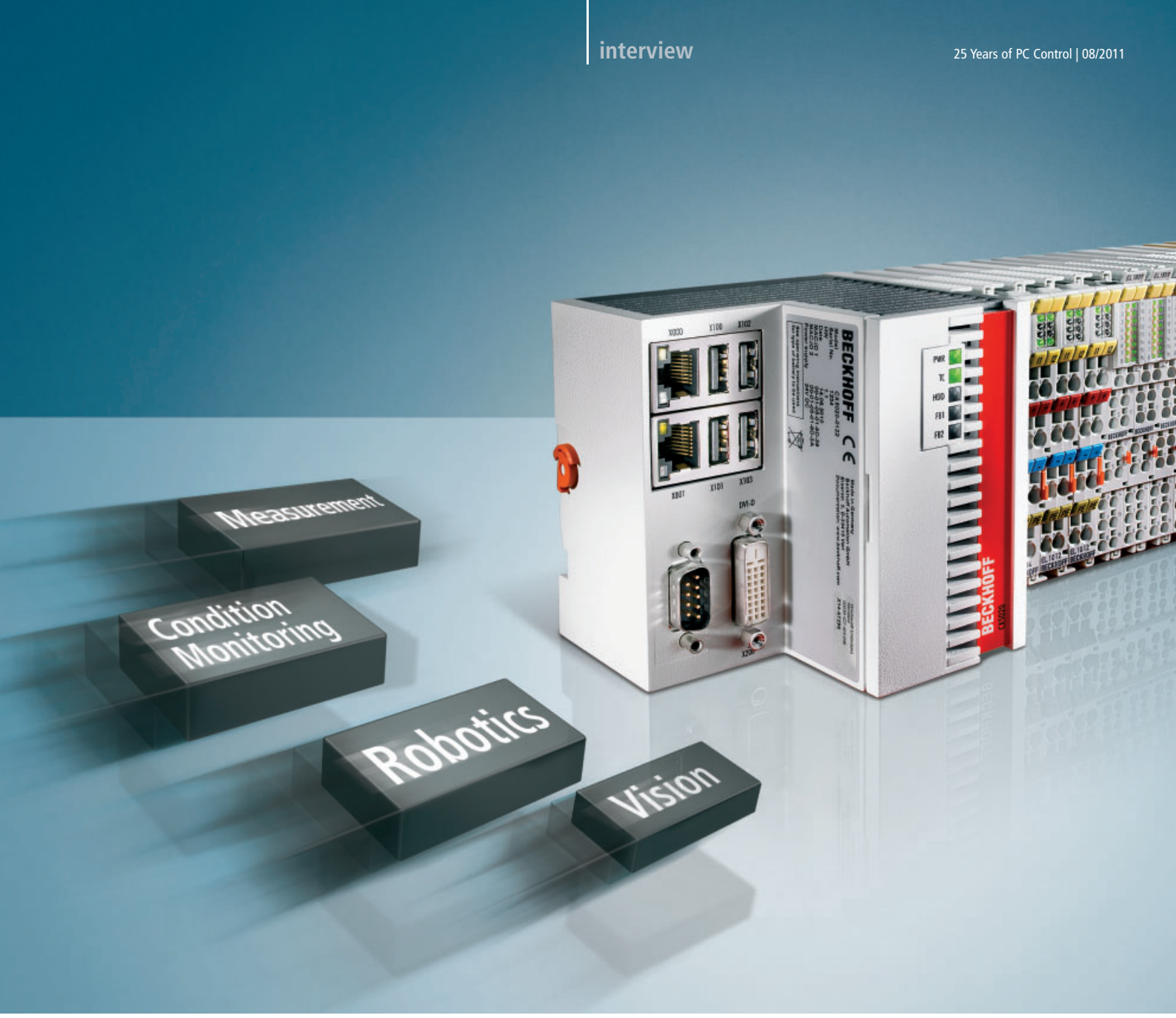
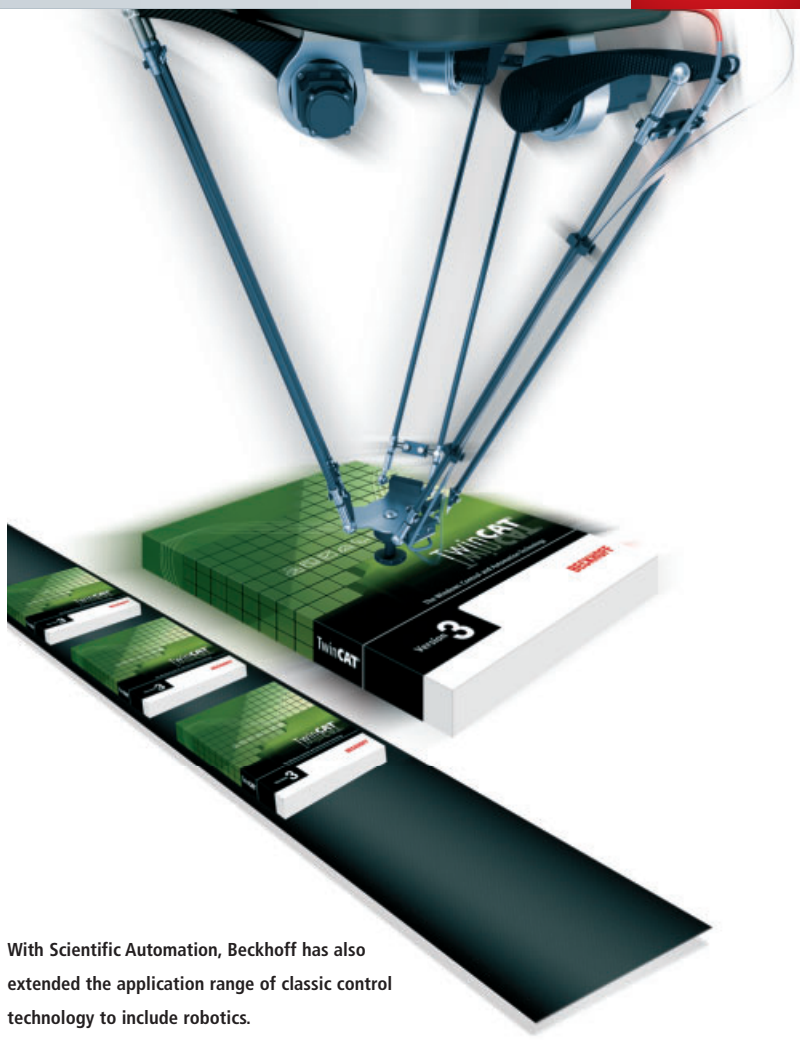


