Technology update

MTU helps to fill a new think tank

A new aerospace think-tank has been established in Germany. **Bauhaus Luftfahrt** (Aviation Bauhaus) involves **MTU Aero Engines**, **EADS**, and **Liebherr-Aerospace** and is a non-profit organization created to serve a systems-integrator function and to forge deeper cooperative ties between the research community and industry.

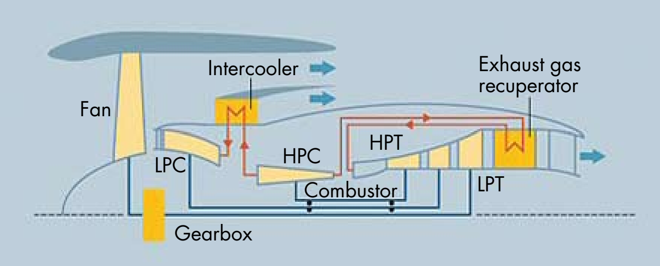
Professor Klaus Broichhausen, former Chief Consultant, Technology Programs at MTU, who chairs the new organization, said that it would bring together engineers, futurologists, designers, and design engineers to facilitate collaboration across their individual disciplines. It will also meld commercial and research competencies.

Broichhausen explained in the MTU publication, *Report*, that the aim of Bauhaus Luftfahrt (named after the **Bauhaus** school of art, design, and architecture), which is based close to **Garching Technical University**, near Munich, was to pursue interdisciplinary cooperative efforts and positive advanced projects but was not to carry out in-depth research or compete with established institutions.

But it will focus on futuristic aircraft construction concepts and take them to application level, optimization studies being paralleled with environmental compatibility and cost-effective analyses. Aims of the integrated research will be to focus particularly on low fuel consumption, noise reduction, and maximum range.

To achieve these aims, the new organization, initially with a staff of 30, has established projects that include a "hybrid airliner" to meet likely future ecological and economic requirements, with what Broichhausen described as optimized individual elements and components. Another significant project is titled "Advanced Aviation Research" and will concentrate particularly on economic issues and attempt to provide strategic forecasts for commercial aviation via cross-industry investigation and analysis.

Broichhausen underlined the fact that Bauhaus Luftfahrt, originally conceived by aerospace publisher Peter Pletschacher, and funded by the Free State of Bavaria as well as the participating companies, is not just German or even European centered but hopes to have inputs from companies and research organizations from across the world, with senior academics possibly collaborating on projects in the role of visiting professors.



MTU's R&D work includes recuperative geared fan technology, a propulsion system that holds promise of significant fuel savings and noise reductions.

While it plays a role in the new Bauhaus Luftfahrt organization and its environmental aims, MTU is closely involved via ACARE (Advisory Committee for Aeronautics Research in Europe) in the development of next-generation, more fuel-efficient, quieter, and environmentally cleaner aircraft. ACARE's key aims include the reduction of airliner fuel consumption by 50% per passenger mile by 2020, noise lowered by 6 dB, and NOx cut by 80%.

Some of these aims can be achieved via improved aerodynamics, weight reduction, and operating patterns, but it is engine manufacturers like MTU that face the most intense pressures to allow targets to be met. It is a complex challenge and there are many contributors to the sum total required. Broichhausen explained in *Report* that one challenge was to optimize existing propulsion concepts, including enhancing the efficiency of individual components, and also to use a stand-alone generator for the aircraft's power supply instead of expecting the engines to deliver it.

The other route to the target was to develop new technologies—and that is probably the only realistic way to achieve the very tough ACARE requirements, he said. In fact, the two routes are linked because "new technologies" in aerospace often involve a direct or indirect extrapolation of what went before. "New engine concepts will work only provided the various components are operating at their very best," said Broichhausen.

MTU's research is focusing on three specific areas: the geared turbofan, an efficiently packaged heat exchanger, and an "active" engine. The geared turbofan comes within the ATFI (Advanced Technology Fan Integrator) demonstrator program involving a partnership between MTU, **Pratt & Whitney**, **Pratt & Whitney Canada**, and **Avio**, which concerns the development of a reduction gear between the fan and the low-pressure turbine. The gearbox decouples the fan from the turbine, enabling the large-diameter fan to run more slowly than on a conventional engine, while the turbine can turn at higher speed. This feature allows each to achieve its optimum speed, making a very significant contribution to efficiency and noise reduction.

