AROSATEC

502937

AROSATEC

Automated Repair and Overhaul System for Aero Turbine Engine Components

Instrument: FP6 STREP

Priority: Aeronautics and Space

Publishable Final Report

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Project coordinator: Dr. C. Bremer

Project coordinator organisation: BCT GmbH

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Publishable executive summary

Project logo and acronym: AROSATEC

Project title: **Automated Repair and Overhaul System for Aero Turbine Engine Components**

Project no.: **502937, FP6, STREP, Priority: aeronautics and space**

Project public website: www.arosatec.com

Project summary description and project objectives

The maintenance, repair and overhaul (MRO) of aero engine components consists of a chain of different processes, e.g. inspection, de-coating/coating, welding, milling and polishing. Today most of these processes are carried out manually.

At present the supply industry is developing improved machining equipment to automate the individual process steps. Nevertheless, the single repair processes remain separate and unconnected. For example, the data which are acquired during the incoming inspection are put down on paper and are not available in electronic form for subsequent repair operations. Even though the single repair operations may be automated, therefore, this does not improve the overall process by promoting data flow and factory automation throughout the entire MRO chain.

The first objective of the proposed project is to improve existing repair methods by employing adaptive machining technology. The adaptive CNC technologies make use of the information provided by the data management system and compensate for the part-to-part variation of the complex components to be overhauled.

The data flow between the adaptive repair steps optimises the single repair technologies as well as the efficiency and the flexibility of the entire chain of repair processes for aero engine components.

The second objective of the proposed project is to develop a data management system which will constitute the core of automated overhaul systems for aero engine components. As part of this innovative data management solution, the single repair process modules are integrated to build an automated repair cell for aero engine components.

Furthermore, it is possible to establish "virtual" MRO workshops. The data management system generates a data set for each individual component and handles the logistics of the components and the accompanying data sets. As result, different MRO processes can be carried out at different facilities without loss of information, efficiency or quality. In addition, the approach described supports efficient life cycle monitoring.

Contractors

1:	BCT	Germany	Industry	SME
2:	Alround	Germany	Other	Non-profit organisation
3:	ISQ	Portugal	Other	Non-profit RTD organisation
4:	Metris	Belgium	Industry	SME
5:	MTU	Germany	Industry	Turbine maintenance industry
6:	Sifco	Ireland	Industry	Turbine maintenance industry
7:	Skytek	Ireland	Industry	SME

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Project Duration:

Start:	01.11.2003
End:	31.07.2006
Duration:	33 months

1 The Problem

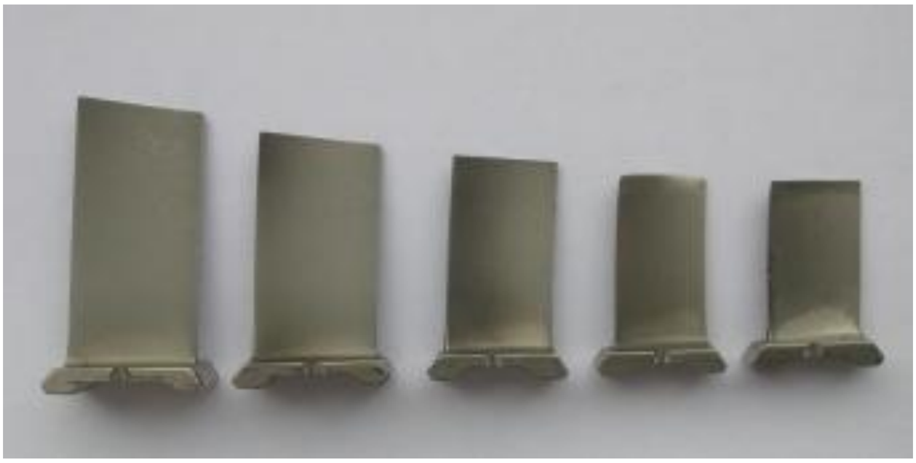
Looking at an aircraft as a composition of replaceable units attached to the airframe, the engines are usually the most expensive individual items. Being essential for flight, the engine condition is monitored closely by different measurement installations and inspections. Besides probes for temperature, pressure or vibration, an engine trending reveals upcoming problems in advance. Scheduled visual and other inspections complete the engine monitoring.

Due to operating conditions, engine lifetime is consumed and finally an engine has to be removed for maintenance, overhaul and repair (MRO). To restore the aircraft to operation, the old engine is removed and replaced by a “fresh” spare engine.

Every engine represents a considerable amount of capital. Thus the turn-around time for the engine has to be limited to a minimum. In order to accelerate MRO, engines are designed in modules.

Usually a turbine engine consists basically of compressor, combustion chamber, turbine and a gearbox attached to the casing. Additionally, these modules may consist of several sub-modules, e.g. the compressor is usually formed by low, intermediate or high pressure compressor sub modules.

Worn out or faulty modules can be replaced in quite short time to have the engine back in the supply loop. While the engine may already be attached to another aircraft, the modules are split up in their sub modules and demounted. Worn out or damaged parts are identified and classified to parts to be repaired or parts to be disposed.



Picture 1 **Compressor blades of a high pressure compressor. When repairing parts like these, their small size becomes a major challenge for tooling as well as for clamping installations. Due to tight manufacturing tolerances the parts are classified as high value parts.**

Especially the blades and vanes are expensive parts due to their complex geometry, material composition and a difficult manufacturing process with tight tolerances. AROSATEC concentrates on these parts and the corresponding repair processes.

For several types of damages on blades and vanes, repair methods are available today. Usually the blades are demounted from their sub module first. Then they are de-coated and cleaned, followed by a visual incoming inspection to detect the damages and to sort out obvious scrap parts. The next step is to measure their size and geometry. Damaged areas will be milled out to have defined boundaries. With a build up welding, material is attached to the prepared areas until the target geometry is covered. Surplus material is milled off, grinding and polishing complete the restoration of the engine blade shape. After an inspection, coating is re-applied and the part can return to the logistic loop.

The repair is usually carried out manually; human factors consequently influence the quality of the whole process. Especially the re-forming of the engine shape strongly depends on the skills and experience of the worker. Besides the blending of old and new surface areas, the shape of the blade tip is demanding. With manual work the tip geometry may vary from the original form and thereby degrade the aerodynamic quality of the blade.

Another characteristic of concurrent repair methods is the fact that these are not interlinked. Although some processes were already carried out with machine support, the overall repair process was missing. Thus work duplications occurred, especially regarding measurement:

The geometry of the blade was investigated during the incoming inspection. For milling out damaged areas measuring was necessary to position the tools, for build up welding – if not carried out completely manually – measuring of the prepared areas and for positioning was mandatory. Again for milling positioning, measuring was required after that. And during the final inspection measuring results were compared to tabled values.