Scientific Automation integrates high-tech special functions into automation

Based on powerful Beckhoff Industrial PCs, the high-speed EtherCAT fieldbus, fast I/O terminals and TwinCAT software, special functions such as high-precision measurement technology, Condition Monitoring and kinematic transformations of robots can be integrated into the PC platform. Beckhoff calls this extension of standard control technology "Scientific Automation" and offers a full solution for it. The range of hardware and software modules is constantly being extended and orientates itself to market needs, explain Michael Jost, Product Manager for EtherCAT and I/O systems, and Dr. Josef Papenfort, Product Manager for TwinCAT, in an interview with the PC Control editorial team.



With Scientific Automation, Beckhoff has also extended the application range of classic control technology to include robotics.

PC Control: With PC-based control, EtherCAT, XFC technology (eXtreme Fast Control) and the TwinCAT software system, Beckhoff has created the important conditions required to achieve Scientific Automation. In which applications is Scientific Automation used?

Michael Jost: The modules from the Scientific Automation solution have established themselves in different industries and in the most diverse applications. You could say that Scientific Automation has "gathered speed" in many areas and has already reached applications, including test bench technology, for example. The primary advantage of our technology is that existing control technology is simply extended with additional software modules or new I/O terminals. With our current offering of measuring terminals, high-end measurement technology functions can already be implemented today with standard EtherCAT Terminals. Frequently requested applications include tasks in the field of Condition Monitoring, such as balancing, and in weighing applications. In addition, independent measuring systems for the monitoring of product quality can frequently be eliminated because the necessary precise monitoring of pressure, temperature, weight, etc. can also be integrated into the control system.

PC Control: Does that also apply to the software aspects?

Josef Papenfort: The software range is involved to the same degree. The areas of application are broadly diversified, from Condition Monitoring to the integration of robotics on the central PC. The general philosophy of Beckhoff is to implement as much as possible in software. To this end, the I/O modules are usually implemented as simply as possible and supply the raw data for the PC controller. The raw data can now be analyzed in the software. The PC is ideally suited to this. The high performance, due among other things to the constantly available floating point unit, allows even the most complicated algorithms to be calculated in real-time.

PC Control: Are the Scientific Automation applications mentioned selective tasks or is a broadly-based trend recognizable?

Josef Papenfort: A broad trend is by all means observable, and we are continually expanding our range of products in accordance with the needs and wishes of our customers. In addition to the standard software blocks, we focus on specific tasks in the development of applications for Scientific Automation. That is also the case in the field of robotics, a very current area of development where we concentrate on various tasks with regard to the kinematics.

