

Off-Highway Equipment Efficiency and Productivity Improvements

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Industry demands for Continuous Improvements



Economic and **world growth** drive off-road **equipment demand**



Businesses that utilize this equipment have strong drivers to stay competitive by **reducing owning and operating costs**



Social / environmental responsibility pressure



Availability of **skilled machine operators**



Need for increased **productivity** and **efficiency** – **TCO improvements**



Demand for developing **technologies** and **methods** for continuous Off-highway improvements

Strategies for Efficiency & Productivity Improvements



Product optimization

- Continuous improvement in component performance
- Highly integrated machine subsystems



Efficient equipment operation

- Applying machine technology enabled solutions
- Deploying operator assist features



Efficient intelligent machines + site solutions

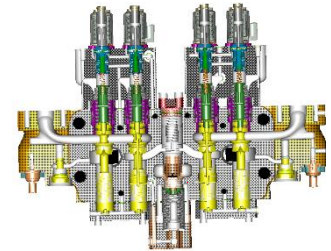
- Operator coaching
- Connected assets and autonomous technology
- Comprehensive site solutions

Product Optimization via Components and Systems Improvements



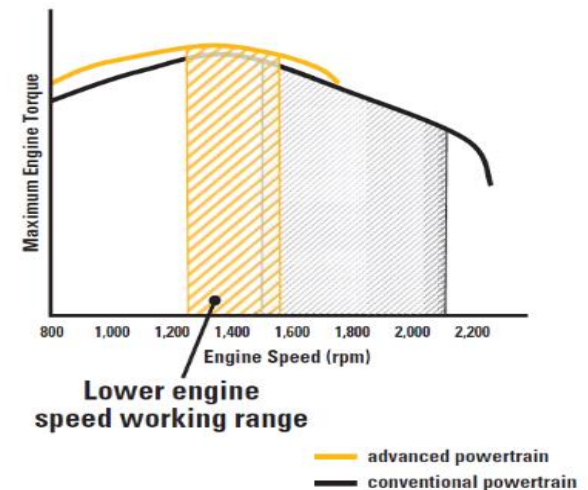
- **Component performance improvement**

- More efficient and programmable valves
- Electronic Programmable Pumps
- Continuous Variable Transmissions (CVT)
- Hydrostatic transmission, etc.



- **Highly integrated machine subsystems**

- Programmable hydraulic systems
- Efficient and integrated drivetrain systems
- EH steering and brake systems
- Energy recovery and reuse systems
- Engine downsizing with peak shaving
- Engine speed and power management strategies



Highly Efficient and Integrated Systems (336 EH Hydraulic Hybrid Machine)



Hybrid Excavator Technologies:

- **Conserve**
 - *ESP pump*
 - *Lower engine speed (1500 rpm)*
- **Optimize**
 - *Adaptive Control System with IMV*
- **Reuse**
 - *Hydraulic hybrid system*



Efficient Equipment Operation



CAT® Grade with Assist (CGA)

- Operator assist feature for HEX enabling **productivity** and **efficiency** enhancement for less skilled operators and experts due to fatigue elimination.



Efficient Intelligent Machines and Site Solutions



Operator coaching tools and technologies:

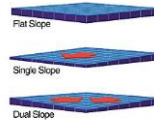
- help minimize number of machine cycles
- provide instantaneous operator feedback



Example: Payload Monitoring technology

Site solutions for productivity and efficiency improvements

- Technology that combines:
 - 1) digital site design data
 - 2) in-cab operator guidance
 - 3) automatic machine implement adjustments



Cat ACCUGRADE™ Laser Grade Control gains:

- ~ 40 % fuel savings
- ~ 90% lower site surveying cost
- ~ 50% less time to complete identical job



Connected Assets and Autonomous Technology



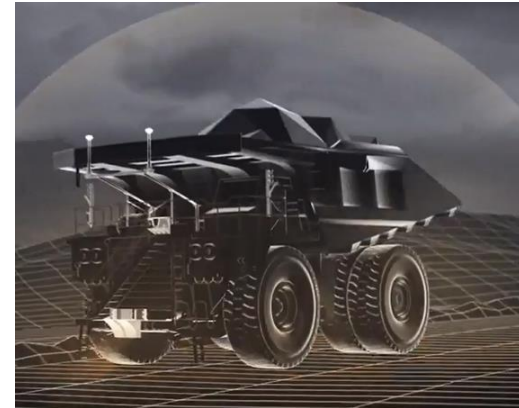
Cat Connect: uses data from machines to:

1. Measure payloads and cycle times
2. Optimize production @ construction & quarry site
3. Reduce loading and hauling costs



Cat MineStarTM - lowest cost/ton of material moved through:

1. Mine site optimization for productivity improvement
2. More *efficient equipment management* and *better uptime*
3. *Autonomous technology* that minimizes interruptions



Summary

- Methods and technologies for **efficiency** and **productivity** improvements:
 - Components and system improvements
 - Deep subsystems integration and energy recovery and reuse
 - Intelligent machine technologies
 - Operator assist and coaching features
 - Connected assets, autonomy and suite of site solutions
- Solutions that **minimize energy** and **time** to complete a job
- “**Inside the machine**” and “**Outside the machine**” solutions
- Developed with **focus** on **sustainability** and **environmental** responsibility