To put it into a nutshell, no superior data flow existed. Hand-over of data between different steps of the repair was difficult and by no means consistent. In addition, all data acquired during one repair cycle was deleted after carrying out the repair. Thus a lifetime data collection for the individual parts was impossible.

2 The Idea

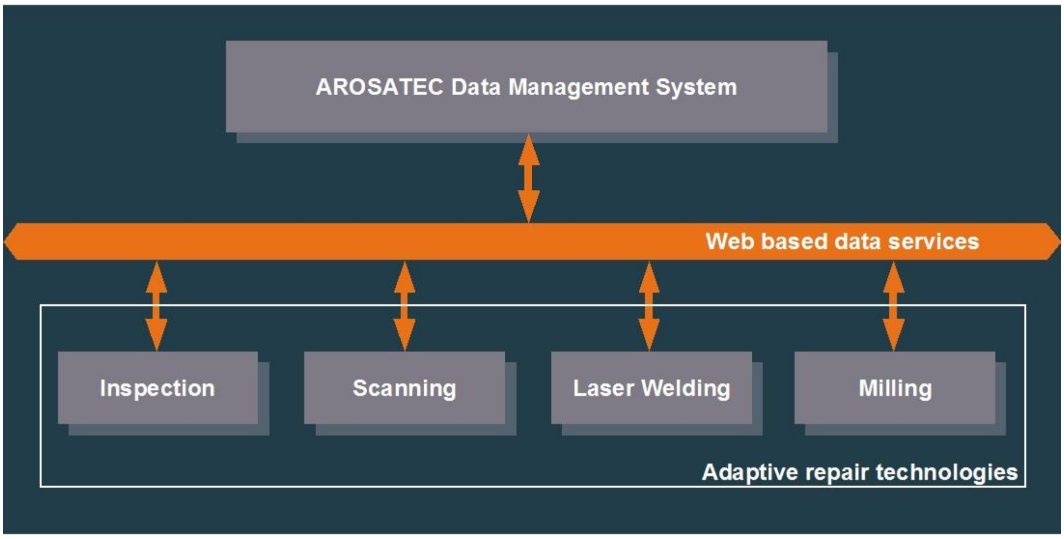
As mentioned above the maintenance, repair and overhaul (MRO) of aero engine components consists of a chain of different processes, e.g. inspection, de-coating/coating, welding, milling and polishing. Today most of these processes are carried out manually.

Although the supply industry is developing improved machining equipment to automate the individual process steps, the single repair processes remain separate and unconnected. For example, the data which are acquired during the incoming inspection are often put down on paper and are not available in electronic form for subsequent repair operations. Even though the single repair operations may be automated, therefore, this does not improve the overall process by promoting data flow and factory automation throughout the entire MRO chain.

So AROSATEC had to aim at two objectives:

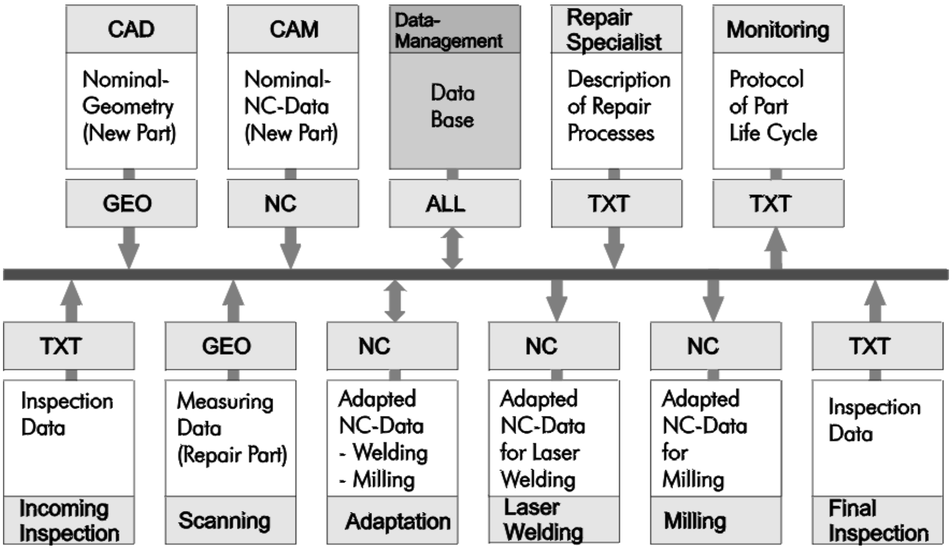
Firstly, to improve existing repair methods by integrating adaptive machining technology. The adaptive NC technologies should make use of the information provided by a data management system and compensate for the part-to-part variation of the complex components to be overhauled. Additionally the part-to-part variation due to the manual treatment would be eliminated.

A continuous data flow between the adaptive repair steps should optimise the single repair technologies as well as the efficiency and the flexibility of the entire chain of repair processes for aero engine components. Thus secondly, a data management system which constitutes the core of the automated overhaul system for aero engine components has to be developed. As part of this innovative data management solution, the single repair process modules should be integrated to build an automated repair cell for aero engine components.



Picture 2 General layout of the AROSATEC Data Management System

In the long run, the AROSATEC concept could also open the possibility to establish “virtual” MRO workshops with the different repair steps carried out in remote countries. The data management system would generate a data set for each individual component and handle the logistics of the components and the accompanying data sets. As result, different MRO processes could be carried out at different facilities without loss of information, efficiency or quality. Work duplication could be prevented and the accuracy of the work carried out could be enhanced. In addition, the AROSATEC approach would support an efficient life cycle monitoring.



Picture 3 **A more detailed view on the different data sources and data users reveals the many of different data formats to be handled and translated / interpreted within the AROSATEC data backbone.**

