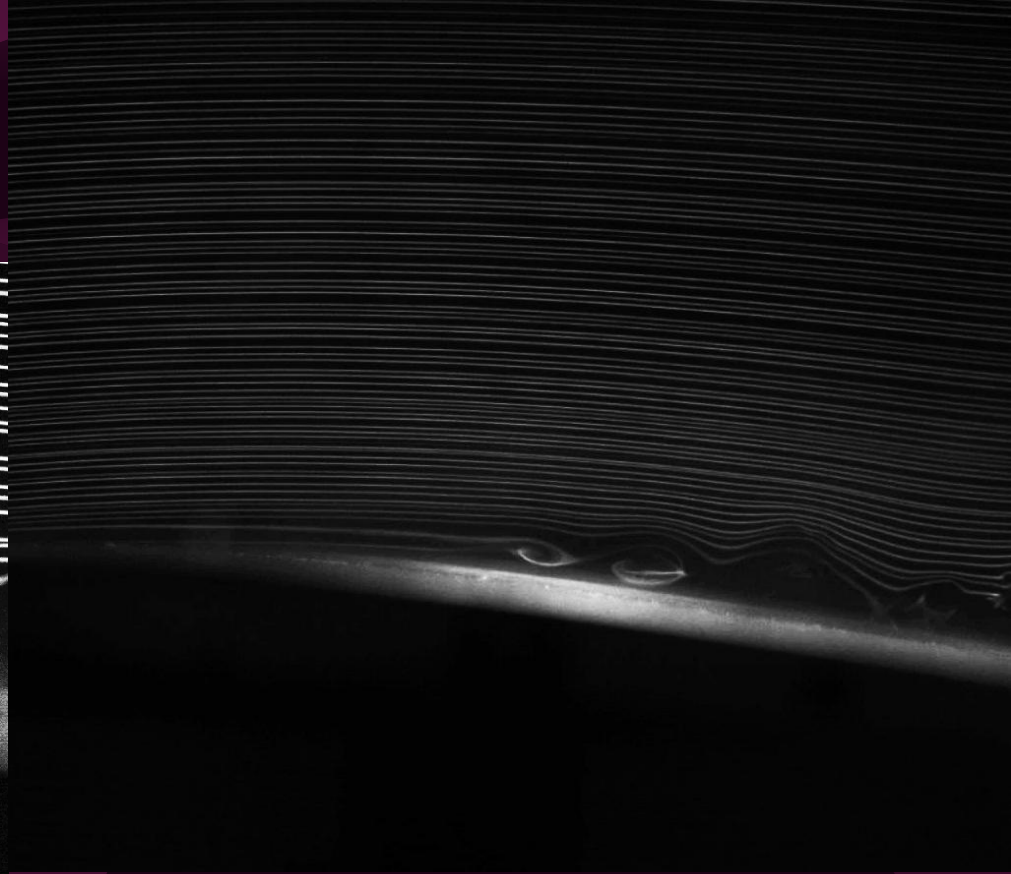


[4]

Vortex shedding

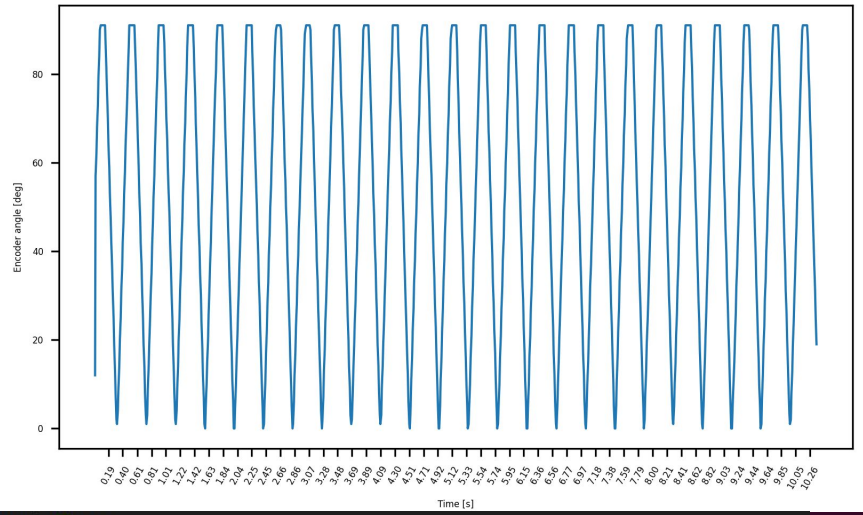
Laminar separation bubble





[4]

Transition between laminar and turbulent flow



Data > 1683 > 1683.txt

```
Measured frequency: 2.38101 Hz vs matlab 2.36314 Hz
Trigger start at 0 deg: 11.251450162407151 s
```

Data > 1683 > 1683.csv

```
t,angle,iteration

0.001,60,1

0.00716,48,2

0.01488,54,3

0.02738,59,4

0.03576,65,5

0.0471,70,6

0.05652,76,7

0.06866,81,8

0.07645,87,9
```

Unsteady state outputs

[4]

Remarks + Importance

- Maximized usage of SFV
- Aided in the study of laminar separation bubbles
- Furthering research in unsteady aerodynamics
- Creation of informative images in a consistent manner
- Versatile setup
- Augmented the usage of other instruments
- Future steps: Capacitors, turbulence grid

Sources

[1] https://en.wikipedia.org/wiki/Lift_(force)

[2] https://www.mdpi.com/2076-3417/10/17/6095/htm

[3] Summary of Low-Speed Airfoil Data (Selig et al., 1995)

[4] FCET Lab Smokeflow, Daniel Asadi and Suraj Bansal

[5] FCET Lab Active Grid, Suraj Bansal

[6] FCET Lab CFD, Suraj Bansal

[7] FCET Lab Active Grid Data, Suraj Bansal

[8] Airfoil Longitudinal Gust Response in Separated vs. Attached Flows (Granlund et al., 2014)

[9] FCET Lab Test Section and Airfoil, Suraj Bansal

[10] http://www.formula1-dictionary.net/wind_tunnel_piv.html

[11] https://www.sciencedirect.com/topics/engineering/particle-image-velocimetry

[12] https://www.sciencedirect.com/topics/engineering/hot-wire-anemometer

[13] https://www.jove.com/v/10464/hot-wire-anemometry

[14] http://www.wseas.us/e-library/conferences/2006elounda2/papers/538-250.pdf

[15] https://www.pngitem.com/middle/iiibmx_arduino-uno-vector-png-transparent-png/

THANKS!

Any questions?

Daniel Asadi, University of Toronto, Division of Engineering Science

Supervised by: Suraj Banal, FCET Lab, UTIAS and Professor Philippe Lavoie, FCET Lab, UTIAS

daniel.asadi@mail.utoronto.ca

https://github.com/DanielAsadi/FCET_SmokeFlow