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SAE Snowmobile Team

Wisconsin–Rotax ACE 674 (WRACE 674)

SAE Clean Snowmobile Challenge
Design Presentation 2018

University of Wisconsin-Madison

Presenters: Andrew Wild and Matthew Massman

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Team Management

- Joined SAE in 1939
- Clean Snowmobile Team has competed since 2002
- Team Structure
  - President/Electrical Lead - James Gerdes
  - Mechanical/Emissions Lead - Matt Massman
  - Controls/Calibration Lead - Andrew Wild

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Team Outreach

- Fundraising and Sponsor Relations
  - SAE Milwaukee Chapter Meeting
  - Annual Presentation at UWGP
  - Shop tours for sponsors
- Community Outreach
  - Engineering Bash
  - Homecoming Parade
  - Engineering Expo

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Design Considerations:

Our 2015 Survey of 25 Wisconsin Snowmobile Clubs

- Customers Want:
  - Trail Handling
  - Fuel Economy
- Historical Best Sellers
  - Ski-Doo Rev XP 600 SDI
  - Polaris Rush 600

Characteristic	Rank
Handling	1
Price	2
Fuel Economy	3
Acceleration	4
Emissions	5
Sound	6

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Engine Selection

Focus Points:

- Fuel Economy
- Engine Out Emissions
- Adequate Power

Base Snowmobile	Power (kW)	Weight (kg)	Fuel Economy (km/L)	Emissions (g/kW-hr)		
				HC	CO	NOx
Ski Doo ACE 600	42	41.1	12.5	6	90	N/A
Ski Doo ACE 900	64.5	51.8	10	6	75	N/A
Ski Doo 1200 4tec	92	60	8.85	8	130	N/A
Polaris 600 Cleanfire	97	35	5.3	60	175	N/A

*Manufacturer reported values
*Polaris represents Two-Stroke for comparison

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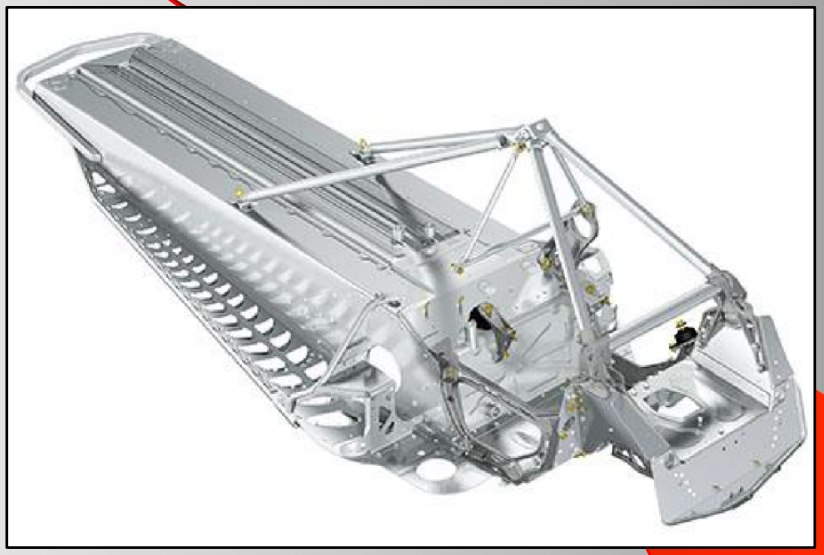
Chassis Selection

2015 Ski-doo MXZ Sport

- Lightweight
- Rider-forward ergonomics
- Cost-effective
- New XS Chassis



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Engine Management

- Woodward/Mototron PCM565
  - Automotive/Marine environments
  - -40 to 130 °C
  - 18 g Shock Load
- Submersible up to 3 meters
- MATLAB/Simulink engine modeling
- MotoHawk automatic code generation

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Design Goals for 2018 CSC

- Rectify engine cooling issues
- Reduce noise levels
- Improve cold start reliability
- Raise catalytic efficiency

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Head Gasket Replacement

- Struggled to maintain a steady operating temperature during 2017 CSC
- Discovered leaky head gasket after competition
- Sourced a different Cometic head gasket
- Maintained compression ratio of 12.05:1