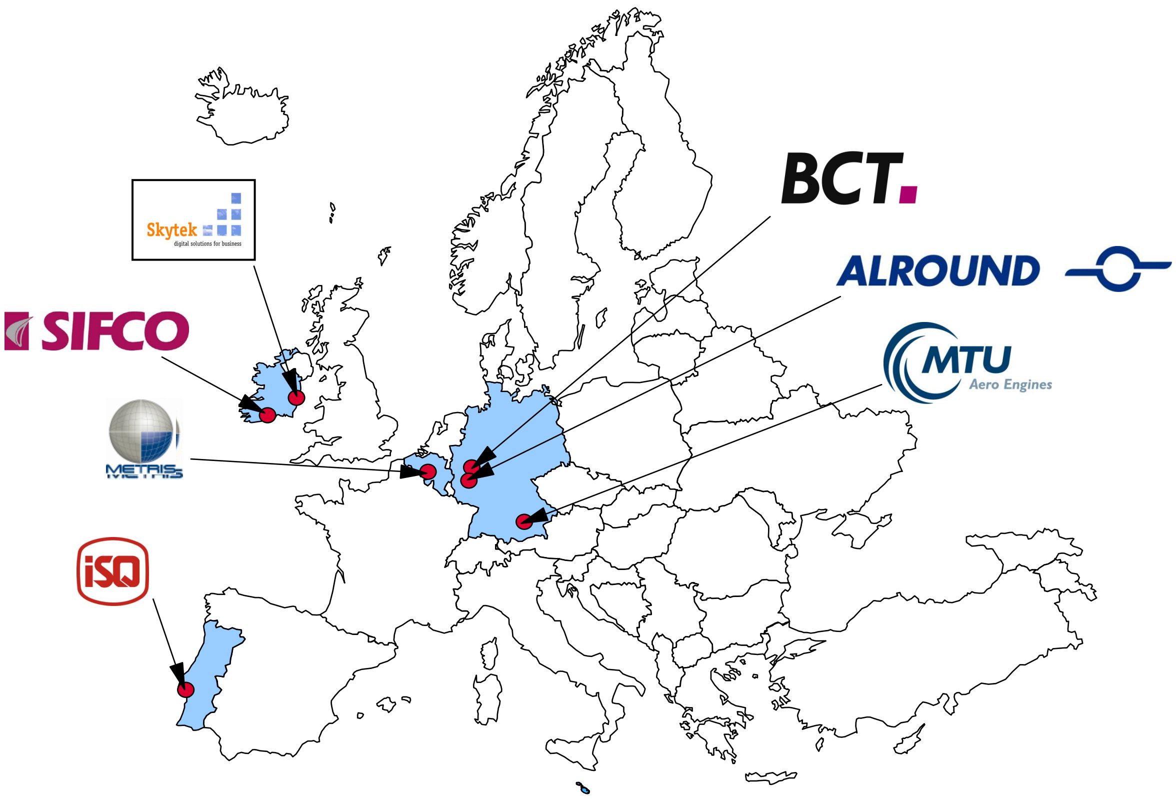
3 The Project

3.1 The project partners

3.1.1 Project partners and their obligation

- BCT coordination and adaptive machining,
- ALROUND administrative management, dissemination and exploitation
- ISQ laser cladding
- Metris laser scanning
- MTU user requirements
- SIFCO user requirements
- Skytek data backbone

3.1.2 Geographical distribution of the AROSATEC partners



Picture 4 Geographical distribution of the AROSATEC partners

3.1.3 The partners' description

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BCT is the AROSATEC project coordinator. BCT is specialized in adaptive machining technologies for repair and manufacturing as well as productive reverse engineering technologies for the workshop. BCT has many years of experience in this area and cooperates closely with end users as well as with manufacturers of machinery, control equipment, sensors and CAD/CAM systems.

The solutions developed by BCT for adaptive machining are already in use for several different applications, e.g. adaptive laser cladding of worn-out tools and dies as well as compressor and turbine blades. For the MRO of turbine components, in particular, various adaptive milling solutions have been developed for tip-welded compressor and turbine blades/vanes as well as for welded and "patched" impellers and blisks.

In recent years, BCT has been involved in several national and international research projects.

As the "integrating" partner, BCT was involved in most of the work packages as the adaptive machining technology is the link between the single repair process, the data management system and the end user. BCT has gathered extensive know-how in turbine MRO applications, adaptive repair processes and data handling.

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ALROUND is the "Association of aerospace oriented SMEs in Germany", founded in 1988. Today, the association has more than 100 members, consisting of companies, universities and research institutes. The ALROUND office is located at Bonn, Germany and serves as network centre between SME, institutes, system industry and public bodies.

The ALROUND portfolio covers fair contributions, work shops, seminars, consulting, lobbying and project support. Especially the fair contribution with group stands, consulting and project support represent the major issue of ALROUND. Project support includes all support of members' projects from the idea to market success, e.g. teaming issues, project management and administrative tasks of regional, federal and European funded projects.

During the last decade, ALROUND has gathered considerable knowledge and experience in EC funded project work. Besides its responsibility for the administrative work in the AROSATEC project, ALROUND is also German servicing partner for the SCRATCH initiative. SCRATCH is a specific support action of the EC, dedicated to support SME in their efforts when preparing and submitting proposals for the various Aeronautics calls in the EC Framework Programme.

As SCRATCH servicing partner, ALROUND supported the international teaming of the AROSATEC consortium and has helped the coordinator to define this project of 3 SME, 2 partners of system industry and an institute.

During the project, one technology consultant and the Managing Director of the ALROUND team took care for a steady and targeted project run. The work carried out in administration and dissemination is complementary to the technical research and development but decisive for an overall success.

Additionally, an information exchange system (PHP) was set up and used to inform the consortium of management issues as well as to assist partners in technical research work.

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ISQ (Instituto de Soldadura e Qualidade) is a private non-profit-making technical and scientific association founded in 1965 as the Portuguese Welding Institute. Originally concerned with welding technology, ISQ subsequently diversified; it now operates in several technical and scientific areas and provides services including technical inspections and non-destructive testing of welded and other types of constructions. Vocational training and technological R&D have always been among ISQ's core activities; today, however, they are part of a wider range of services. ISQ derives more than 80% of its income from the provision of services to industries and other businesses in Europe and abroad. National and EU funding of RTD and training projects account for the remaining income.Over the past ten years, ISQ has been involved in numerous high-tech research projects with national and EC funding; these projects have distinctly expanded the know-how base for its various areas of activity. Material testing and the characterisation of mechanical, chemical and metallurgical properties of materials can be carried out at ISQ's laboratories, which have been accredited by IPQ, the testing authority within the Portuguese National Quality System.

Over the years ISQ has developed expertise in many areas of production technology. More recently, it has made a large investment of money and effort to transfer its acquired know-how to applications in the aeronautics industry. The around 600 staff are teamed with customers, partners and alliances in more than 20 countries worldwide.

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Metris is a hardware and software company providing solutions for quality control, reverse engineering and 3D scanning to the design and manufacturing community. It designs, develops and markets a unique range of 3D hardware and software inspection systems for the automotive and aerospace sectors and is also active on the markets for consumer products, medical and dental equipment, furniture, toys, shoes and the "free form" industries. The comprehensive product family covers the full range of measurement volumes required by customers, in both fixed and portable configurations and with optical and touch sensors.

Metris develops and markets both laser scanners and handling software for reverse engineering and quality control applications such as dimensional inspection. It is the market leader for coordinate measuring machine laser stripe scanning. This scanning technology, as well as the handling of the resulting point clouds, is completely developed in-house by the company's software engineers. Metris is recognised as the major European software supplier in this field. Metris scanners and software for reverse engineering and quality control are distributed via a direct sales network in the EU and the USA and through dealers in the rest of the industrialised world.

