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GM Collaboration Powertrain Efficiency Programs

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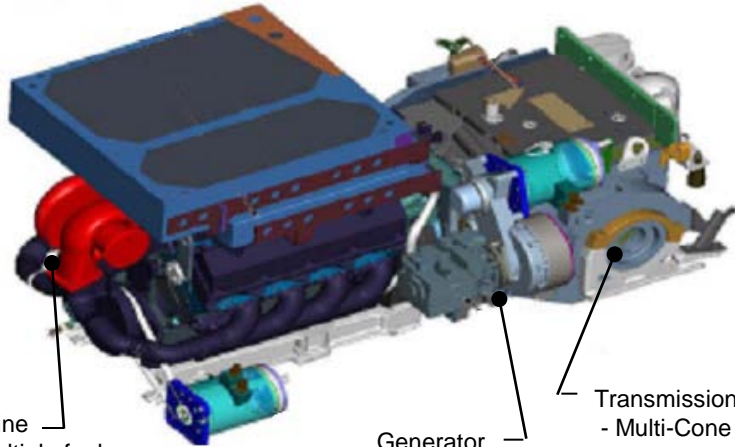
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Engine
- Multiple fuels
- Integrated Controls
- Noise abatement

Generator
- Hardware
- Controls

Transmission
- Multi-Cone clutches
- Wide-spread, equally progressive gear ratios
- Low parasitic oil mgmt.
- Variator technologies
- Integrated controls

Payoffs:

- Improved vehicle mobility performance.
- Dramatically more electrical power available to meet future vehicle equipment demands.
- Improved engine power density on logistic fuel.
- Quieter engine idle to reduce vehicle acoustic signature during silent watch/mounted surveillance missions.
- Transitions to follow on ATO-D which will provide TRL 6 efficient powertrains to PM customers (HBCT, SBCT) by FY17

Purpose:

Provide efficient, reliable powertrain technologies that will improve the energy productivity of existing military ground vehicle engine-transmission while using less space, improving vehicle mobility, fuel consumption and reducing thermal load.

Products:

- Highly integrated, fuel efficient powertrain achieving a TRL 5.
- Next-generation, binary logic based transmission technologies improving energy productivity and lowering system parasitic losses.
- Innovative engine controls that will seamlessly adapt to a range of military fuels with no power degradation.
- Electrical power generation sources integrated into the powertrain to provide enough power for all planned future non-mobility power demands
- Acoustic signature reduction technologies to quiet main engine at idle to address future silent watch requirements.



