

Innovating for Clean & Quiet Snowmobiles: Michigan Tech SI Design Strategy for 2019



Presented by Josh Carpenter & Liam MacGillivray

Presentation Agenda

- Primary Innovations for the 2019 MTU SI Snowmobile
- Team Management and Structure
- Chassis Noise Reduction Strategy
- Emissions Reduction Strategy
- Exhaust Noise Reduction Strategy
- Overall Snowmobile Performance & Summary
- Questions



Basis of 2019 MTU SI Snowmobile Entry

- **2016 Yamaha RS Venture**

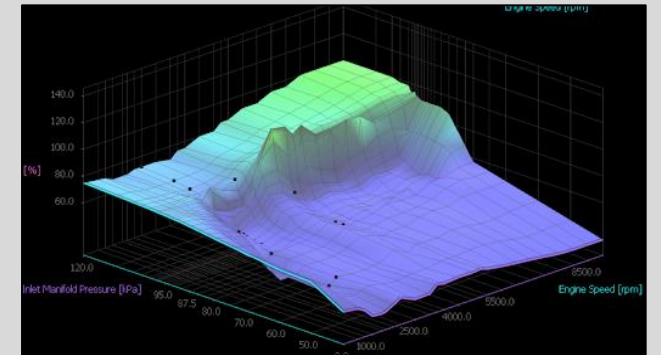
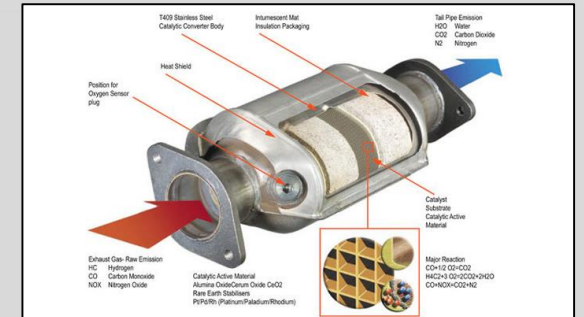
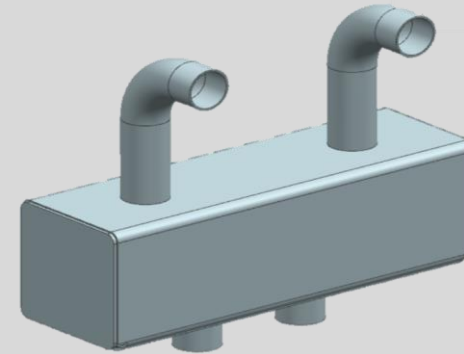
TF BAT

- Engine: 1049cc Yamaha Genesis
- Four-Stroke
- Liquid Cooled
- 3 Cylinder
- Track: Ported Camso Crossover
 - 151" x 15" 2.52 pitch



2019 MTU Spark Ignition Snowmobile Primary Innovations

- Tunnel vibration damping plates located at tunnel resonation area
- Stoichiometric engine calibration for low emissions & high performance
- Advanced & data-focused catalytic converter selection
- Custom secondary muffler for reduced sound levels
- Retains innovative quarter-wave intake & exhaust resonators from 2018



Team Management and Structure

- Members of the team are part of the MTU Enterprise Program
- Three sub-teams: Chassis Team, Engine Team, and Business Team
- The team is led by an executive board
 - The executive board is led by one team president and a member from each sub-team and works in conjunction with our CI team
- Team members complete their senior design projects for the team
- All members receive academic credit for engineering & design work on the team



Chassis Noise Reduction Strategy

- Chassis noise reduction: primary noise related focus in 2019
- Track & engine firing frequencies identified through sound testing
- Impact testing and modal analysis indicated tunnel excitation and resonance due to track frequencies
- Tunnel vibration damping plates added in areas of high tunnel resonance
- Damping plates reduced noise in the loudest frequencies by 3.5 dBA on average

Mode Shapes at Track Frequency of 982 Hz



Tunnel Vibration Damping Plate

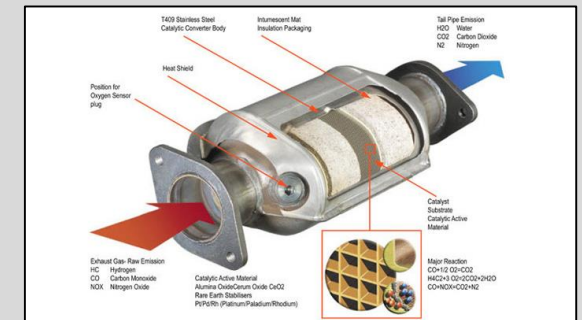
Chassis Noise Reduction Strategy

- Additional chassis noise reduction innovations for 2019:
 - Replaced steel torque arm guides with rubber wheels
 - Isolated exhaust header mounts from tunnel (hard-mounted to tunnel from factory)
 - Increased sound deadening material (Soundown Mass Loaded Vinyl) in panels to reduce escaping clutch & chain case noise