The Metris Headquarters are based in Leuven (Belgium) with additional production and development centres in UK (Derby, London) US (California, Virginia), China, Russia, India and Bulgaria. Metris provides a worldwide network of sales and support offices located in Europe, Asia, and the United States.

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Nationally and internationally, MTU Aero Engines is a strong player in the development, manufacture and repair of commercial and military engines. Nationally, it is Germany's leading manufacturer of engine modules and components and of complete aero engines. Internationally, it is strongly positioned in all significant regions and markets. In its globalization effort, the company is continuously expanding its leading-edge position through cooperative efforts and joint ventures.

MTU Aero Engines is Germany's leading engine manufacturer and an established global player in the industry. It engages in the development, manufacture, marketing and support of commercial and military aircraft engines in all thrust and power categories and industrial gas turbines. The German manufacturer employs approximately 6,700 people overall and with its various affiliates has a presence in all significant regions and markets worldwide. In fiscal 2005, it had 2.15 billion euros in consolidated sales. In the years ahead, MTU will focus its resources on its core business, seek stakes in emerging engine programs and expand its service offerings.

MTU's technology leadership bases not only on its engine component manufacturing activities but also on the innovative techniques it uses to repair components. True to its motto "Repair beats Replacement", the company's proprietary processes achieve a level of restoration that is unique in the world: MTU will still repair where others have long resorted to replacement. This helps protect the environment and saves the customers money.

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Sifco Turbine Component Services operates facilities for turbine component maintenance, repair and overhaul in Cork, Ireland. Sifco specialises in component repair of "hot section" turbine blades and vanes. In association with OEMs and international RTD organisations, Sifco both leads and participates in international research projects.

SIFCO HIT, is a specialized provider of services to the Power Generation industry. Serving the Heavy Industrial Turbines (HIT) and the Light Industrial Turbines (LIT) market with manufacturing and refurbishment capability.

Founded in 1983, the company is an approved provider of component repair services to powerplants such as General Electric, Siemens, Rolls-Royce, Solar and others.

The company is equipped to manufacture and refurbish high technology components of the most modern powerplants. SIFCO's employees are committed and capable of meeting the full range of needs for the customer.

SIFCO is committed to sustained continuous improvement of product and service to its customers. As supplier and vendor SIFCO provides a competitive advantage by:

- Maintaining high standard of modification
- Lowering cost of power plant ownership
- Identifying and meeting exact requirements

The personnel at SIFCO are aware of the need to respond to the ever changing environment where continuous improvement is vital. Through expertise, dedication and determination SIFCO employees deliver the best possible service.

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Skytek is an SME based in Dublin, Ireland. During the last several years Skytek has gained extensive expertise and knowledge regarding the development of software solutions for process management, maintenance operations and the dissemination of maintenance data to remote locations. For example, a system has been developed for the European Space Agency to be used on board the International Space Station to assist astronauts in repair operations and data capture, and to facilitate remote monitoring by ground control personnel.

Technological expertise, commitment to research and real understanding of client organisational challenges - these are the foundations of Skytek's success.

Since the mid-1990's, Skytek has been a leading player in the creation of information and operation based tools. The clients include the European Space Agency and NASA. From space, Skytek is now addressing the more terrestrial needs of complex industries such as natural resource mining and aerospace. The ability to update, disseminate, access and apply operational knowledge is of critical importance within any organisation, but in particular those which deal in complex operations.

3.2 Project implementation

AROSATEC was proposed in the 1st call of the 6th EC framework programme and passed the evaluation. After the contract preparation phase and the negotiations, AROSAETC started on November 1st, 2003 with the kick-off meeting held in Bonn.

With at least one progress meeting every six months, the overall project progress and a targeted project run in detail were ensured. Upcoming problems were detected at an early stage and corrective actions could be taken in good time.

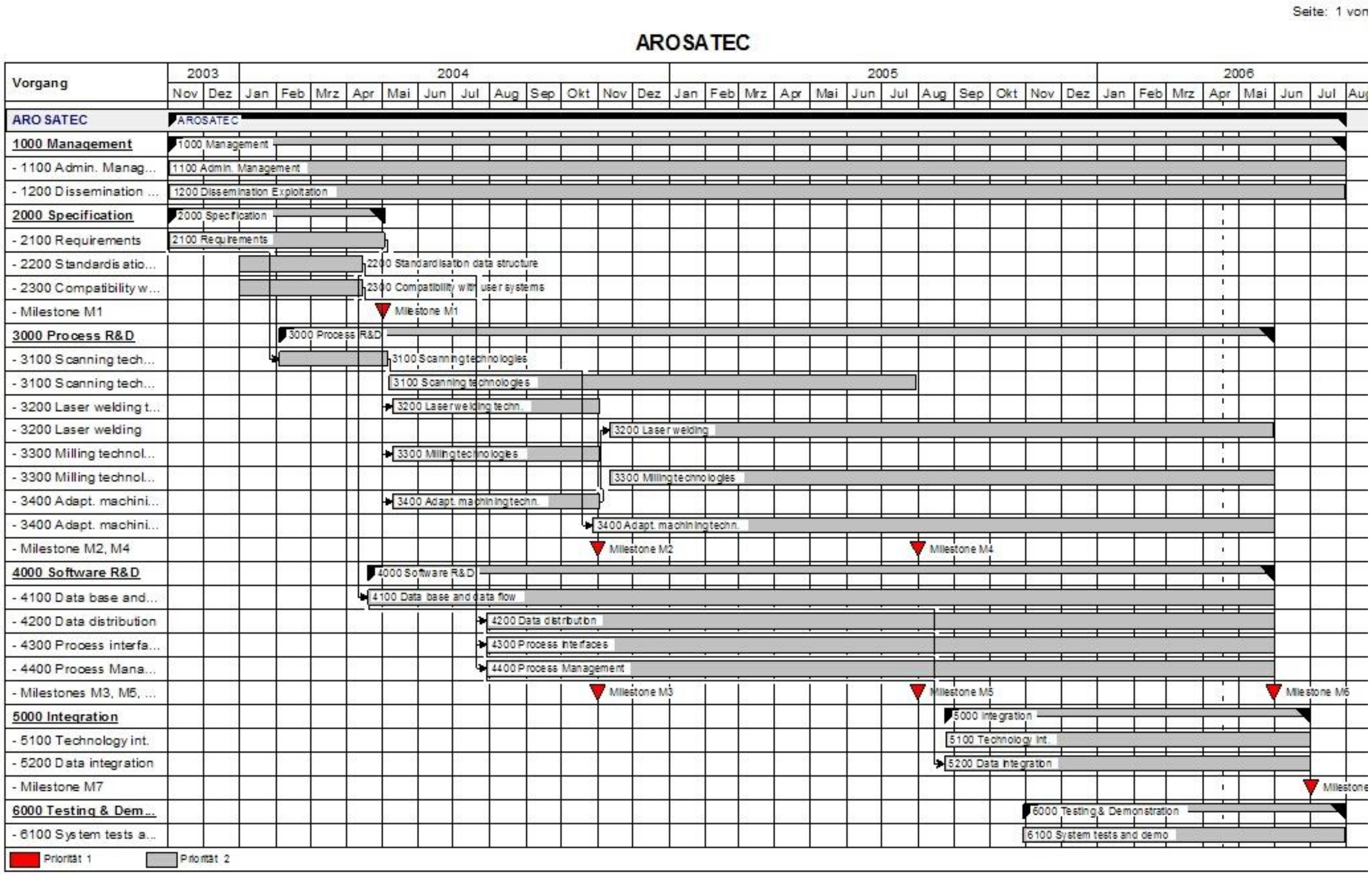
During the first half period of the project, especially the end user requirements were investigated. MTU and SIFCO defined the repair processes to be incorporated in AROSATEC, resulting in the detailed requirement specifications. These were analysed by the partners and compared to technologies already available. The gap between contemporary technology and requirements defined the development needs and goals for AROSATEC.