PC Control: Beckhoff offers numerous software libraries for TwinCAT. Which libraries are specifically aimed at Scientific Automation?

Josef Papenfort: Our TwinCAT software has a modular structure and can be assembled or extended in accordance with a "construction kit" principle. It is supplemented with a set of libraries and so-called supplements. Let's take the control technology supplement, for example. With the TwinCAT Controller Toolbox, the most complicated controller structures can be simply assembled and executed in the shortest cycle times. The Kinematic Transformation library permits the control and regulation of robots with different kinematics. Simple configuration and programming in TwinCAT are further advantages here. The most important aid with all Scientific Automation applications is the TwinCAT Scope 2 solution. It enables the recording and display of different signals even at sampling rates in the 100 KHz range. We have developed a software library for Condition Monitoring which is used in various applications, for example for drilling machines and balancing. We presented such an application for balancing at Hannover Messe 2011, which met with great interest among the trade show visitors.

Michael Jost: "With our EtherCAT Terminals we can acquire raw sensor data with high precision at up to 100,000 samples/s (analog) or 1,000,000 samples/s (digital) via distributed clocks. The data is evaluated on the central PC."

Michael Jost, EtherCAT and I/O systems Product Manager, Beckhoff Automation

High-end measurement technology

PC Control: In the range of I/O terminals there is already appropriate measuring hardware for several physical variables. Which physical variables are still not covered or what do the customers need?

Michael Jost: Our I/O systems with IP 20 and IP 67 protection cover almost all standard signals. In the field of standard measurement technology we offer I/O function blocks for the measurement of current, voltage, temperature, frequency, position or pressure. We understand Scientific Automation more as high-end measurement technology with terminals for high-speed or high-precision measurements as well as energy or mains monitoring. In addition, the complete range of XFC terminals enables us to record raw sensor data with high precision at up to 100,000 samples/s (analog) or 1,000,000 samples/s (digital) via distributed clocks, for example using the oversampling method. There have been numerous inquiries for new developments, for example, for special sensor interfaces for the measurement of pH values. In the field of test bench technology in particular there are requirements aimed at implementing the entire test bench as far as possible with a single system. Reasons frequently given for the employment of the Beckhoff system are, on the one hand, the scalability of the hardware (12-, 16- and 24-bit analog modules) and, on the other, the openness of the hardware and software interfaces.

High-precision temperature measurement and signal detection in Miele quality assurance

PC Control: The EtherCAT Terminal system has been supplemented in recent years with numerous terminals in the "high-precision measurement technology" category. How does Beckhoff define the term "high-precision?"

Michael Jost: As an example, one can describe the EL3602 ±10 V analog input terminal with an accuracy of 0.01 % as highly precise in comparison with standard terminals with a measuring error of 0.3 %. Where thermocouples are concerned, we compared the precision and examined the usual measuring error accuracy for this. The result was that we are already very good with our standard terminals compared to other automation suppliers. In high-precision temperature measurement technology we are even better by orders of magnitude and can compare ourselves with leading suppliers from the field of measurement technology. With the recently introduced EL3314-0010 thermocouple terminal in particular, we are approaching the limits of the accuracy attainable with this sensor technology. For certain customers from the semiconductor and solar industry, the accuracy of temperature measurement and control is a decisive criterion for process control. The temperature has a direct influence on the product quality. The PT100 temperature measuring terminal has been in our portfolio for some time. The high-precision variant, the EL3201-0020, with a calibration certificate and a measuring error of < 0.1 °C, is used in industrial applications as well as in research.

PC Control: High-precision I/O terminals are also available for resistance measurement and for the evaluation of resistor bridges. Where are the areas of application here?

Michael Jost: The EL3692 EtherCAT Terminal was developed for the high-precision measurement of resistances in both the mΩ and MΩ ranges. It has different measuring ranges and thus makes a wide application area possible. Its classic area of application is the test bench; for example, one of our customers uses this terminal to measure seat heaters in the production process. These heaters must have a certain, specified resistance value. Other areas of application are, for example, the measurement of defined contact resistances at terminal points, plugs and wiring harnesses. In other development areas, in particular in weighing technology, Beckhoff offers in the EL3356-0010 EtherCAT Terminal. This terminal provides a resolution of 24 bits and a fast conversion time of 100 µs, offering many application possibilities on the basis of numerous customer inquiries. One example is the dynamic measurement of torque. The advantage for our customers is that they have integrated weighing equipment in their machine and don't need additional hardware and software from other vendors.