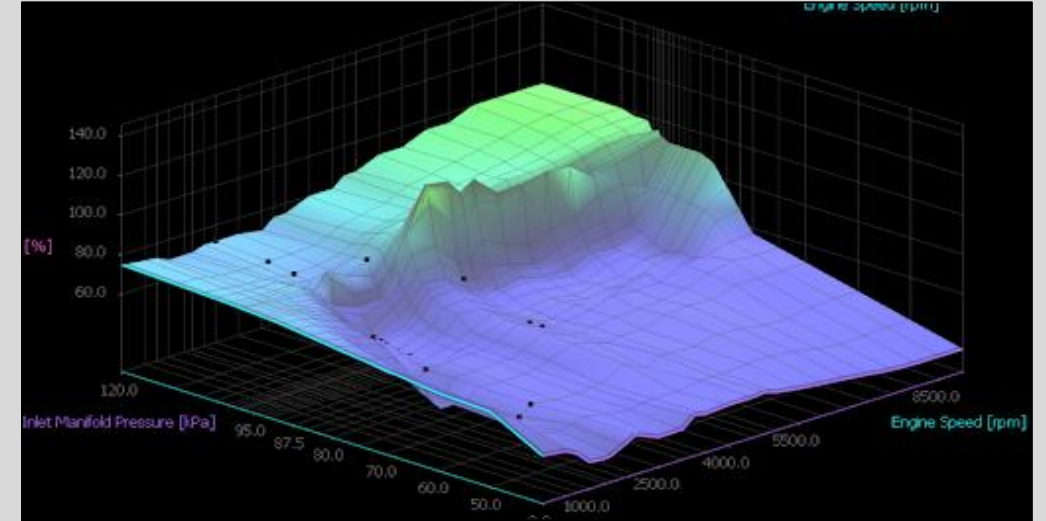
2019 Emissions Reduction Strategies

- Focused on data-driven testing for engine calibration and aftertreatment selection
- Organized, iterative engine calibration process with Motec M1 Tune and M130 ECU
- Development of a complete emissions measurement system capable of measuring and calculating E-Score for every iteration of engine calibration and aftertreatment
- Closed-loop fueling constantly targets lambda 1.00 for precise control of both transients and steady state operating conditions



2019 Emissions Reduction Strategies

- Calibration process
 - Speed density calibration – RPM and MAP
 - Fueling (injector open time) and ignition (spark timing) adjusted for every engine operating condition across entire map
 - 2019 engine calibration targets a stoichiometric burn (lambda 1.00)
 - Each major calibration change verified on-snow and on-dyno
 - Wideband O2 sensors for each cylinder (dyno)
 - View MAP, RPM, ethanol content, lambda on snowmobile display
 - Calibration and aftertreatment tested for emissions performance



2019 Emissions Reduction Strategies

- Verification of emissions levels & performance
 - Major advance of 2019 was implementation of fuel flow meter with Horiba 5 gas analyzer & E-Score calculation ability
- MTU SI team used E-Score calculation ability to determine an optimal catalytic converter
- Three custom catalytic converters from V-Converter tested against a Magnaflow catalytic converter
 - Specific emissions of CO₂, CO, NO_x, and HC measured for each catalyst
 - Data used to calculate E-Score for each and choose best performing catalyst

Specific Emissions for Magnaflow 337304			
HC (g/kW-hr)	CO (g/kW-hr)	CO ₂ (g/kW-hr)	NO _x (g/kW-hr)
0.10	13.17	1329.15	1.05



205.9

Specific Emissions for V-Converter 22889-4			
HC (g/kW-hr)	CO (g/kW-hr)	CO ₂ (g/kW-hr)	NO _x (g/kW-hr)
0.14	19.36	1326.81	0.10



205.0

Specific Emissions for V-Converter AMX97-33			
HC (g/kW-hr)	CO (g/kW-hr)	CO ₂ (g/kW-hr)	NO _x (g/kW-hr)
0.06	15.94	1331.13	0.04



205.9

Specific Emissions for V-Converter TEX0587			
HC (g/kW-hr)	CO (g/kW-hr)	CO ₂ (g/kW-hr)	NO _x (g/kW-hr)
0.22	23.07	1321.89	2.30



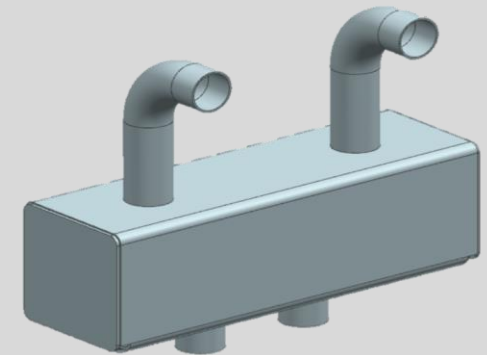
202.5

Calculated E-Score
(87 octane E8%)