A heat exchanger would complement a geared turbofan. However, a major problem with most heat-exchanger designs is their size and weight, both enemies of efficient airliner operation. MTU has demonstrated the utility of recuperated geared turbofans via the European CLEAN (Component Validator for Environmentally Friendly Aero Engine) program, which entails the heat exchanger picking up residual heat in the exhaust gas stream and dumping it in the air stream from the high-pressure compressor before it reaches the combustor. The system could produce very substantial fuel savings, possibly as much as 20%, believes MTU.

To help overcome the packaging prob-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Professor Klaus Broichhausen chairs the new aerospace think-tank, Bauhaus Luftfahrt (Aviation Bauhaus), which was created to serve a systems-integrator function.

lems of aero-engine heat exchangers, the company has developed almond-shaped recuperator tubes that allow dense packing but with a large heat transfer area.

Working with **Rolls-Royce** and other European companies, MTU is involved in the NEWAC (New Aero Engine Core Concepts) program to explore fresh core engine technologies. It is specifically looking to develop an "active" core engine with a smart compressor able to adjust to specific aspects of a flight regime.

Günter Wilfert, MTU's NEWAC Program Manager, explained that achievement could be had by using active clearance control, adjusting the width of the gaps between the compressor blade tips and inner compressor casing wall. This change would also allow the engine to operate more efficiently by running closer to the surge limit, the technology involved providing early detection and control of incipient surge. The active engine has also been designed to incorporate cooling air control, the cold air influx metered to match engine power output for added efficiency. But the active engine is probably a couple of decades from production, and it may be 10 years before a complete prototype runs.

A further example of MTU's research achievements is another partnership with Pratt & Whitney for development of a lightweight, high pressure compressor (HPC), particularly for single-aisle airliners. The HPC would have a pressure ratio of at least 17:1—the ratio for the current PW6000 engine is 11:1—and would have more stages (at least eight) than current types that typically have six. Weight-saving integrally bladed rotor or integrally bladed disk (often referred to as blisk) technology is central to MTU's thinking on new HPC designs.

Stuart Birch

Composite solutions from GKN

With the delivery of the first all-composite wing spar for the **Airbus** A400M military airlifter, **GKN Aerospace** moved engineering up a step of the technology ladder. The 20-m-long spars for the aircraft represent the first ever application of carbon composites for a primary structure on a large transport aircraft wing, according to the company.

"The wing incorporates two front and two rear spars, each in two sections and, in a unique development, each with fully integrated carbon pads to enable the associated structures such as engine nacelles and flap track beams to be attached to them," said Phil Grainger, Group Technical Director, GKN Aerospace.

Knowledge-based engineering and the application of **Dassault Systèmes**' CATIA C5 played major roles in the design engineering process. Making maximum use of innovative automated processes, the manufacturing process is seeing sections measuring up to 14.5 x 2.5 m produced in 24 h, compared to a previously typical time of about a week.

"The use of the latest automatic tape-laying techniques, 'double diaphragm forming' processes, and highly accurate **Henri Liné** machining ensure a build tolerance for the spar of 0.25 mm and that it is finished to the high standard typically

The 20-m-long, all-composite wing spar for the Airbus A400M military airlifter is being completed by GKN Aerospace.

Surface preparation is done by a GKN Aerospace specialist prior to application of an electro-thermal heating element.

associated with finely machined metal components," said Grainger.

Designed in partnership with **EADS** CASA, the company is also supplying what it describes as an "innovative" air inlet for the A400M's EuroProp engine, its technology including welded aluminum. Thermal heating for anti-icing is via jackets lining the inside face of the intake duct that channels hot air from the engine over the air-washed surface of the duct.

The company has announced that it has also won a contract from **Pratt & Whitney** to develop electro-thermal heater mats for the EIPS (engine ice-protection system) of the F135 engine for the **Lockheed Martin** F-35 Joint Strike Fighter. It will overcome the need to bleed hot air from the engine—the traditional solution for de-icing. GKN stated that an electro-thermal system was more fuel efficient, leading to increased performance and endurance for the engine and reduced and simplified maintenance needs. The company is responsible for the integration of the mats into the engine's forward fan case, which it has been contracted to develop and supply.

Working with Airbus to create composite assemblies for the wings of the A380, GKN Aerospace has developed a new composite manufacturing system. Called Resin Film Intrusion (RFI), it is also being applied to the manufacture of aero-engine nacelles and components, including inlets and fan cowl doors.