PC Control: The standard Bus Terminals already have a resolution of 16 bits. The high-end measuring terminals are offered with 24 bits. What are the advantages for the user here?

Michael Jost: The high signal resolution is demanded by some users who are acquainted with metrological systems. In relation to the absolute accuracy, the high resolution does not always appear to be necessary. In many applications, however, it is not the absolute accuracy that is decisive, but rather the relative accuracy; in other words: how good is the possibility to make comparative measurements? The high resolution helps in determining the reproducibility of controllers, in particular if a calibration of the entire measurement chain is additionally carried out, because even slight deviations can be detected.

PC Control: The mains monitoring terminal was presented as a new item at Hannover Messe 2011. What are the highlights of this new development?

Michael Jost: The development of the mains monitoring terminal is a further stage in the extension of our power measuring terminal technology. The idea is to acquire the complete raw data, as far as possible, independently of the PLC cycle. The evaluation then takes place in the software running on the high-performance PC controller. This task can only be solved with the principle of oversampling, which is an integral component of EtherCAT. With the EL3773 EtherCAT Terminal the raw data for voltage and current are sampled synchronously at high speed. The distributed clock function of EtherCAT is used for this. The further analysis steps then take place entirely in software on the PC. One application is the synchronization to the grid of a generator in a hydroelectric power plant.

High-precision temperature measurement in the EtherCAT terminal system: Due to the high basic accuracy the measuring error is reduced to ±0.1 K of the temperature measuring range. The factory calibration is recorded in an individual certificate.

Condition Monitoring

PC Control: A TwinCAT library exists for Condition Monitoring. What functionalities does it offer?

Josef Papenfort: The TwinCAT Condition Monitoring library is a software library that receives raw values, for example, from the EL3632 EtherCAT Terminal. The EL3632 is a special terminal for the connection of vibration sensors. The sensors are connected directly to the vibration measuring terminal with no electrical converters in between. This results in significant cost reductions. EtherCAT is required in order to transport the data into the PC. The TwinCAT Condition Monitoring library is required for the evaluation of the data on the PC. Apart from the classic filtering algorithms such as the Fourier transformation, there is a series of function blocks that perform statistical calculations. Pattern recognition algorithms must filter the relevant information from a large number of data. In principle our CMS solution is independent of the sensor. The main fields of application of this software library are mechanical engineering and wind turbines. PC-based automation from Beckhoff offers the great advantage that the data of all acquired signals are available on the PC. As a result, it is possible to link the data from different signals with one another, i.e. a temperature signal can be combined, for example, with a vibration signal and the loading state of a machine and a corresponding evaluation can be carried out.

TwinCAT Scope 2

PC Control: TwinCAT Scope 2 is a popular and important tool for numerous users. How important is it for Scientific Automation?

Josef Papenfort: TwinCAT Scope 2 is a central tool in Scientific Automation. It consists of two functional units, namely the viewer for displaying the data and the server, which in principle collects the data. Naturally, that can take place on the same PC, but it can also run distributed in the network. The collected data are all provided with highly precise time stamps. The recording of oversampling terminals is also supported accordingly. By activating triggers, the storage of certain important data can be initiated at certain points in time. The openness of the Scope 2 is also reflected by the extensive export interfaces. This way, the data can also be stored, for example, in the CSV format, in order to view it in Excel.

PC Control: If the measuring technology requires a test arrangement with Hardware-in-the-Loop, a calibration of the sensor connection may be necessary. Can TwinCAT Scope 2 be used for this?

Michael Jost: Recalibration is not necessary with standard signals, but it is by all means of some importance in some temperature measuring circuits. As a matter of principle, our measuring terminals offer the customer the option to carry out a so-called customer calibration. Our customers use this function too, both with standard signals, such as ±10 V or 4 to 20 mA, and with the high-precision temperature measuring terminals. In this way, they can match their total measuring circuits and also achieve the necessary accuracy. The subject of calibration is becoming increasingly important for some customers. We already offer terminals which we supply with an additional calibration certificate. This certifies that the individual terminal has the appropriate accuracy. Of course, this calibration procedure is repeated if the customer so wishes. However, the entire measuring circuit is more frequently calibrated together with the sensor. We can imagine a goal for the weighing technology similar to that of the temperature measuring technology.

Multi-core CPUs – the basis for Scientific Automation

Robotics

PC Control: A further field of application for Scientific Automation is robotics. What advantages arise as a result of the integration of kinematic transformations on the central IPC?

