



# Efficiency in the Field

Regular gear shifts are becoming rare in modern tractors. When Valtra's Direct tractors work the fields, their continuously variable transmission (CVT) keeps the optimum speed range to increase fuel economy and efficiency.

To find the optimum CVT, Valtra requested the Technical University Tampere, Finland, to evaluate the CVTs available on the market. The university team used a newly developed static calculation model to visualize the attributes of various CVTs as a tractive force/speed diagram. They also looked at the efficiency of the hydraulic converter in relation

to overall efficiency, calculating the pressure level of the hydrostatic converter, and the torques and speeds of all rotating parts. Thus it was easy to compare the attributes of the different gear constructions. The research showed that no CVT completely fulfilled Valtra's high demands, so Valtra decided to develop its own.

#### CVT Requirements





Valtra identified the following requirements for a high-performance, high-efficiency CVT:

- Robust design
- Easy operation
- Various adjustment and control options with automatic help functions
- Minimal changes to Valtra's existing transmission concept



Continuously variable transmission with power-split driveline for more power and lower costs

Figure 1: In Valtra's Direct tractors, the ideal work area for the task at hand can be selected. The speed range for each begins at 0 km/h and offers stepless speed adjustment, even in reverse.

				
	<b>Work Area A:</b> Heavy pull/ special crop	<b>Work Area B:</b> Field work	<b>Work Area C:</b> Fast work	<b>Work Area D:</b> Road transport
<b>0-9 A</b>	For the heaviest work, like low speed tillage or special crop harvesting. Ideal when maximum pulling force is needed continuously, or when the most precise speed adjustment is required. Extremely high pulling forces with power take-off (PTO) driven trailers.	Universal field work range. Ideal from seeding and faster tillage to various forage operations. Easy control of different operations (like harvesting speeds) essential. Also suitable for work such as transport through forest.	Ideal for transportation across fields. Suitable for many local services. Efficient start-up with heavy loads.	Ideal for road transport at high speeds.
<b>0-18 B</b>				
<b>0-30 C</b>				
<b>0-50 (40) D</b>				
0 km/h 50				



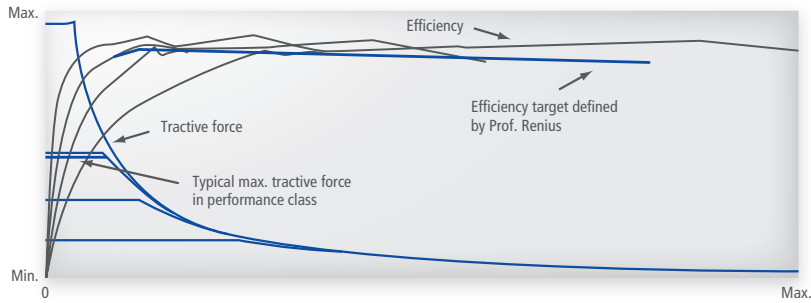


Figure 2: Full-load transmission efficiency. The achieved efficiency meets the target defined by Professor Karl Theodor Renius. Professor Renius was a professor for agricultural machines at the Technische Universität München, Germany, with an international reputation for his contributions to tractor research and technology transfer and his role in agricultural engineering education.

“Using the dSPACE HIL simulator meant that we had the freedom to consider all the possible variants.”

Ville Viitasalo, Valtra Oy

- Cost-effective production and operation
- Suitability for arctic conditions
- Long service life
- Easy maintenance

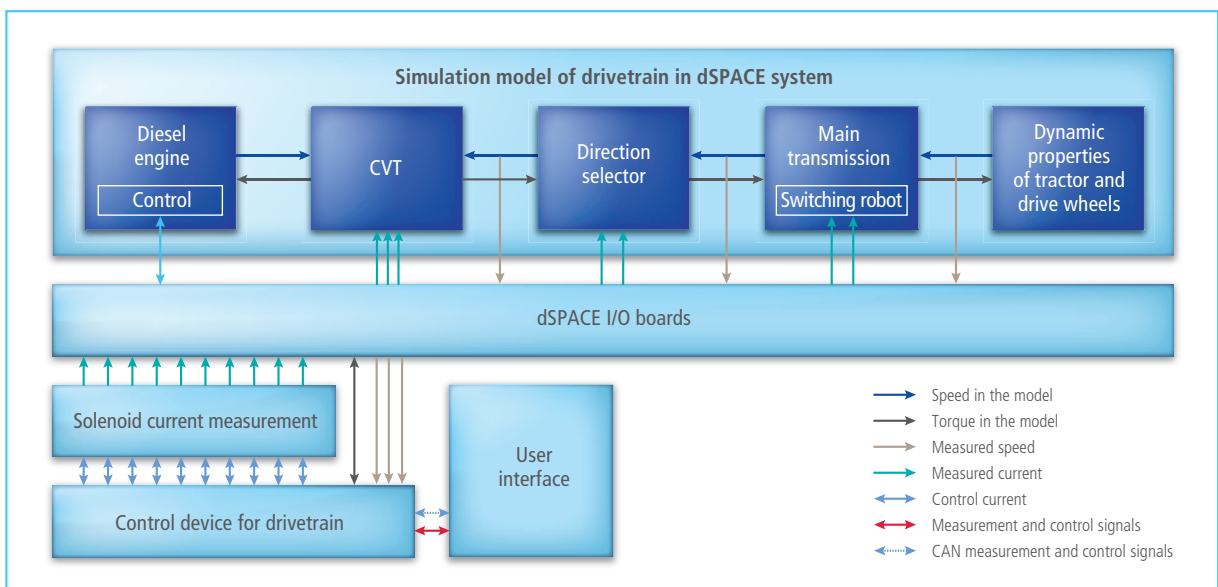
The best solution out of hundreds of possible variants was selected with the help of the static calculation model.