Beside setting up the detailed requirement specification, the scanning process and data-treatment optimisation started. In the course of AROSATEC new scanners were tested and optimised, software interfaces were also optimised and adapted. Additionally, the general layout of the data backbone was set up and the concept was tested and verified.

The second year of AROSATEC was dedicated to optimise the different repair steps, from scanning to laser welding and to adaptive machining. While scanning improvements were made with use of new, high accuracy scanners, welding demanded sophisticated tooling, especially for complex geometries like on nozzle guide vanes, and intelligent welding strategies. A major problem for the adaptive machining was to find suitable fixture solutions and references to detect the positioning of the part automatically. Additionally, the data backbone was developed and improved.

During the third project period, the focus was upon integration of the processes and the adaptation of the data management. Fixtures for adaptive machining were successfully tested, also the use of reference points and tactile measurement for automated high accuracy tool positioning was implemented. With the milling of the first blades also the adaptive machining part was completed successfully.

All these steps are reflected in the Gantt chart, which also gives a first impression of the interaction between the different work packages.



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AROSATEC
1000 Management
- 1100 Admin. Manag...
- 1200 Dissemination ...
2000 Specification
- 2100 Requirements
- 2200 Standardisatio...
- 2300 Compatibility w...
- Milestone M1
3000 Process R&D
- 3100 Scanning tech...
- 3100 Scanning tech...
- 3200 Laser welding t...
- 3200 Laser welding
- 3300 Milling technol...
- 3300 Milling technol...
- 3400 Adapt. machini...
- 3400 Adapt. machini...
- Milestone M2, M4
4000 Software R&D
- 4100 Data base and...
- 4200 Data distribution
- 4300 Process interfa...
- 4400 Process Mana...
- Milestones M3, M5, ...
5000 Integration
- 5100 Technology int.
- 5200 Data integration
- Milestone M7
6000 Testing & Dem...
- 6100 System tests a...
1100 Admin. Management
1200 Dissemination Exploitation
2000 Specification
2100 Requirements
2200 Standardisation data structure
2300 Compatibility with user systems
Milestone M1
3000 Process R&D
3100 Scanning technologies
3200 Laser welding techn.
3200 Laser welding
3300 Milling technologies
3400 Adapt. machining techn.
Milestone M2
Milestone M4
4000 Software R&D
4100 Data base and data flow
4200 Data distribution
4300 Process interfaces
4400 Process Management
Milestone M3
Milestone M5
Milestone M6
5000 Integration
5100 Technology int.
5200 Data integration
Milestone
6000 Testing & Demonstration
6100 System tests and demo
Priorität 1
Priorität 2

3.3 Problems encountered - Solutions found

During the project implementation several problems were encountered.

In the first time of AROSATEC, especially the question for a data standard had to be answered. This question finally turned out to be of major importance, as the data standard could limit the applicability of the AROSATEC process to certain machines / tools and thus a wrong decision could be quite counterproductive.

However, the solution was found in XML, allowing the definition of open data formats which could serve directly as input file for machines as well as original for translation to specific formats. The greatest advantage of XML is the universal applicability, as it is set up in ASCII and could be read by humans and by machines.

Another challenge was to accelerate scanning and receive high accuracy results. This problem was overcome by development and use of new software modules and scanners with a wider field of view. Also the question of using what reference points at what time was answered satisfactory.

Prior to AROSATEC, automated welding of complex geometries like airfoils or generally, surfaces that show curvatures along two coordinate directions, was a demanding and often impossible task. However, the development of the welding cradle now allows a more-than-5-axis welding of such surfaces. Additionally new welding strategies were tested to reduce the burn down of the leading and trailing edges especially of compressor blades. Accompanied with this was the challenge to control the temperature of part during welding. Thus besides positioning, the fixtures also had to deliver suitable chilling to the blade.

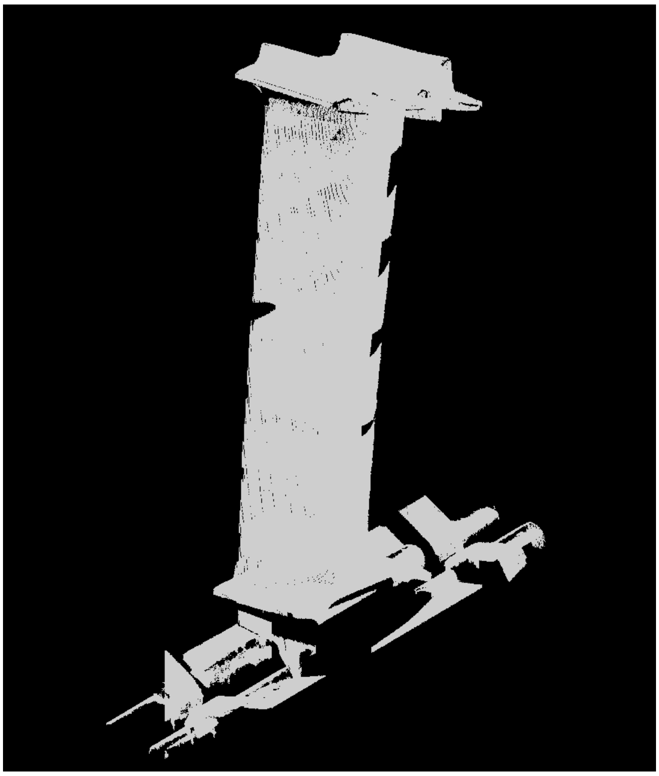
But the question of the best fixture strategy had also to be answered on a different background. On the one hand, these fixtures had to be small enough to give maximum access to the surface of the part, mandatory for reaching the reference points and for surface treatment, on the other hand they had to be tough enough to withstand the forces induced during milling and to keep the blade at the correct position while being milled. As a result a thermoplastic mass was successfully employed for fixing issues during the adaptive machining process.

4 The Results

The AROSATEC process was set up successfully. During the income-inspection, the cleaned blades or vanes are inspected by the improved laser scanning technology.

Picture 5 A typical laser scanner as used for incoming inspection. Line scanners of this type like the one showed deliver a point cloud (meshed data STL)

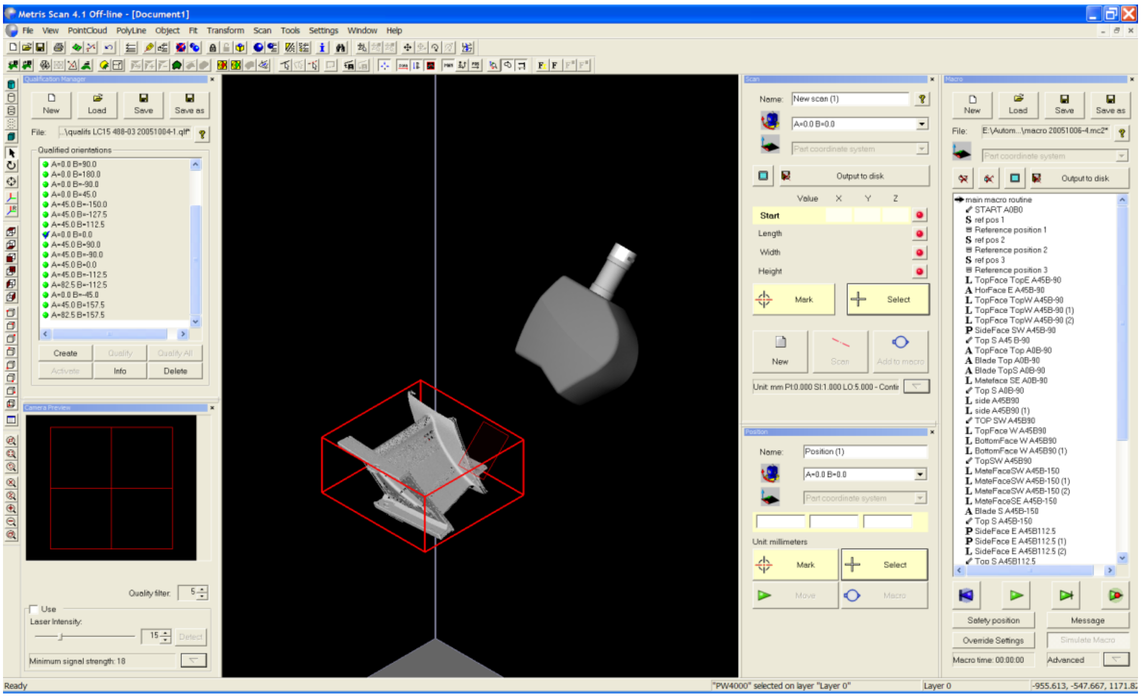
Picture 6 Laser scanner scanning a turbine blade



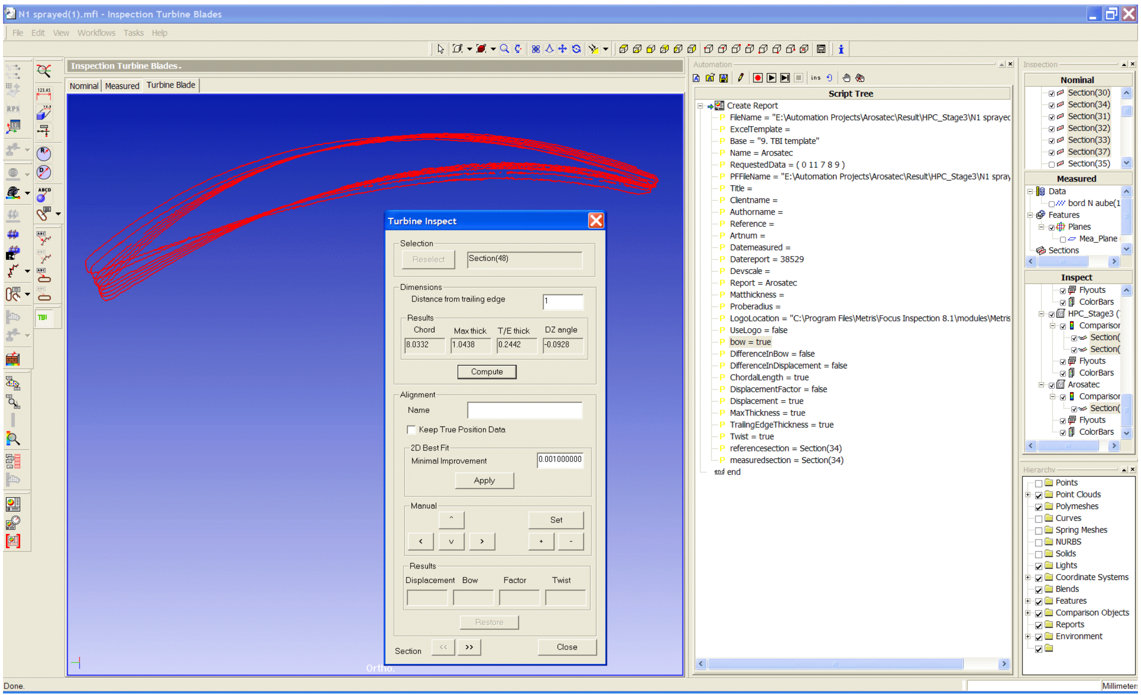
Picture 7 The scanning result: A high-accuracy point cloud. From a numerical point of view, these points are discrete points and need to be triangulated to gain the equations that describe the surface.

The laser scanner delivers a point cloud, a huge amount of discrete points on the surface of the scanned object. These points are a three-dimensional representation of the scanned part. To create a three-dimensional triangular mesh , the data are triangulated.

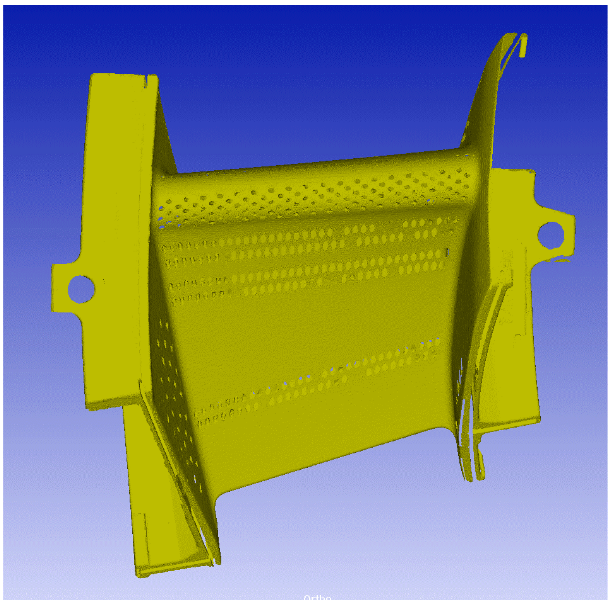
Picture 8 Scanning of an airfoil



Picture 9 The software solution developed for AROSATED to overview the scanning process.

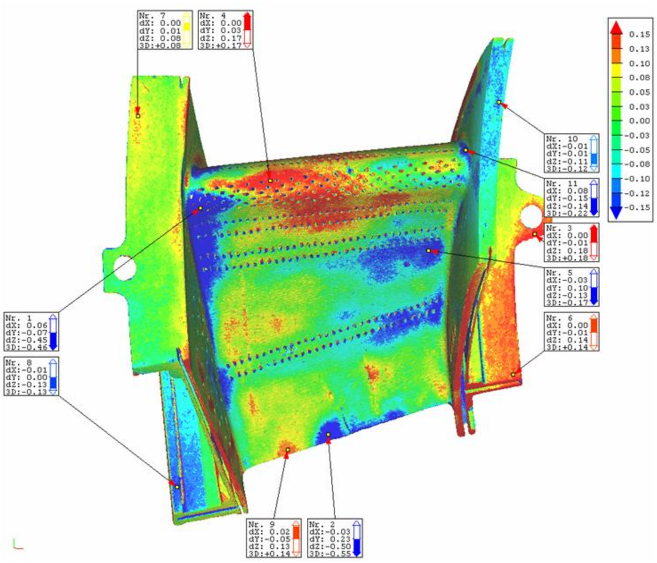


Picture 10 **After digitising, also different intersections of the scanned part can be calculated – inevitable to adjust actual and nominal geometry**



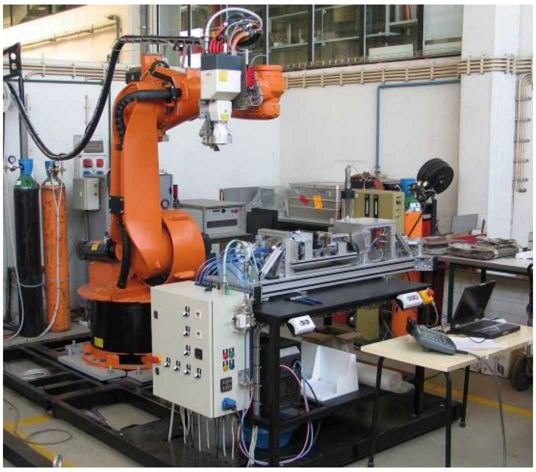
Picture 11 **The digital representation of the airfoil.**

For the inspection this geometry is then compared to CAD data where available or to accordingly digitised data from a master part. The comparison identifies and localises damaged areas on the surface of the scanned part. To have defined boundaries, the damaged areas are milled out.



Picture 12 **The comparison of the actual scanned part with the nominal geometry reveals where the part shows signs of wear and the (damaged) areas to be restored.**

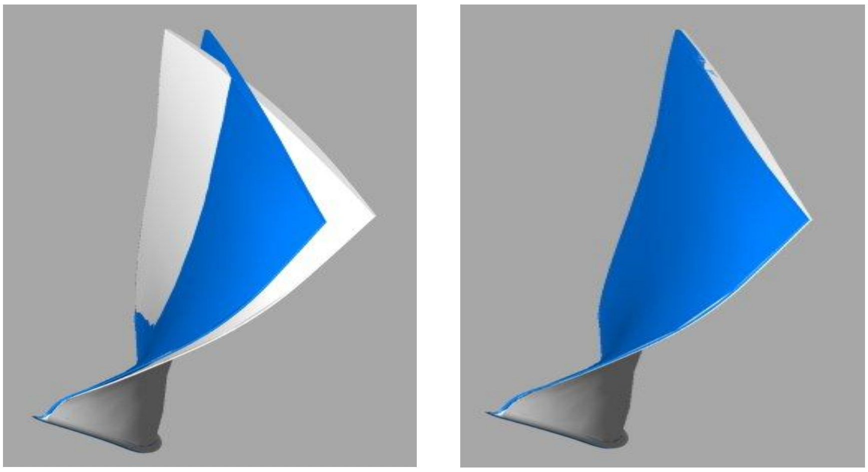
During the next step, material is added until the target shape is fully covered. This is done by build-up laser welding or laser cladding. Especially the tip build up welding proved to be demanding and required testing of numerous welding strategies. Finally a welding strategy was developed which delivered acceptable results.



Picture 13 **Robotic cells for laser welding at ISQ. Two different strategies were tested: First to have the part fixed in a cradle and moving the robot only and secondly moving the part coordinated with the movement of the welding robot.**

Picture 14 **Some welding results during the second period. Especially the leading and the trailing edge points were a challenging task to be solved. In the course of trials, the results improved significantly.**

After welding, the part has to be milled. With milling, the nominal shape of the surface has to be restored. Thus, CAD data or nominal data from the master part and the geometry of the actual part need to be adapted to have a smooth transition between the surface areas.



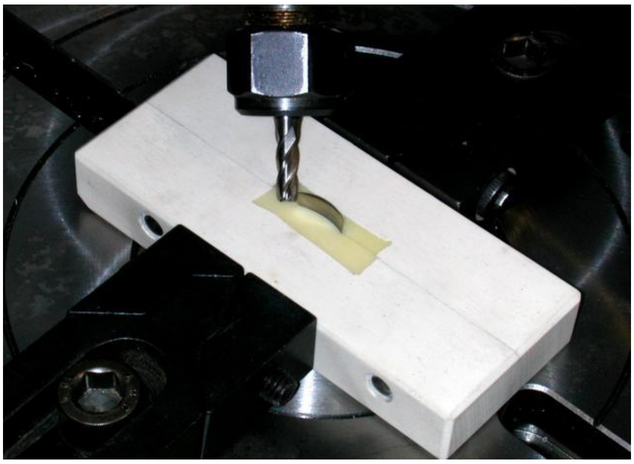
Picture 15 **The adaptation of actual (blue) and nominal geometry of a blade.**

Additionally precise positioning is mandatory. The positioning of the part and additional measurement points are taken with the help of tactile measuring. Milling and grinding complete the front end AROSATEC process.

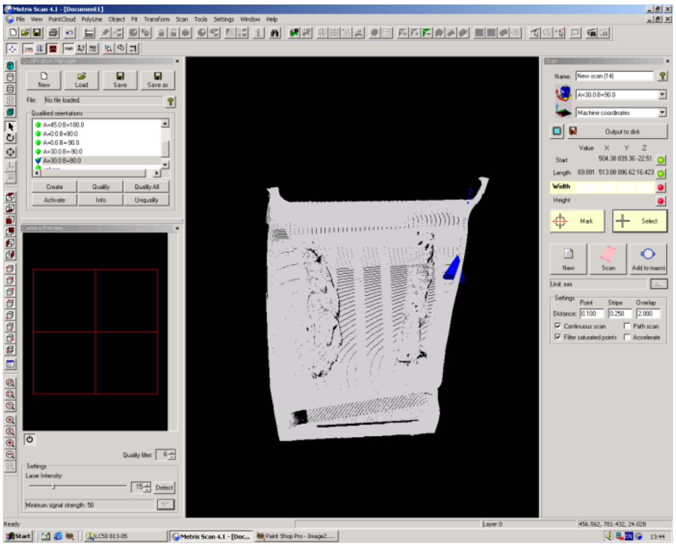
Picture 16 **Touch-trigger-probing, a form of high accuracy tactile measurement, of characteristic points to check for the part's positioning**

Picture 17 **Machining of the z-shaped interlocks, another challenging task. The interlocks can only be milled and grinded with highly specialised tooling and require a high working effort.**

Picture 18 **The machining cell at BCT**



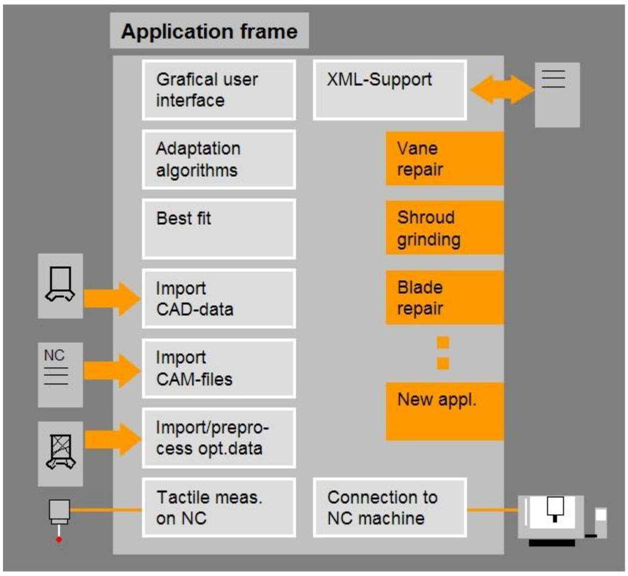
Picture 19 **A compressor blade tip being milled. Due to its size, special methods of fixture had to be employed.**



Picture 20 Automated detection of the welded areas on a training part in the shape of an airfoil and display by the software system

The described process runs on the second – and probably most important – achievement of AROSATEC: the data backbone. Every individual step of the repair process uses and creates a data flow.

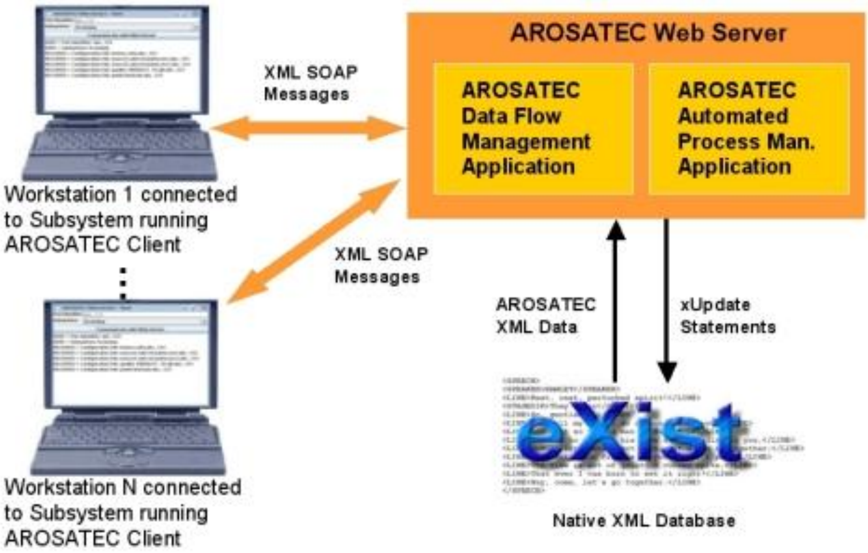
For every type of blade, nominal geometries are required, either from CAD or calculated based on the scanning of a new or unused master part. The nominal geometries serve as reference when calculating part to part deviations actually in charge. Every part creates a new set of data files, from the incoming inspection to the final inspection. The AROSATEC advantage is that these data files are generated once and can then be used in all relevant repair steps. The interaction between incoming and outgoing data is complex.



Picture 21 Application framework supporting the development of new repair strategies

Especially the question for a data standard had to be answered. This question turned out to be of major importance, as the data standard could limit the applicability of the AROSATEC process to certain machines / tools and thus could be counterproductive.

The solution was found in XML, allowing the definition of open data formats which could serve directly as input file for machines as well as original for translation to specific formats. The greatest advantage of XML is the universal applicability, as it is set up in ASCII and could be read by humans and by machines.



5 Planned exploitation

Especially the industrial end users, MTU and SIFCO, were expected to exploit the AROSATEC process. But of course, all other participants exploit the results, too.

During project implementation especially the gain of knowledge and experience in international cooperation and the constitution of a new network became a clear benefit to the partners. Although this cannot be quantified, the partners view this as clear benefit and will make use of this when preparing and implementing further projects.

Looking at more tangible results, every partner has identified ways of exploitation of AROSATEC. To sum it up, the new scanners developed in AROSATEC and the improved scanning strategies are already in use for other projects and are basis for further development. Also welding solutions are employed for executing other tasks. The optimised milling strategies and new milling technologies will be used in succeeding projects as well as the XML-based program interfaces. Additionally the ability to grind turbine shrouds was acquired and is expected to be offered to the market after some further refinement.

But what is most important, is the way the AROSATEC industrial end users exploit the results: SIFCO, an aero turbine engine components repair shop, will utilise some of the adaptive machining processes improved in AROSATEC. To MTU, who also already have turbine blade repair processes, the AROSATEC data backbone and the data flow as developed during the project are the primary choice for exploitation and will be employed soon.