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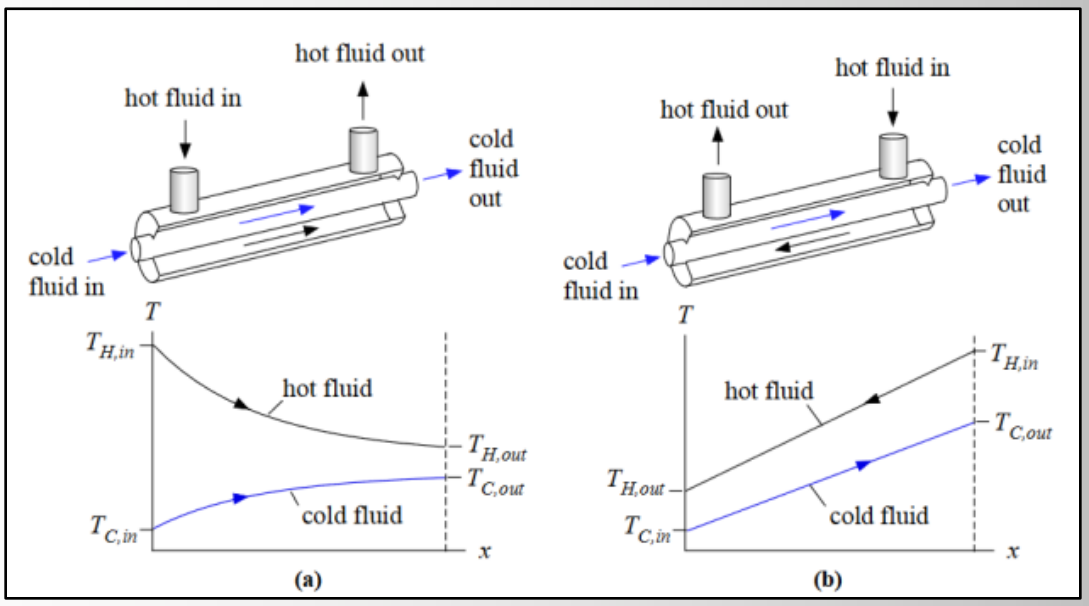
EGR Cooler Modification

- Deduced that cooler had effect on cooling problems
- Altered cooler design from counter current flow to cocurrent flow



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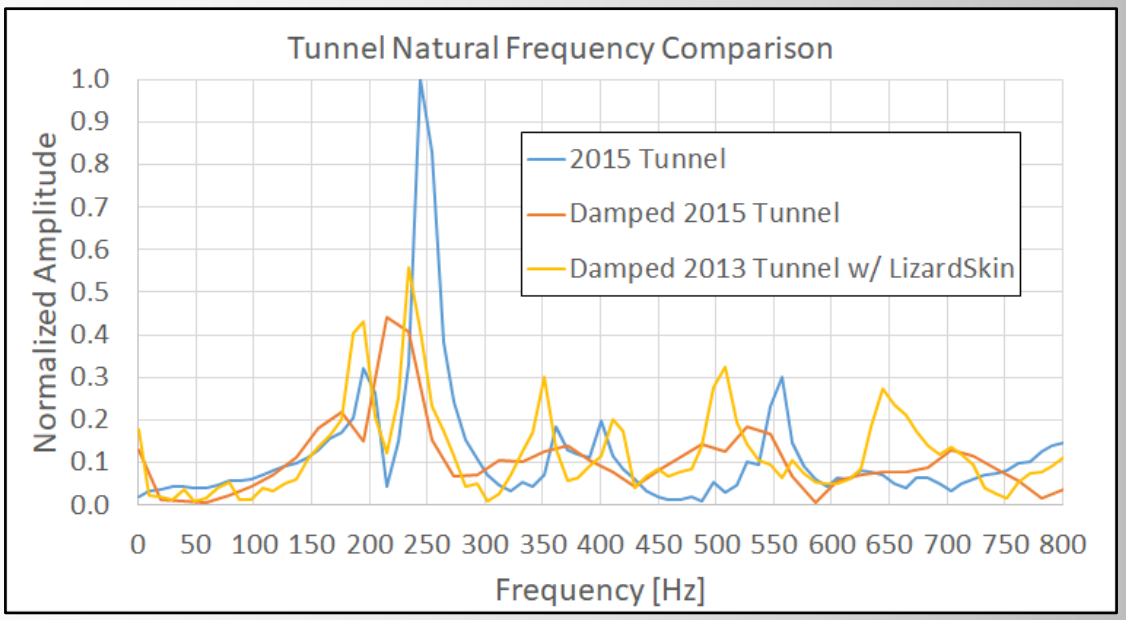
Noise Reduction