#### Different Driving Strategy for Each Work Area

Valtra analyzed tractors’ different operating modes and developed an optimum driving strategy for each work area. All driving strategies start at 0 km/h and accelerate continuously until they reach the maximum speed. The CVT consists of a

power-split driveline which has been fitted with a Linde Hydrostatic Drive. Shifting between the different work areas is done via a multi-plate clutch. A powershift direction selector makes smooth start-up and change of direction possible at driving speeds less than 10 km/h in work areas A and B. The main gears for all work areas can be selected at the touch of a button and the actual gear change is performed by a robot. The selected drive design achieves optimum efficiency for each work area and fulfills the efficiency target defined by Professor K.T. Renius (figure 2).

Figure 3: The dSPACE HIL system supports Valtra in testing control algorithms for the CVT.



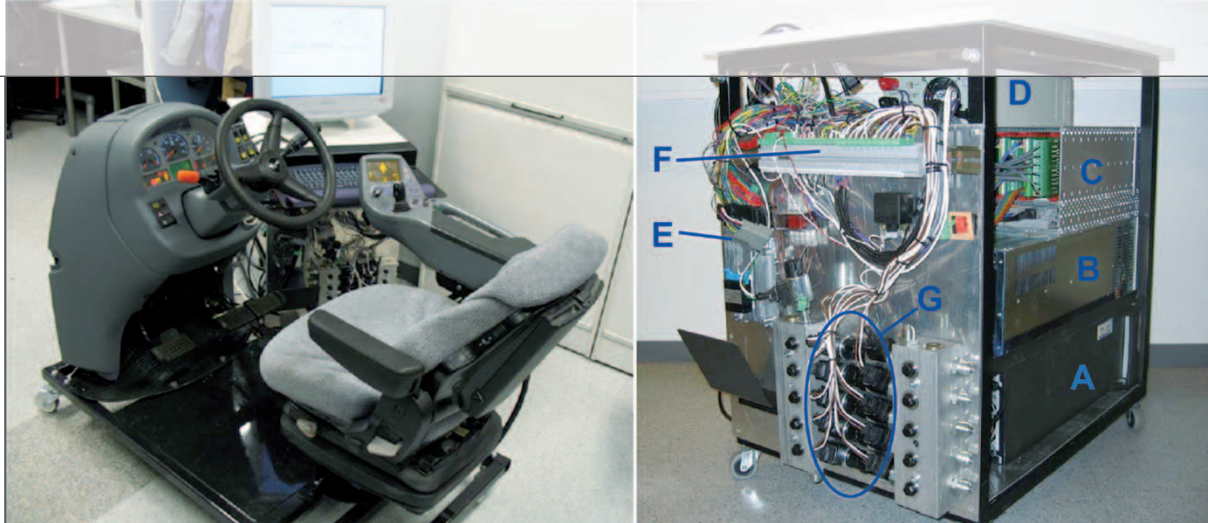


Figure 4: HIL user interface and system (A – PC, B – dSPACE AutoBox with processor and I/O boards, C – transformer, D – power supply, E – drivetrain control, F – connector strip, G – solenoids).

“This project has shown that cooperation between university and industry can produce excellent results.”

*Dr. Mikko Erkkilä, Technical University Tampere*

### Developing the CVT Control with HIL Simulation

To develop the drive control for the new CVT, a dynamic drivetrain model was created, covering everything from the diesel engine to the pulling tractor wheels. Valtra built a hardware-in-the-loop (HIL) system based on this dynamic model and used it to develop the control algorithms and program the drivetrain control.

The HIL system consists of a dSPACE processor board that runs the simulation model and several dSPACE I/O boards. The control signals are measured and converted to digital values to control the simulation model. Some control and measurement signals are transmitted through the CAN bus according to the SAE J1939 standard. The HIL simulator makes it possible to test the control device

under realistic conditions at the developer’s desk. Errors and hazardous situations can be checked extensively to improve the control’s safety. ■

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#### *Dr. Mikko Erkkilä*

*Dr. Mikko Erkkilä wrote his dissertation “Modeling and Simulation of CVT Drive Lines” at Tampere University of Technology in cooperation with Valtra Oy. He is now technology coordinator at Hydac Oy in Vantaa, Finland.*



#### *Ville Viitasalo*

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## Conclusion

The static calculation model is a powerful tool for developing new transmission and drivetrain concepts. Simulation-aided design tools plus steady-state, dynamic and HIL simulation models all make it possible to reduce design time and cost. More time and effort can then be used for virtual and field testing, and for increasing the functionality and reliability of the machines. Cooperation between university and industry went well. The meeting of practical skills and theoretical knowledge produced excellent results.