The company stated that the RFI system includes the laying-up of dry, multi-axial fabric interleaved with resin film, which is then cured using either an oven or heated tools. The system has been developed to reduce manufacturing cycle times and component weight, and enhance quality and manufacturing consistency. It also overcomes part size limitations normally inhibited by the necessity to cure in an autoclave.

Stuart Birch

Tunnel view of Advanced Hawkeye and F-35

DNW, the German-Dutch Wind Tunnels organization, has won a **U.S. Naval Air Systems Command** testing contract and a subcontract to **Northrop Grumman** for the manufacture of the wind tunnel model of the **U.S. Navy**'s E-2D Advanced Hawkeye aircraft. The model manufacture was subsequently subcontracted by DNW to the **NLR** workshops, which have long experience of creating propeller-driven and rotary wing scale models.

The E2D Advanced Hawkeye is to replace the currently in-service aircraft that is equipped with the AN/APS-145 radar system and other components that require up-dating and/or replacement. The Advanced Hawkeye—essentially a new aircraft—will be fitted with eight-bladed carbon fiber propellers.

A 12% jet effects scale model of the STOVL F-35 Joint Strike Fighter in the DNW Large Low-speed Facility. Particle image velocimetry is used by DNW for ground visualization of the exhaust flow of the aircraft and to give quantitative information about flow velocity.

DNW is also involved with the development of the **Lockheed Martin** F-35 Joint Strike Fighter. With the support of its parent organizations, NLR and DNW, it has developed what it describes as "world class" experimental simulation capabilities in its wind tunnels.

DNW was established in 1976 by the **National Aerospace Laboratory** of the Netherlands and the **German Aerospace Center** for the benefit of national and European aerospace and research programs. It now has 10 wind tunnels plus an engine calibration facility. It is used by companies and research organizations from across the world.

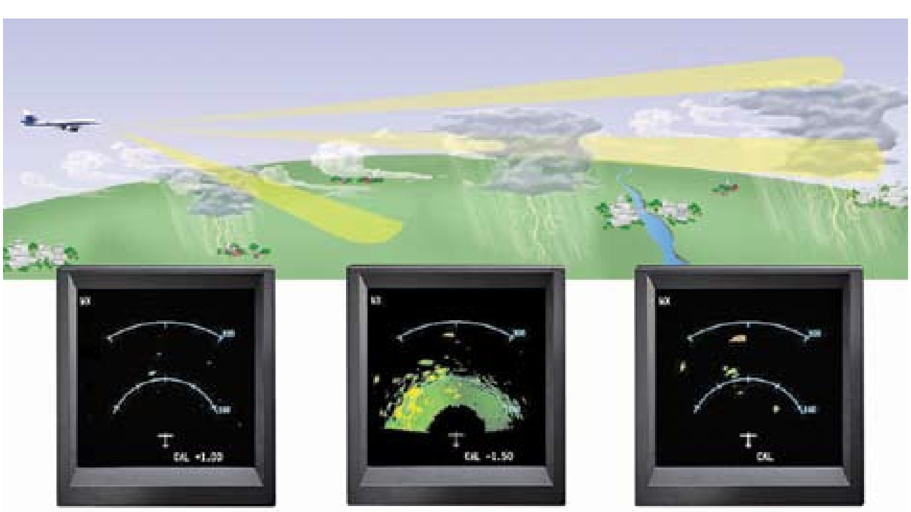
Stuart Birch

Weather hazard avoidance

Rockwell Collins says its next-generation weather radar, the MultiScan Hazard Detection system, has been improved to enable aircraft safer, smoother, and more efficient flights "through continuous field research and listening to the desires of the pilot community."

"We're introducing new features that offer an innovative approach to detecting, assessing, and displaying weather hazards," said Kelly Ortberg, Vice President and General Manager, Air Transport Systems, Rockwell Collins. "This next-generation system has created a whole new category of weather detection and analysis capabilities."

The system includes five technologies that Rockwell Collins says go beyond today's most advanced radar systems by adding predictive weather-analysis and hazard-detection features, including what it has labeled Directed Sequential Hazard Assessment, Flight Path Hazard Analysis, Storm Top Information, Predictive Overflight Protection, and Enhanced Turbulence Detection.



Rockwell Collins says its WXR-2100 MultiScan weather radar provides pilots more complete information about weather hazard avoidance, unlike conventional weather displays shown in the other three images.

At the foundation of the system's new capabilities is Directed Sequential Hazard Assessment, which offers a more comprehensive way of presenting meteorological information. This patented technology allows MultiScan to detect weather hazards and then, using a combination of horizontal and vertical scans, perform a threat analysis tailored to the phase of flight.

It allows the system to change radar parameters such as frequency, wave length, and pulse width to thoroughly evaluate the specific weather and determine its threat potential, transforming MultiScan into a threat detector instead of being a rain gauge. The end result is the ability to provide flight crews information on storm height, growth rate, and turbulent potential all referenced to the aircraft flight plan.

Flight Path Hazard Analysis takes the information provided by the Directed Sequential Hazard Assessment feature and combines it with flight path information to evaluate and display the actual weather threat along the aircraft's flight path tailored to the phase of flight. Each phase of flight uses radar techniques best adapted for the weather detection and evaluation in that region to display the actual threat.

Rockwell Collins MultiScan algorithms provide a method for estimating the top of a weather system. Storm Top Information can be displayed on the navigation display and, when combined with the typical plan form radar display, allows flight crews to determine the best possible weather-avoidance maneuver by giving them all the critical information required to determine the best route of flight.

MultiScan's Predictive Overflight Protection further enhances hazard detection capabilities by measuring the storm growth rate and then predicting whether the storm or the clear air turbulence bubble above a developing storm cell will reach the aircraft's flight level. The radar will then display the predicted area of turbulence on the radar display to alert the flight crew of the potential hazard.

In addition to detecting and assessing storm systems, the Enhanced Turbulence (E-Turb) feature of the system detects light-to-moderate turbulence events and provides flight crew warnings up to 40 nmi ahead of the aircraft. Speckled magenta areas on the radar screen indicate light-to-mild turbulence and solid magenta areas identify regions of moderate or greater turbulence. E-Turb functionality was made possible through a 2004 contract with **NASA** that Rockwell Collins won to bring E-Turb to the market.

The new system builds on the success of the MultiScan radar, which entered into service in 2002 as the first commercially available, automatic weather radar. Other core capabilities in the MultiScan radar system that will remain in the Hazard Detection System include 320 nmi weather-detection and -display capabilities, ground clutter suppression, and geographical weather correlation. The system is in use with more than 80 customers, and is software upgradeable to the new MultiScan Hazard Detection system.

Jean L. Broge

What to wear in a Typhoon

A new weapons systems integrated helmet for pilots of the **Eurofighter** Typhoon has been successfully trialed. The **BAE Systems** Helmet Equipment Assembly (HEA) was tracked into the Typhoon's computer systems.

The HEA project started in 1997 and the helmet had already been subjected to extensive testing, including detailed prototyping of weapon system interaction in the active cockpit, plus rig, centrifuge, and flight testing of the physical system to optimize mass and balance. It was also tested to verify required pilot protection levels, completing high speed wind blast and ejection trials.

The new helmet, with a mass of about 2 kg, gives the Typhoon pilot the ability to slave weapons and sensors to high off-boresight angles while maintaining situational awareness with eyes out of cockpit or "through" it, via sensors and symbols in the helmet.

The helmet is made by BAE Systems Electronic and Integrated Solutions at its Rochester, UK, facility, with the Italian company, **Gallileo Avionics**, as a work-share partner. As the end user, BAE Systems Air Systems is also closely involved in the project. All four Eurofighter partner nations will use the helmet, which is slated to be in squadron service in 2008-2009. The production helmet will be designated Mk. II.

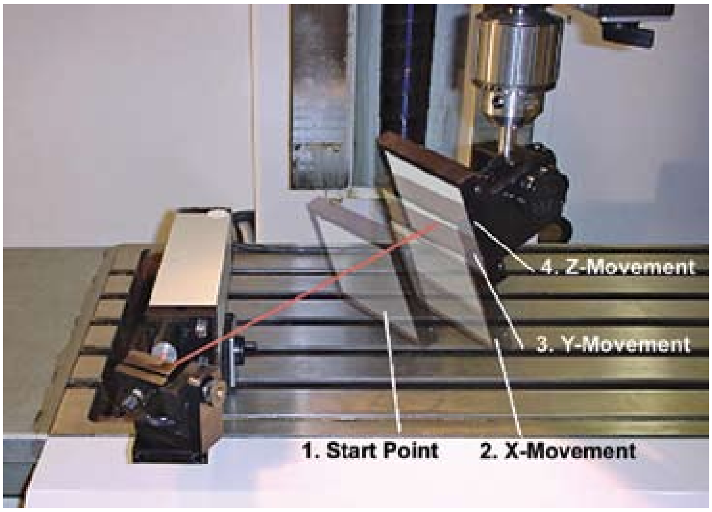
Stuart Birch

Eurofighter Typhoon pilots will get a weapons systems integrated helmet now under development by BAE Systems and Gallileo Avionics.

Calibration of CNC machine tools

Once considered strictly a quality issue, calibration and compensation have been directly linked to cycle-time reduction. A machine tool within tolerance can run higher feed rates and still maintain tolerances. Calibration allows online part inspection, saving time shuffling parts back and forth between the machine tool and CMM. Additionally, regular calibration can be used to predict when a machine tool will go out of tolerance.

Two separate laser heads for master and slave axes measurement validate gantry-type machine tools, even with very long travels.



Stop-action photograph of Sequential Step Diagonal Measurement Method shows each of the steps for measuring 3-D (volumetric) errors in as little as two hours without removing machine tool covers.

To operate laser calibration equipment a metrologist was once required. Machine tool covers had to be removed to align optical components on the table, spindle, and free-standing tripod. The process of 3-D (volumetric) calibration required several days, depending on the size of the machine. Therefore, calibration was not considered necessary when parts measured on a CMM were found within tolerance.

Today, technology and processes have significantly reduced the cost of laser calibration equipment such as that provided by **Optodyne**, the need for a metrologist or outside service, and machine tool downtime. A machinist with one day of laser calibration training can perform 3-D calibration of a 1-m^3 machine tool in as little as a half-day. The software automatically writes the compensation tables and uploads the CNC control.

For years, the Body Diagonal Displacement Method (BDDM) defined in the **ASME** B5.54 or **ISO** 230-6 standards has provided a quick check of volumetric error for such aerospace companies as **Boeing**, and many others. BDDM measures the four diagonals of the machine tool's work envelope cube, generating four sets of data, which includes all errors. However, it does not provide enough data to identify exactly where the error is located.

A newer process—the Sequential Step Diagonal Measurement Method (SSDMM)—collects 12 sets of data with the same four diagonal setups. Based on this measurement data, all three displacement errors, six straightness errors, and three squareness errors are determined without lengthy machine tool down time. Additionally, the measured positioning errors are used to generate a 3-D compensation table.

The SSDMM differs from BDDM in that each axis moves separately in sequence and the diagonal positioning error is collected after each separate movement of the x-, y-, and z-axis, providing three times the amount of data and allowing the positioning error for each separate axis movement to be measured.

The trajectory of the target is not a straight line and the lateral movement is quite large. A conventional interferometer cannot make these measurements because it does not tolerate such a large lateral movement. However, single-aperture laser interferometers, such as a Laser Doppler Displacement Meter, are unaffected by large lateral movements. With a flat mirror as the target, the movement parallel to the mirror does not displace the laser beam and does not change the distance from the source.

Predictive Maintenance (PDM) and other programs such as Machine Tool Variability Management System, Reliability and Maintainability, Failure Mode and Effective Analysis, and Total Productive Maintenance predict machine tool failure (out of tolerance). By comparing current and historic data collected with such instruments as laser calibration, vibration analysis, and IR thermography equipment, a prediction can be charted of when such machine tool components as the CNC, ballscrew, way systems, or servomotors will require compensation, service, or other necessary repairs.

A machine tool rated at 0.0002 in is checked every six months. Assume that at each of the last three calibrations, the tolerance has degraded by 0.000050 in. Based on the historic information, it is reasonable to predict calibration will be required within six months. Similarly, vibration analysis can reveal information about the spindle and other critical components for predicting maintenance and repair operations.

Establishing a PDM program is a long process, beginning with the selection of machine tools for the program and technologies to calibrate and collect data. Next calibration equipment must be evaluated and purchased, then PDM procedures can be established, using the following basic steps:

- Monitoring machine tool conditions
- Diagnostics to identify problems
- Data analysis and corrective actions, and
- Early warning and prediction by integration of precision measurement system directly into the manufacturing operation.

After the basic steps have been detailed with specific repeatable procedures, acceptable levels of performance and accuracy must be defined. Additionally, measurements to establish a machine tool baseline must be taken. Machine tool measurements must be made at regularly specified time intervals and from the analysis, maintenance, and repair predictions integrated into production schedules.

Using a 3-D-capable machine tool for (in-process) part inspection can significantly reduce cycle time and improve accuracy. In the aerospace industry, in-process inspection has failed to gain momentum because resolving positioning errors on the same machine tool that cut the part was expected to result in repeating the errors during the inspection process. However, newer laser calibration technology and processes meeting such requirements as ISO 9000 and ISO 17025 satisfy both manufacturing and quality programs and allow the use of on-machine inspection as a viable and credible process.

For example, gage accuracy requires a ratio of 4:1; therefore, CNC machine tool accuracy must be four times more accurate than the specified accuracy of the part. For on-machine inspection to meet this requirement, the accuracy of the machine must be verified. Using the measured 3-D positioning errors, a lookup correction table can be generated automatically by software, enabling in-process inspection software to compensate the machine's 3-D positioning errors.

When using a machine tool for in-process part inspection, the cutting tool is replaced with a suitable probe, which measures part dimensions. The 3-D positioning errors can be tabulated as lookup tables or compensation tables, allowing the software to correct measured probe positions. With 3-D error correction, inherent errors in machine tool geometry and positioning can be eliminated to provide accurate dimensional measurement. Therefore, by satisfying the 4:1 gage accuracy ratio with volumetric error compensation, a CNC machine tool can provide the same high-accuracy as a CMM.

Optodyne's MCV 5004 aerospace laser kit for measuring 3-D errors of CNC machines.

This article was written for *Aerospace Engineering* by **Charles Wang**, President, Optodyne.

Cabin image makeover

ICI Imagedata has launched a new decoration technology called Pictaflex that it believes would be suitable for aircraft cabin applications. Developed in collaboration with **Applied Effects Laboratories** and the **University of Warwick** in the UK, it enables any 3-D object to be decorated with a full color design or photographic quality image, using dye diffusion, which bonds it to the surface.

ICI Imagedata's Pictaflex imaging technology enables 3-D surfaces to be decorated with a full color design or photographic image.

A specially coated recyclable polyester film is printed using aqueous inkjet technology. The ink is then fused into the surface of the object by application of heat and pressure in a Pictaflex press. The company sees Pictaflex as suitable for large-scale production or individual product personalization applications of finished parts and components made from plastic, metal, wood, and glass, plus some composite materials.

Pictaflex has been designed to be applicable to both interior and exterior trim. "Literally any digital image can be reproduced on the chosen part, enabling the product designers to create their own visuals or use existing imagery from photographs or scans," stated ICI Imagedata. "The process can print highly complex 3-D parts and can wrap around angles tighter than 90°. As images can be printed on demand, it is unnecessary for users to hold costly film stock."

Stuart Birch

Flying a Pixy UAV

ABS Aérolight, manufacturer of the Pixy compact UAV aeromodel paraglider, has introduced a new surveillance version, the Maxi 210, for use in hostile environments. It has a load capability up to 30 kg, is 1750 mm long, 130 mm wide, and has a span of 15 m. The Maxi 210 has been designed to fulfill various roles including tactical operations, law enforcement, border survey, search and rescue, and night/day battlefield reconnaissance. Scientific uses are potentially wide.

Pixies can fly: ABS Aérolight's Pixy is in use for scientific research and photography.

The Maxi 210 has been designed for use in harsh conditions with a TIG-welded aluminum airframe and Zicral spars. Its sprung landing gear includes three low-pressure wheels. Engine is a single cylinder SOLO two-stroke producing 11 hp. Empty weight of the Maxi 210 is 25 kg and it can attain speeds up to 65 km/h. Maximum endurance is six hours.

The Maxi 210 uses many of the design and structural methods of the smaller and established Pixy, which also has a two-stroke engine (Tech 23) but of 3 hp. It has also a TIG-welded aluminum airframe with Zicral spars, is only 840 mm long, 63 mm wide, and has a 295-mm span. Payload is 5 kg. The Pixy can be equipped with regular cameras, IR, or multispectral sensors.

The Pixy's maximum operating altitude exceeds 2000 m and visual piloting is possible within a 1500-m radius of the operator. Altitude is controlled via throttle settings.

Stuart Birch