- 5th place in noise with 81.0 dBA in 2017
- Looked to attenuate chassis noise
- Tunnel vibrational data collected with accelerometer and analyzed using Fast Fourier Transform



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Noise Reduction (cont.)

- LizardSkin sound control used to dampen tunnel

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Cold Start Reliability

- Failed cold start in 2017
- Room for improvement in crank fueling control
- Over 50 cold start data logs collected and analyzed

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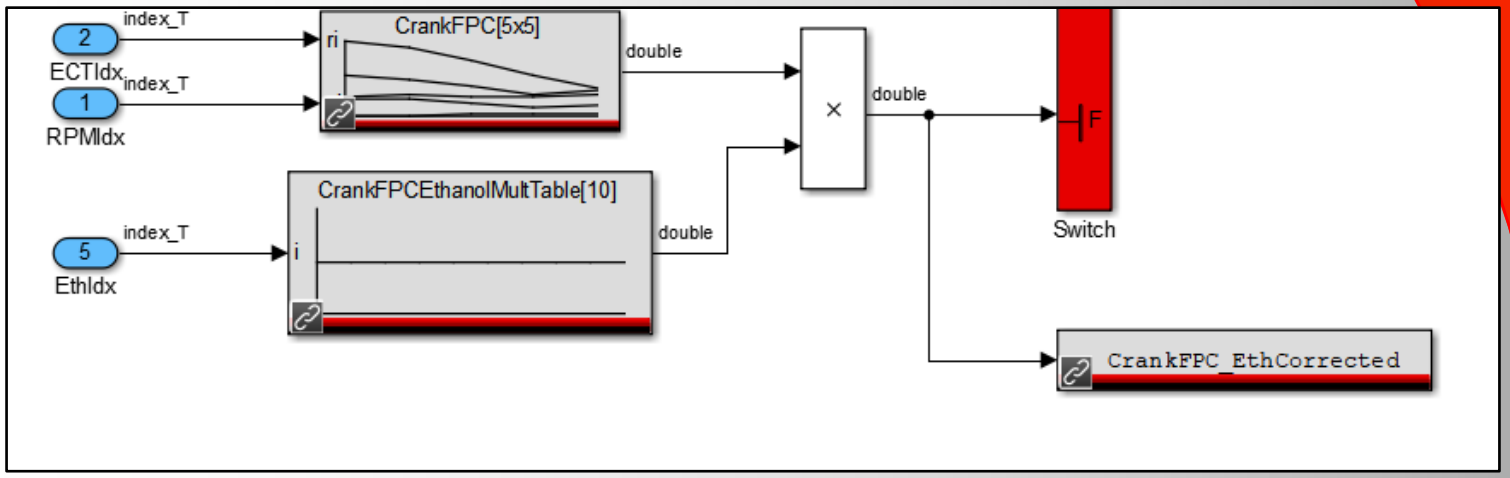
Crank Fueling Changes

- Developed ethanol percentage based crank fuel multiplier code
- Calibrated base fueling table for E0
- Ethanol multiplier table tuned for optimal starting reliability



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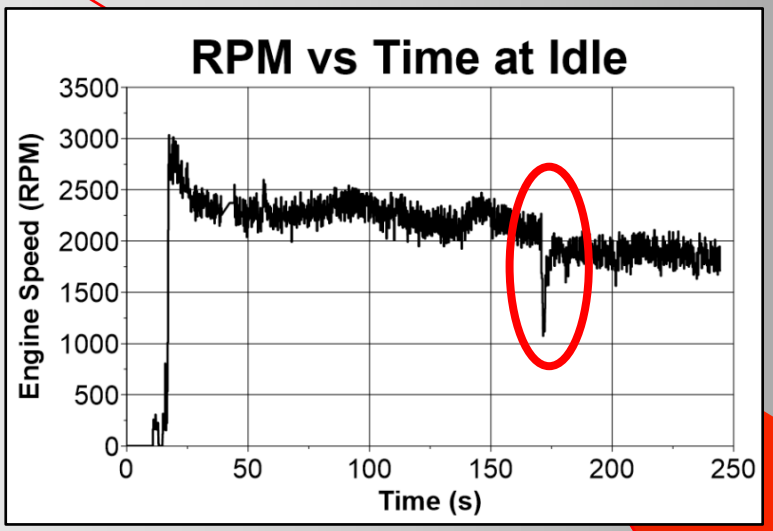
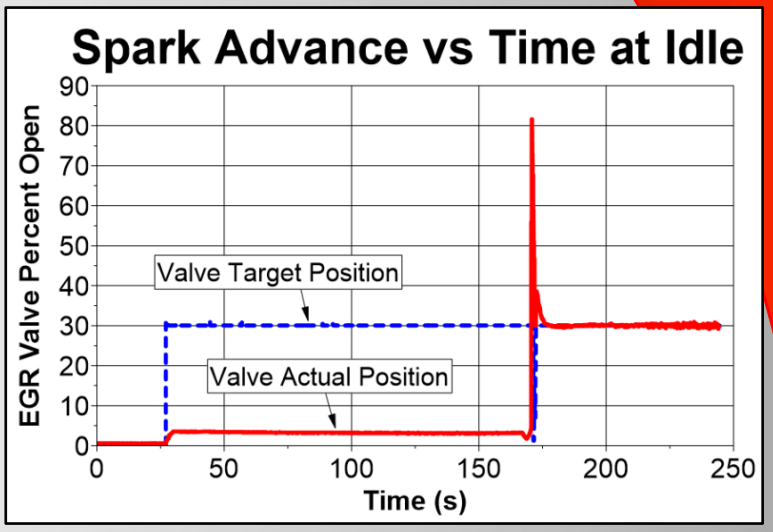
Cold Start Near Stall

- Sudden RPM drop at idle after cold starts
- Investigation revealed condensation froze EGR valve in place
- EGR Valve PID was experiencing I-term windup leading to overshoot





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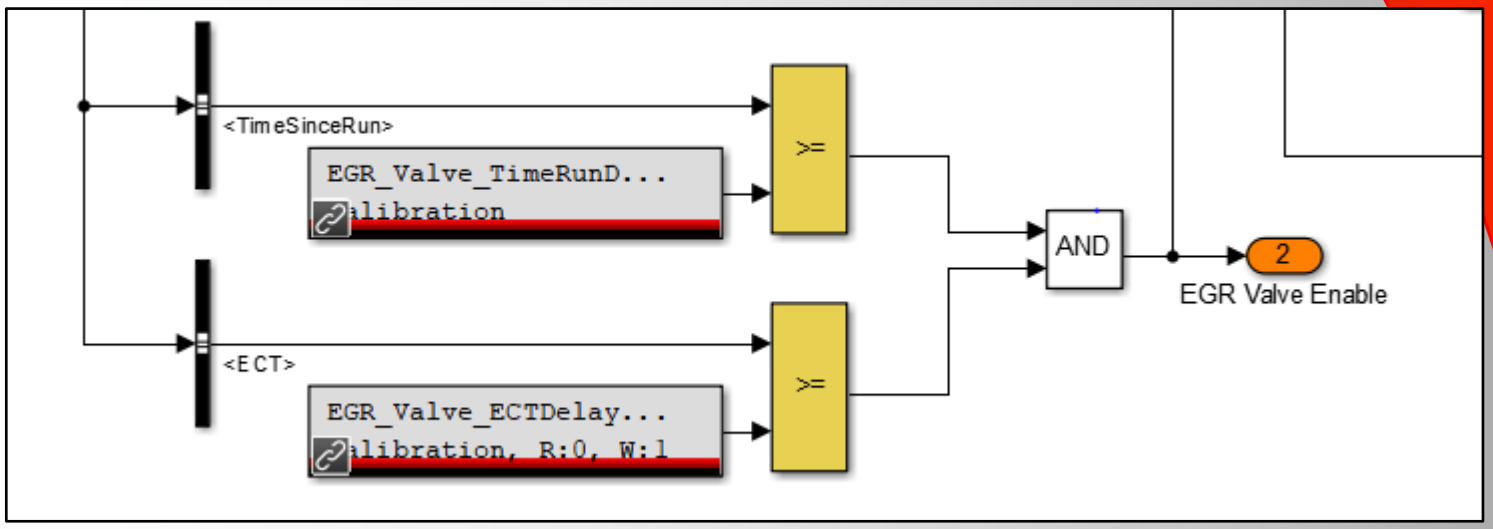
EGR Valve Enablement

- EGR valve thawed and overshot at 30-40°C ECT
- ECT-based EGR valve startup delay created
- Delay temperature calibrated to prevent sudden engine speed reduction



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Catalyst Selection

- Lean to rich fuel oscillation around stoichiometric fueling led to use of three-way catalyst

	2018 Catalyst	2017 Catalyst
Washcoat	W. C, Heraeus GmbH	W. C, Heraeus GmbH
Substrate	Emitec Metal Honeycomb	Emitec Metal Honeycomb
Diameter	92 mm	92 mm
Length	168 mm	168 mm
Foil thickness	0.03 mm	0.03 mm
Density	400 cpsi	400 cpsi
Loading	Platinum 11.1 g/ft^3	Platinum 24.7 g/ft^3
	Palladium 55.6 g/ft^3	Palladium 45.2 g/ft^3
	Rhodium 8.3 g/ft^3	Rhodium 4.1 g/ft^3

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Catalyst Summary

- Projected E-Score increase of 2.2 from testing
- Low NO_X conversion due to EGR

	HC	CO	NO_X	Projected E-Score
2017 Catalyst Efficiency	92.8%	86.8%	24.3%	203.7
2018 Catalyst Efficiency	99.9%	92.4%	34.2%	205.9

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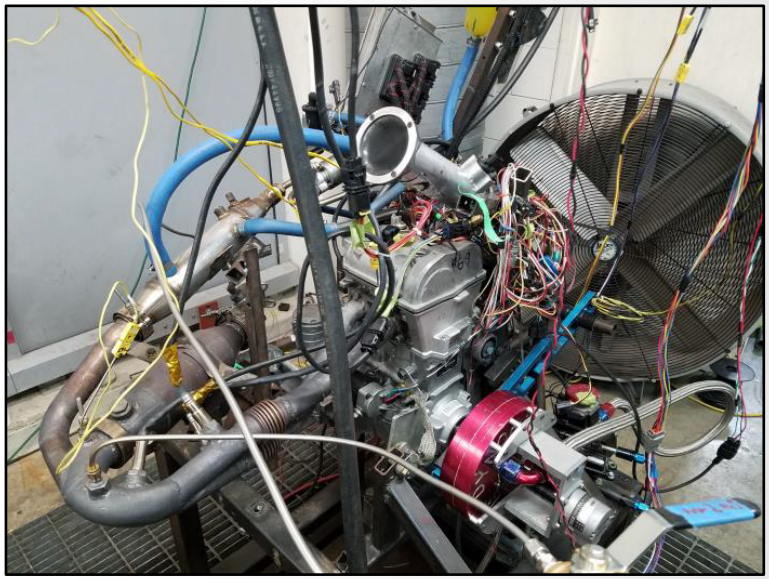
Dyno and Vehicle Testing

- Initial testing and calibration completed on dyno
- Over 350 miles of trail riding on 2018 design
- Used Vector CAN data logger



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WRACE 674 Summary

- Low MSRP of $10,700
- Increased peak torque from 44 to 53 N-m and power from 31 to 35 kW
- E-Score improved from 190 to 206

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Acknowledgements

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College of Engineering
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MichiganTech
Keweenaw Research Center

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References

[1] MTU KRC. *2018 Snow Challenge Logo*. 2018. [Online] Available: http://www.mtukrc.org/images/SnowChall_Logo18_blueglow_sm.jpg [Accessed 23 02 2018].

[2] G. Nellis and S. Klein, *Heat Transfer*. Cambridge University Press, 2009.

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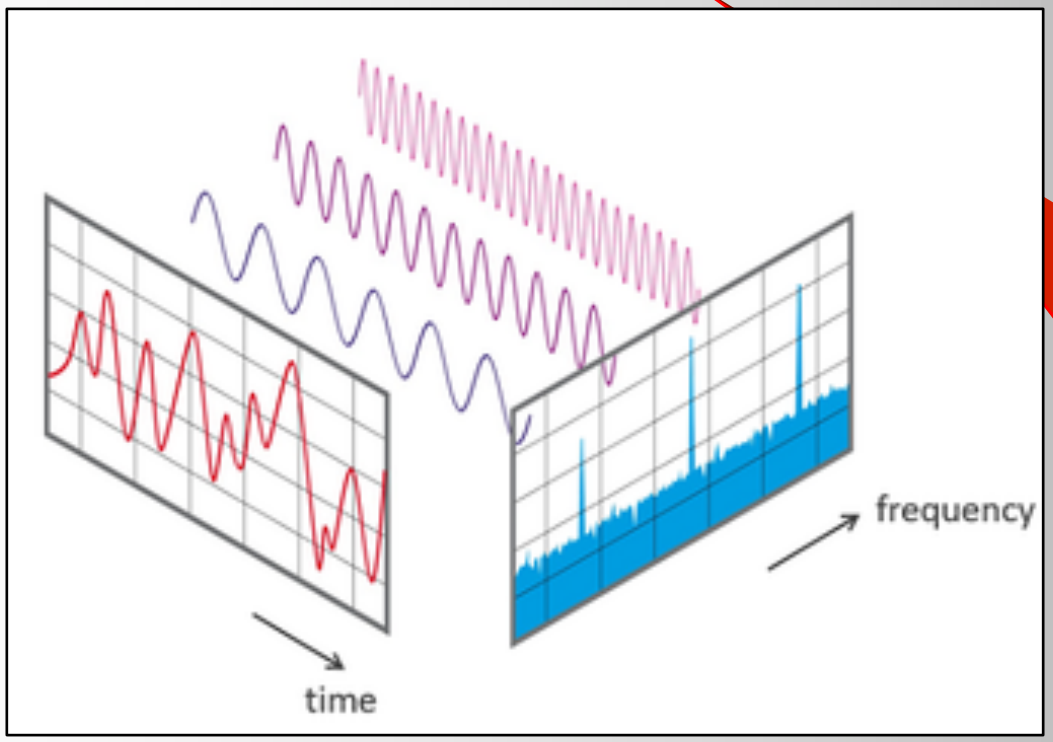
Fast Fourier Transform



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Catalyst Data

2017 Catalyst Data					
Mode	RPM	Torque (ft lb)	HC (ppm)	CO (ppm)	NO_X (ppm)
1	6150	30.5	7.75	805.56	1587.64
2	5200	20.0	0.00	648.83	723.17
3	4650	13.5	0.49	224.41	124.66
4	4000	8.0	152.38	829.41	18.69
5	2000	1.0	65.44	370.58	26.16

2018 Catalyst Data					
Mode	RPM	Torque (ft lb)	HC (ppm)	CO (ppm)	NO_X (ppm)
1	6150	30.5	0.00	478.57	1588.52
2	5200	20.0	0.00	559.04	392.20
3	4650	13.5	1.18	0.00	105.92
4	4000	8.0	0.00	725.00	12.78
5	2000	1.0	0.00	5.95	29.17