Josef Papenfort: The kinematic transformation – or, to put it another way, the control and regulation of robots in software on the same CPU as the "normal" controller runs on – demonstrates the enormous advantages of the Scientific Automation approach for users. On the one hand, the user saves money, since the robot controller no longer has to run on dedicated hardware. Much more is saved in the engineering, however. The robot programmer no longer has to program in the robot language of the robot; instead the PLC programmer takes care of that in the familiar PLC programming languages. In addition, the performance of plants with an integrated robot improves. If the motion controller for a conveyor is processed on the same PC with the same clock speed as the robot, which must synchronize itself to the conveyor, then the delays are reduced to almost zero. TwinCAT Kinematics currently integrates 2-D parallel kinematics, 3-D delta, shear kinematics, SCARA, Cartesian portals, crane and roller kinematics. At present, we are working on the development of the kinematic transformation of six-axis jointed arms or articulated robots. The strategic goal is to control and regulate any articulated robot and to connect this solution module with the standard automation. Our users buy robots from the market and it is our goal to integrate these robot applications in a complete automation solution.

PC Control: One function that is necessary in many robot applications concerns the inclusion of the industrial image processing, for example to enable tracking. Will this be achievable with TwinCAT?

Josef Papenfort: Industrial image processing systems are also already frequently combined with TwinCAT on a PC. That is one of the advantages of an open PC-based control technology. Our customers use these systems for recognition of the positions of parts on a moving conveyor, for example. Another application is the quality checking of products in automatic manufacturing processes. Beckhoff's own solution is on the roadmap and will be presented shortly. Image processing is an important component of Scientific Automation.

Dr. Josef Papenfort, TwinCAT Product Manager, Beckhoff Automation

Dr. Josef Papenfort: "On the basis of Scientific Automation we are able to implement the complete control and regulation of a robot with an Industrial PC or to integrate them into an automation solution and to execute them together in real-time."

PC Control: How important is simulation for automation?

Josef Papenfort: The integration of Matlab®/Simulink® in TwinCAT 3 gives rise to various fields of application, for example in wind energy, in classic mechanical engineering or in plant and process technology. The Matlab®/Simulink® simulation enables the development and optimization of controllers. These controllers are designed for the specific application and optimized, and are then usable at the push of a button, for example, in the PLC. That is one of the possible applications. A further application case is the simulation of a machine or a plant before the installation at the end customer. This way, critical states can be tested before commissioning. The simulation can encompass kinematic and dynamic processes. For example: does a drive manage to reach the intended speed within a certain timeframe? Another simulation concerns the controlling of emergency situations: how does the machine react when an emergency stop button is pressed? How does it come to a stop and is it restarted?

Outlook

PC Control: The basis for Scientific Automation is the constant increase in processor performance. One of the important features of TwinCAT 3 is its active support for multi-core CPUs. What does that mean for the user?

Josef Papenfort: The multi-core technology brings a further boost in performance for PC-based control. Numerous applications require a high degree of computing power. Whereas 10 to 20 axes still moved a machine 15 years ago, the ever increasing degree of automation means that today you can easily find 50 to 100 axes on the same machine. Many mechanical couplings and cam plates are now being replaced by electronic couplings and cam discs. The same applies to controllers. Whereas many dedicated compact controllers were still in use 15 years ago, that is now implemented in software on the central controller today. Of course, Scientific Automation will also contribute to the utilization of the available resources in the future. New processors will have more and more cores and will naturally also be used in the industrial environment. New processor generations will be equipped with 16 or perhaps even 50 cores in the next few years. In order to utilize these, TwinCAT 3 offers the option to distribute functions to the different cores. And the short-term objective, i.e. that of implementing image processing systems in software on the PC, could then be distributed to a number of cores, while the remaining cores execute the PLC or Motion tasks as well as the measuring technology.

PC Control: The Scientific Automation solution is continuously being extended. What is currently on the software and hardware roadmap?

Michael Jost: Naturally I cannot divulge specific future development projects here. In principle we can still do a great deal with the signal variety in terms of measurement, because EtherCAT offers the corresponding possibilities for that. There will be further activities with regard to the signal qualities and new types of signals. Furthermore, we consider that there is still development potential in the areas of speed and resolution.
Josef Papenfort: The release of TwinCAT 3 at SPS/IPC/DRIVES fair in November 2011 is on the software roadmap. In addition to IEC 61131 programming with the object-oriented extensions, C++ support and Matlab®/Simulink® will also be integrated. In TwinCAT 3 we offer a system that is fully integrated into Visual Studio® on the engineering side. Visual Studio®'s plug-in technology is used, and in the future it will offer the option to integrate even more engineering components into the existing environment in a simple manner. We also expect that many modules will be created in the future that will be executed in the TwinCAT 3 runtime.

www.beckhoff.com/scientific-automation