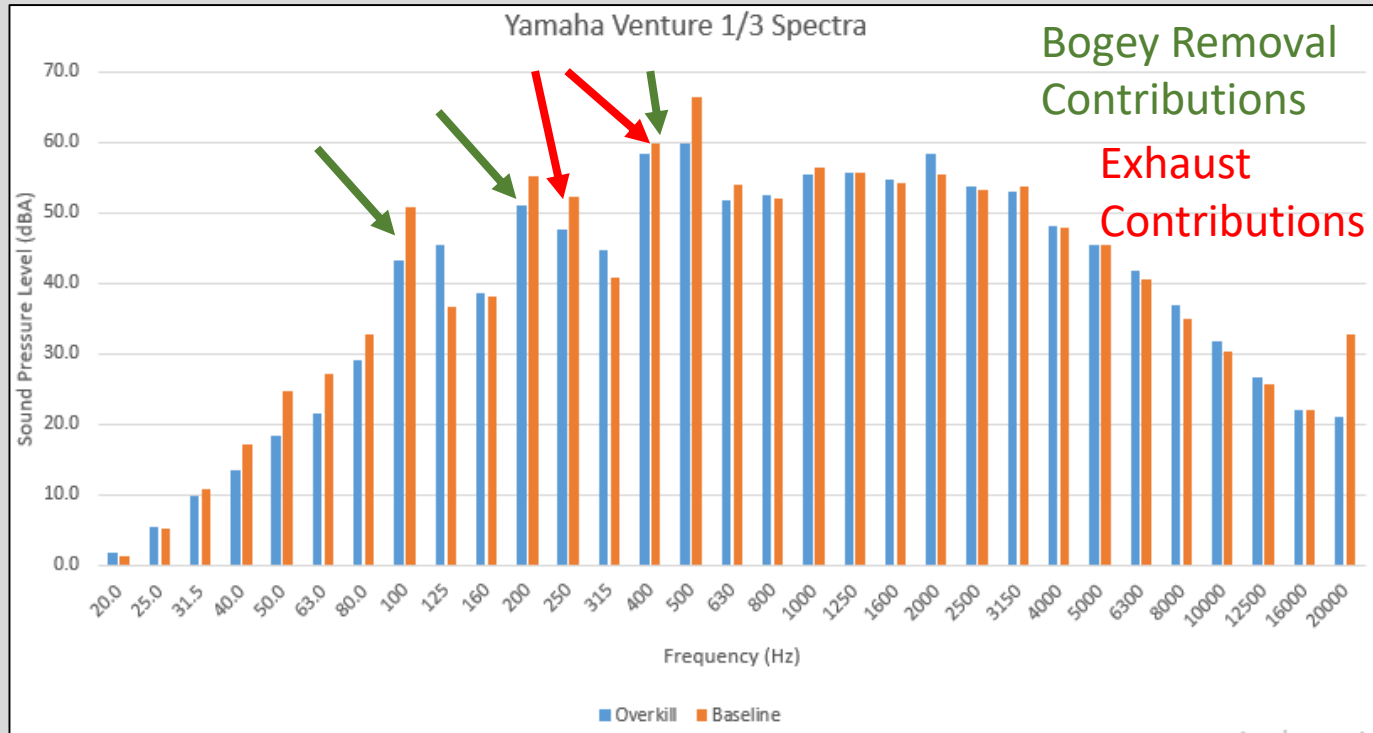
Engine Noise Reduction Strategy

- “Overkill” exhaust & intake (max volume) from 2018 testing indicated that increased exhaust volume would reduce noise levels
- Secondary muffler added after OEM dual-outlet muffler
 - Dual entry, dual exit
 - Filled with fiberglass four-stroke exhaust packing
- Secondary muffler redirects exhaust downward into the snowpack to reduce sound
- 2019 SI snowmobile retains intake and exhaust resonators targeting 265 & 397.5 Hz (3.1 & 2.4 dBA reduction respectively)



Engine Noise Reduction Strategy - Testing

- “Overkill” exhaust & intake from 2018 testing indicated that increased exhaust volume would reduce noise levels: reductions in noise in 250 and 400 Hz bins. Also removed bogey wheels based on findings.



Overall Snowmobile Performance & Cost

- The 2019 MTU SI Snowmobile entry is designed to be a clean, quiet touring snowmobile for increased rider comfort and reduced environmental impact
- Engine Performance: 58 HP, 37 lb-ft torque (8200 rpm)
 - Increase of 24 HP over factory BAT low emissions & sound configuration
 - Designed to be cleaner and quieter than low-emissions snowmobiles on the market today while maintaining enjoyable trail performance.
- MSRP of \$17,137



Image Credits:

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S4 & 8 (catalyst): newroads.ca

S7 (ECU): rywire.com

S9 (Dyno): mickpeterson.org

All other photos by MTU Clean Snowmobile



Questions?