3 BAA Topics for Powertrain Systems

- 7 to 9 ton
- 15 to 19 ton
- 20 to 40 ton

Program Metrics

Engine

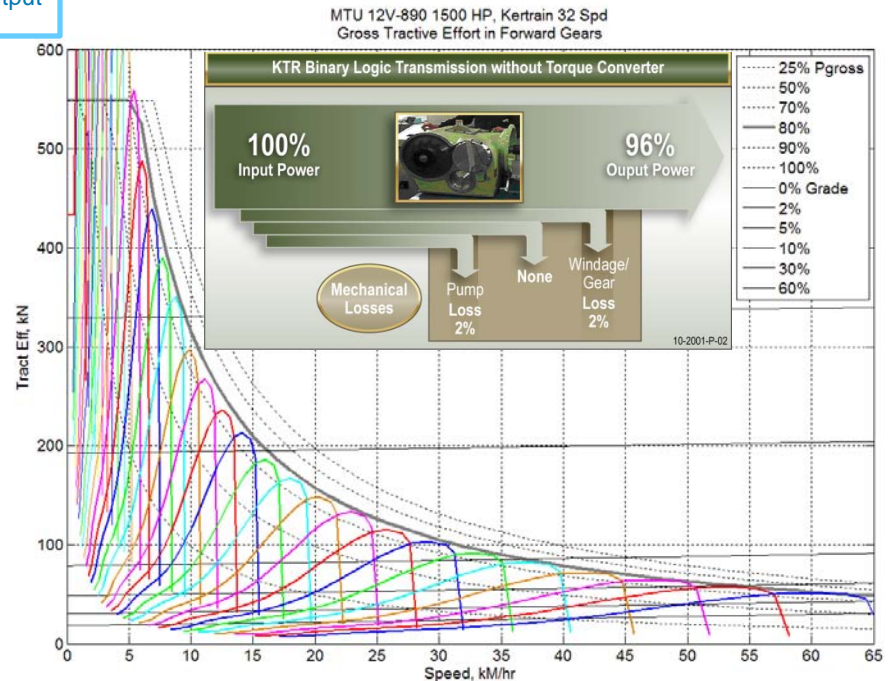
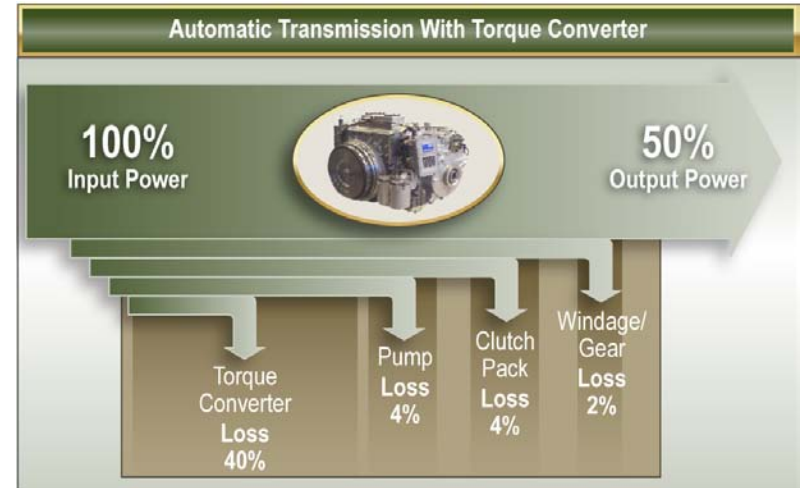
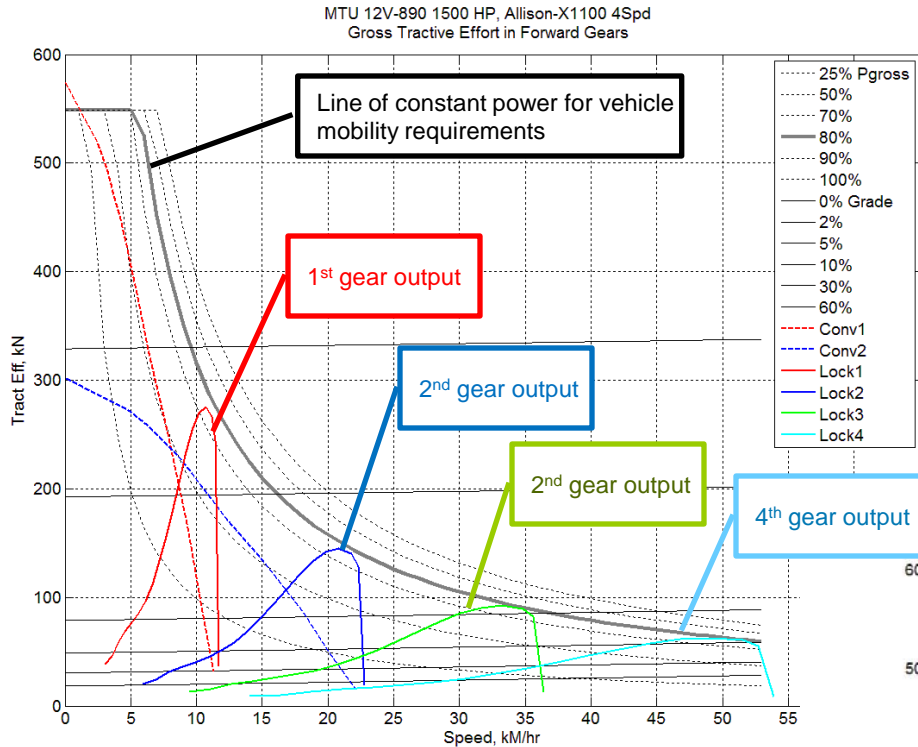
Thermal Efficiency	44% or greater
Heat rejection	0.6 kW/kW or less
Emissions	No Aftertreatment nor EGR; must conform to 1998 emissions standards
Power	150 to 300 Hp
Fuel Compatibility	DF-2, ULSD, JP-8, JP-5, Jet-A, and mixture

Transmission

Configuration	Automatic Longitudinal or Cross Drive (20-40 ton)
Ratio spread	Greater than 10.0
Transmission Efficiency	90% or greater

Generator

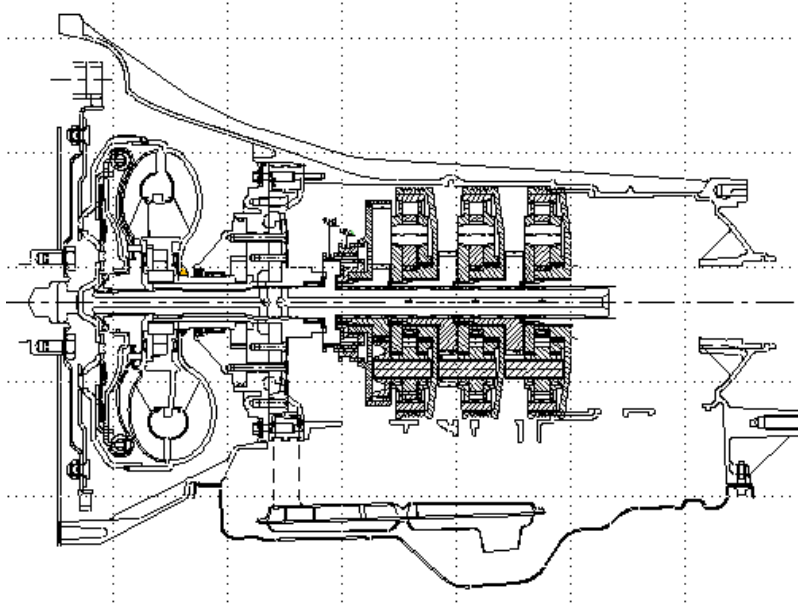
Electrical Power Generation	85kW continuous	150 kW (20-40 ton)
Generator Output Voltage	350 – 600 Volts DC	



The Binary Logic Transmission features:

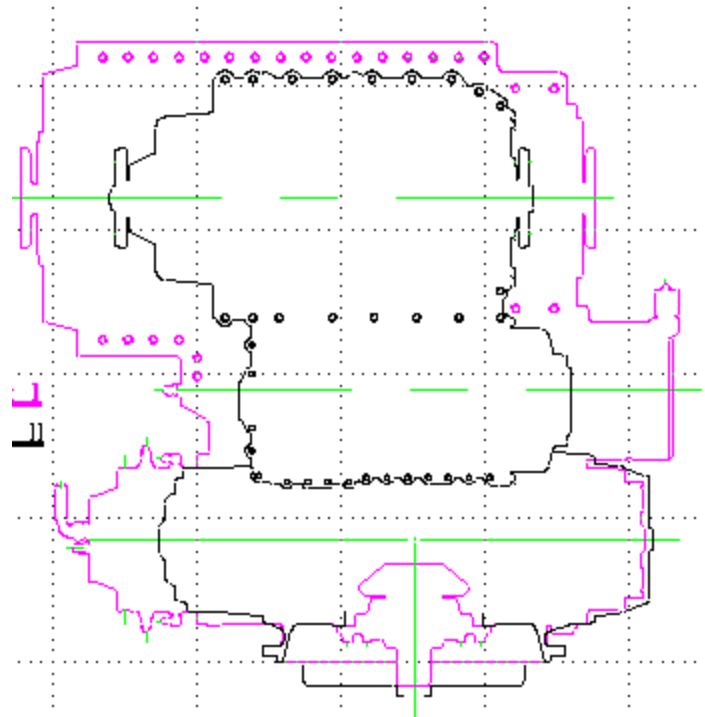
- Eliminating the torque converter
- Utilizes multiple gears in various combinations to achieve the desired gear ratio for maximum efficiency, 20:1 to 100:1 or more
- High efficiency, > 90%
- Enables optimum engine performance and efficiency
- Reduces cooling requirements
- 30-40% less volume/size, weight and parts

- Incrementally Variable Transmissions
- Infinitely Variable Transmissions
- Launch Clutches
- Torque Converters
- Transfer Cases
- Controls Strategies
- Clutch systems
- Differentials
- PTO Gearing



Longitudinal Application

Cross Drive Application



- Substitute for a planetary gear set
- Specifics in size and through torque is twice that of a planetary
- A 50/50 torque split differential is achievable
- Different DP's between the Pinion/Cluster and Cluster/Annulus is achievable
- High tooth contact
- Quiet operation
- Reduced gear tooth speeds
- Patented addendum contact tooth profile



Binary Logic Transmissions

- 32 forward and reverse speeds with only 5 gear sets
- High tooth contact ratio (up to 16)
- No torque converter
- Reduction ratio 20:1
- High efficiency, > 90%
- Precise mechanical steering, no slippage
- Electronic Shift Control
- Reduced cooling needs

Variator Advantages:

- High Efficiency (+94%) throughout range
- Full engine braking
- Smaller package
- Reduced Weight
- No horsepower restrictions (scaleable design)
- Full range from 0 to ± 1
- Adaptable to fit existing transmission envelopes

Efficiency Curve Trends:

