SOMMACT

PROJECT FINAL REPORT

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1 Executive summary

SOMMACT develops and validates an innovative production hardware and control system founded on understanding, evaluating and controlling large machine tools production performances.

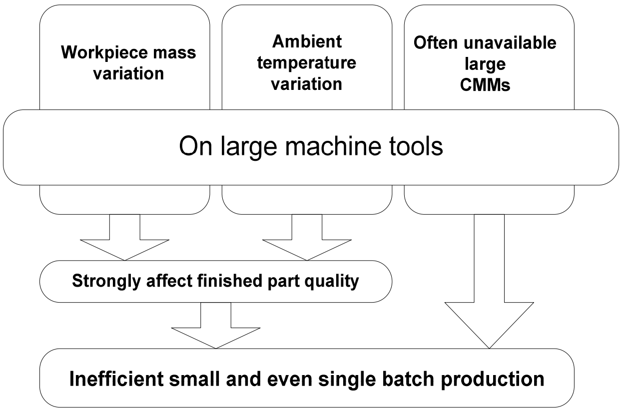


Figure 1.1 – The problems to be solved

Small and single batch production, particularly for large (some cubic metres), heavy (several tons), and complex workpieces, is still a challenge for machine tools users (see Figure 1.1).

To achieve high product quality, timely QC (Quality Control)-production loops are required, which are inefficient and expensive.

The organisation and sequencing is also difficult because the process performance practical knowledge is almost unavailable. As a consequence, this type of production is still affected by inefficiencies and waste (energy, raw material and time).

SOMMACT approaches these issues by the detection (in-process embedded traceable measurements) and compensation (adaptive control and self-learning) of geometrical effects of varying external and internal quantities, such as temperature gradients and workpiece mass (see Figure 1.2).

The SOMMACT vision is based on three pillars:

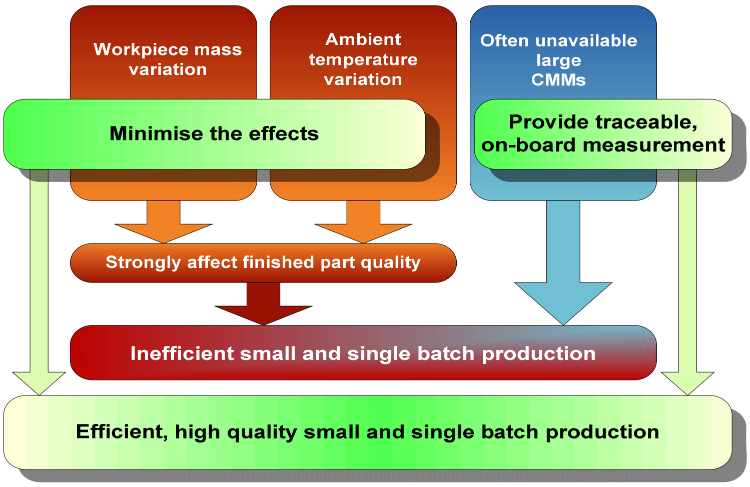


Figure 1.2 – SOMMACT approach

1. A new metrological concept to enhance the measuring capabilities of machine tools, to monitor their geometrical deformations reliably and to inspect machined parts characteristics traceably.
2. Enhanced sensor systems, measuring the 6 degrees of freedom (dof) of each machine component, and a control system integrating machine and workpiece data with environment and load conditions, and adapting machining accordingly.
3. A self-learning model of the system performance, accumulating knowledge on the machine behaviour, based on calibration and real-time measurement data, and on their relationship with workpiece characteristics (e.g. mass).

The advantages are an improved product quality at competitive costs, and a prediction capability of the system performances based on an increasingly reliable model.

The machine tool measuring capabilities are enhanced to the point that it can be used as a Coordinate Measuring Machine (CMM). This (i) avoids or reduces QC-production loops, (ii) provides workpiece traceable measurement results and (iii) inputs valuable data into the self-learning core.

SOMMACT measures the effects of process disturbances on geometric errors of individual machine components, store the corresponding data, associate them with corresponding known disturbances (e.g. ambient temperature and workpiece mass) and apply quasi real-time adaptation of geometric compensation tables under the supervision of the self-learning core.

Self-optimisation methods are applied to steadily improve the product quality. Individual stored geometric errors are combined with (i) on-board workpiece measurement results, (ii) possible independent CMM measurement results, (iii) timely, swift re-tuning data and (iv) possible full recalibration data.

2 Project context and objectives

2.1 Challenges within the current industrial context

2.1.1 State-of-the-art of relevant technology

At very early project stage, a thorough analysis of the State-of-the Art (SoA) provided very valuable information related to five main areas: (i) Metrological design, (ii) Calibration and benchmarking, (iii) Error modelling and compensation, (iv) Supervision and self-optimisation and (v) Communications.

Relevant information was constantly updated during the project execution. A knowledge-base of 137 very valuable documents is now available to SOMMACT project partners on the project private web-site area.

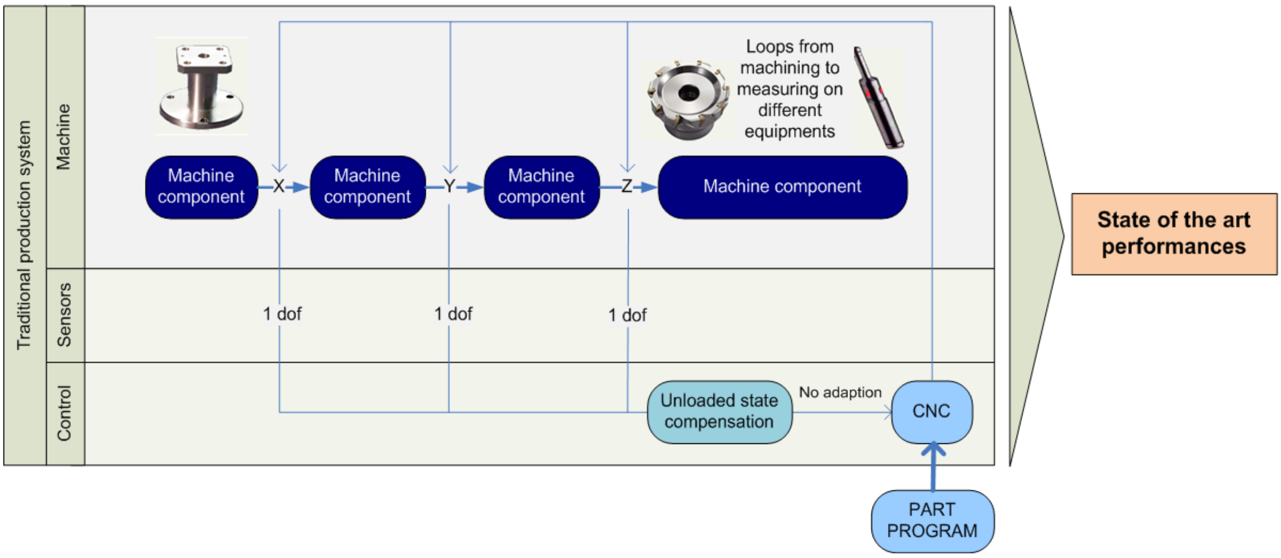


Figure 2.1 – SoA system architecture

Figure 2.1 summarises the system architecture of SoA numerical compensation of machine tools, extracted from Figure 1.5 of the project Description of Works (DoW). It is here reported that, in practical terms, no significant advancement with respect to the originally reported situation has been made available to the industry at large.

2.1.2 Present context in the numerical compensation of geometric errors

At present, machine tools (MT) undergo calibration procedures just once or few times in their lifespan: after their first installation in production environments or after major accidents/adverse events. Despite this, machine tool accuracy sensibly varies according to external factors like (i) foundations stabilization, (ii) environmental temperature variation and (iii) workpiece mass variations which directly induce deformations in the MT structural components.

The application of numerical compensation of geometric errors is typically applied with the specific (and limited) objective to comply with the prescriptions set forth by machine-tool specific national and International Standards that only specify maximum permissible limits for each individual error.

The systematic application of the error compensation functionality can significantly improve the final machined part quality but, at present, its effective use by machine tool manufacturers is still not widespread and typically limited to the few cases when the end user specifically makes request of it. This is mainly due to the fact that currently:

a) Technological knowledge on the subject is very limited;
b) CNCs manufacturers clearly state that they provide the functionality “as is” and they are neither involved with MT error determination, nor with the validation of the effectiveness of applied compensation;

c) There is a lack of accessible tools (both from the ease of use and from the cost point of view) capable to provide the user with an adequate support to measure and calculate the actual compensation values to be fed into the CNC.

2.1.3 Market awareness

Even if state-of-the-art solutions for the numerical compensation of geometric errors are implemented by the major CNC vendors, market awareness on their availability is still very limited (source: CNCs application engineers). The main reasons for this situation can be identified on one side on the intrinsic complexity of the topic and on the other side on the lack of accessible tools (both from the ease of use and from the cost point of view) capable to fill this gap.

2.1.4 Lack of support for the determination of geometric errors and for the validation of the effectiveness of applied compensations

At present, CNC manufacturers clearly state that their responsibility is limited to providing algorithms for the (volumetric) compensation of geometric errors. They are not involved neither in the determination (measurement) of such errors, nor in the validation of the effectiveness of the relevant applied compensations. The result is that volumetric compensation solutions are applied only in those cases where the end user (e.g. aeronautic parts production industries) specifically requests the enhanced machine tool geometric performances that can only be attained by the application of such compensation strategies.

2.1.5 Current methods for on-machine inspection

Industrially applied methods for large workpiece measurements are either not very sophisticated or very time consuming. Often, only simple one-dimensional measurements can be conducted with callipers or other gauges. This type of equipment is inherently lacking the required flexibility and accuracy for many of the high-tech parts which are produced at the end users. Manual measurements are furthermore prone to handling errors. Measurement data are typically manually recorded and the collation of such data to compose the workpiece measurement report is prone to typing errors and it is time consuming.

For more complex measurements, sophisticated but expensive Coordinate Measuring Machines (CMMs) are indispensible. However, the process of unclamping the part and setting it up on the CMM is very time-consuming, especially for large high-value parts. Many manufacturing enterprises, of which a large share are SMEs, cannot even afford a CMM.

2.2 SOMMACT responses to existing industrial challenges

2.2.1 Performance/research indicators

SOMMACT *measures* the effects of process disturbances on geometric errors of individual machine components, store the corresponding data and associate them with corresponding known disturbances (e.g. ambient temperature and workpiece mass), and apply quasi real-time adaptation of geometric compensation tables under the supervision of the self-learning core.

Self-optimisation methods are applied to steadily improve the product quality. Individual stored geometric error data are combined with:

- On-board workpiece measurement results;
- Independent CMM measurement results;
- Timely, swift re-tuning data and
- Possible full recalibration data.

All SOMMACT performances were thoroughly tested on a real 5-axis machine tool.

The following scheme summarises the SOMMACT advancements over the state of the art:

State of the Art	SOMMACT Advancement
Static geometrical compensation;	Quasi real-time adaptation of Compensation;
On-board metrological system (position sensors, 1 dof) calibrated only at commissioning or at subsequent, rarely performed and expensive recalibrations;	A new metrology system enabling periodic machine recalibration in loaded conditions; the self-learnig core predicts optimal recalibration time
Virtually no capability of performing traceable geometrical workpiece measurements;	Traceability of measurement either by swift, partial recalibration prior to workpiece measurement, or by "learned" metrological system behaviour;
1 dof position sensor system;	Enhanced knowledge of quasi-real time machine geometry, thanks to the 6 dof sensors equipping each machine component;
No correlation among data on calibration, workpiece features, environment, workpiece measurement results and actual machine performaces;	SOMMACT built-in capabilities to correlate all such data to each other;
No self-learning, nor adapting capability;	SOMMACT offers adaptability and self-learning capabilities, both as an independent system and as integrated into a production management system;
No prediction capability;	Prediction capabilities of machine response to varying production conditions and application of virtual metrology methods.
Europe as provider of mature machining systems	**EU-MADE adaptive self-learning SOMMACT system**

2.2.2 Building market awareness

Market awareness on available solutions for the numerical compensation of geometric errors is still very limited. This problem has been tackled within SOMMACT project by allocating significant resources to the generation of a high-level informative document to be published by ISO (International Standard Organization) as ISO/TR 16907 – *Numerical compensation of geometric errors of machine tools*.

Such document is being drafted under the leadership of the SOMMACT project technical coordinator. Its publication is expected by beginning of year 2014.

2.2.3 Advanced solutions for numerical compensation of geometric errors

2.2.3.1 Determination of geometric errors and validation of the effectiveness of applied numerical compensation

At present, the measurement of geometric errors is typically performed by specialised service providers that apply expensive equipment and tend to avoid transferring their (valuable) knowledge to the machine tool manufacturers.

The result is that volumetric compensation solutions are applied only in those cases where the end user specifically requests the enhanced machine tool geometric performances that can only be attained by the application of such compensation strategies.

The SOMMACT project outcomes show that excellent results can also be achieved by the appropriate use of measuring instruments that are typically available at the machine tool manufacturer's final assembly facilities when used in conjunction with:

- The application of adequate, pre-defined measurement strategies;
- Automatic acquisition of the measurement data output from conventional measuring instruments (e.g. inclinometers);
- Automatic acquisition and conversion of the output format of measurements performed by commonly available laser interferometers to conform to the CNC volumetric compensation files format.
- Assisted validation of the effectiveness of applied compensations.

Within SOMMACT project, a comprehensive tool kit of solutions has been developed to assist the machine tool manufacturers, the service providers and the end users, in the efficient and effective determination and compensation of geometric errors.

2.2.3.2 Application of the rigid-body model on the machine tool in its unloaded state

State-of-the-art compensation strategies offered by CNC manufactures are based on the application of the rigid body model and on measurement and compensation of geometric errors that are determined with the machine tool in its unloaded state. SOMMACT project results show that the rigid body model cannot be applied to adequately compensate geometric errors deriving from the effective use of the machine tool, especially when the mass of the workpiece is significant.

Within SOMMACT project, significant resources were devoted to develop and successfully validate a new geometric error compensation strategy that effectively compensates the non-rigid body behaviours of the machine tool and compensates for the variation of such non-rigid body behaviours in response to workpiece mass variations and to ambient temperature variations.

2.2.4 Traceable on-machine inspection

With SOMMACT, the machine tool geometric accuracy is enhanced to a point that makes it compatible to the performances of Coordinate Measuring Machines (CMM) of comparable size that are available on the market.

Thanks to the integration of the high accuracy RENISHAW RMP600 radio transmission touch-trigger probe and the DELCAM *PowerInspect OMV Pro* software application, the user of the enhanced SOMMACT machine tool has the on-machine availability of virtually all functionalities that are available on CMMs.

Traceability of measurement results is obtained by the use of novel, calibrated, carbon fibre reference artefacts (see Figure 2.2) that were specifically designed and developed for application at the workshop level.

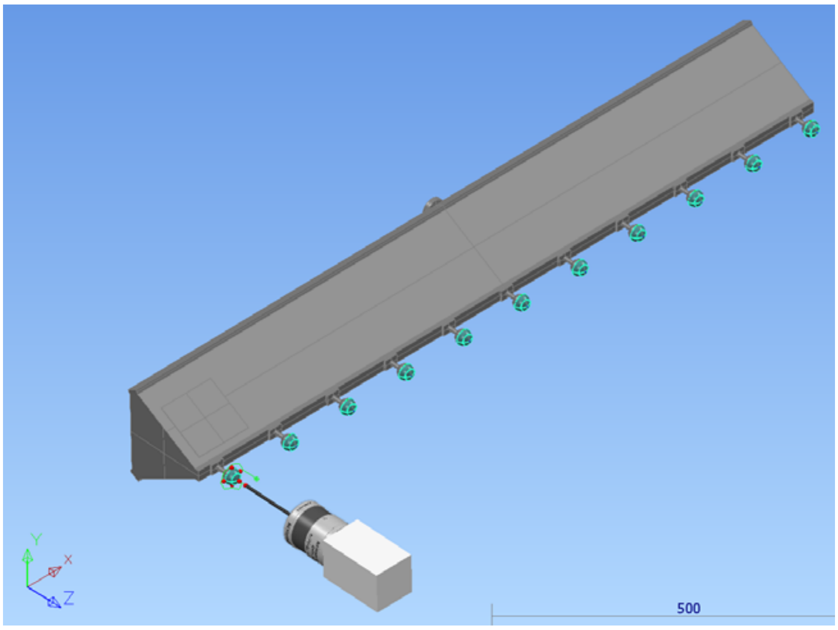


Figure 2.2 – Example of newly developed carbon fibre reference artefact

3 Description of main S&T results/foregrounds

3.1 Specific measurable objectives attained by the project

The SOMMACT project successfully attained all specific, measurable objectives that were set forth in the Description of Work (DoW). Considerations on these objectives are reported in the following sections, maintaining the original sequence in which they were listed in the DoW.

3.1.1 Enhanced machining accuracy

Machine tool (MT) geometric errors are directly transferred to machined workpiece quality. Relevant measurement results show that such errors, in usual workshop conditions and with variable workpiece load, will be reduced by more than 75%, provided machining good practice is applied. This objective is reached through the cumulative application of all newly developed technologies and its validation derives from the analysis of an outstanding amount of data collected during demonstration activities. Such data are thoroughly documented in Deliverable D5.6 – *Final Measurements Report*.

For the convenience of the reader, all major non-confidential information is reported here with the specific intention of highlighting the fact that the SOMMACT project has been conducted with ***innovation*** in mind and that significant resources have been devoted to effectively validate the project outcomes.

The significant number of project exploitable results that were generated show that this was the right strategy.

In the following, information is provided on the methods and procedures that were applied for the effective validation of SOMMACT project results.

3.1.1.1 Plan for the validation of the project outcomes

At proposal stage, a clear definition of the activities that should be performed for appropriate demonstration of project outcomes was prepared and it is depicted in Figure 3.1 (shown in next page).

At very early project stage, very valuable information were defined and reported in Deliverable D2.4 – *Specification of the validation plan of the adopted technical solution*. The document thoroughly addressed the following topics:

1. *Identification of critical issues*, including: (i) economic issues, (ii) feasibility issues and practical constraints, (iii) selection of possible sensors systems and embedded reference frames setups and (iv) identification of critical error functions and parameters;
2. *Demonstrator requirements*, including preliminary specification related to: (i) the demonstrator machine tool and its foundation, (ii) the thermally controlled environment, (iii) the loading/unloading facilities for different masses, (iv) the anthropomorphic robot, (v) the self-centring probe and (vi) on-machine inspection facilities including probe and measuring software;
3. *Determination of the effectiveness of the demonstrator test chamber*;
4. *Thermal characterization of the demonstrator machine tool*;
5. *Standard geometric performance and functional tests*;
6. *Preliminary specifications for mass variation tests*;
7. *Preliminary specifications for ambient temperature variation tests*;
8. *Preliminary determination of sensitivity of error functions to mass variation*;
9. *Preliminary repeatability and stability tests*;
10. *Validation of state-of-the-art (SoA) compensations*;
11. *Determination of SoA on-board inspection performances*;
12. *Individual sensor systems/artefacts preliminary validation tests*;
13. *Individual software modules validation*;
14. *Individual and collective validation of SOMMACT project concepts*, including: (i) stabilisation of machine tool performance under variable workpiece mass, (ii) stabilisation of machine tool performance under variable ambient conditions, (iii) performance, stability and traceability of on-

machine inspection facilities, (iv) assistance to the operator for re-tuning and re-calibration decision making and (v) prediction of machining performances.

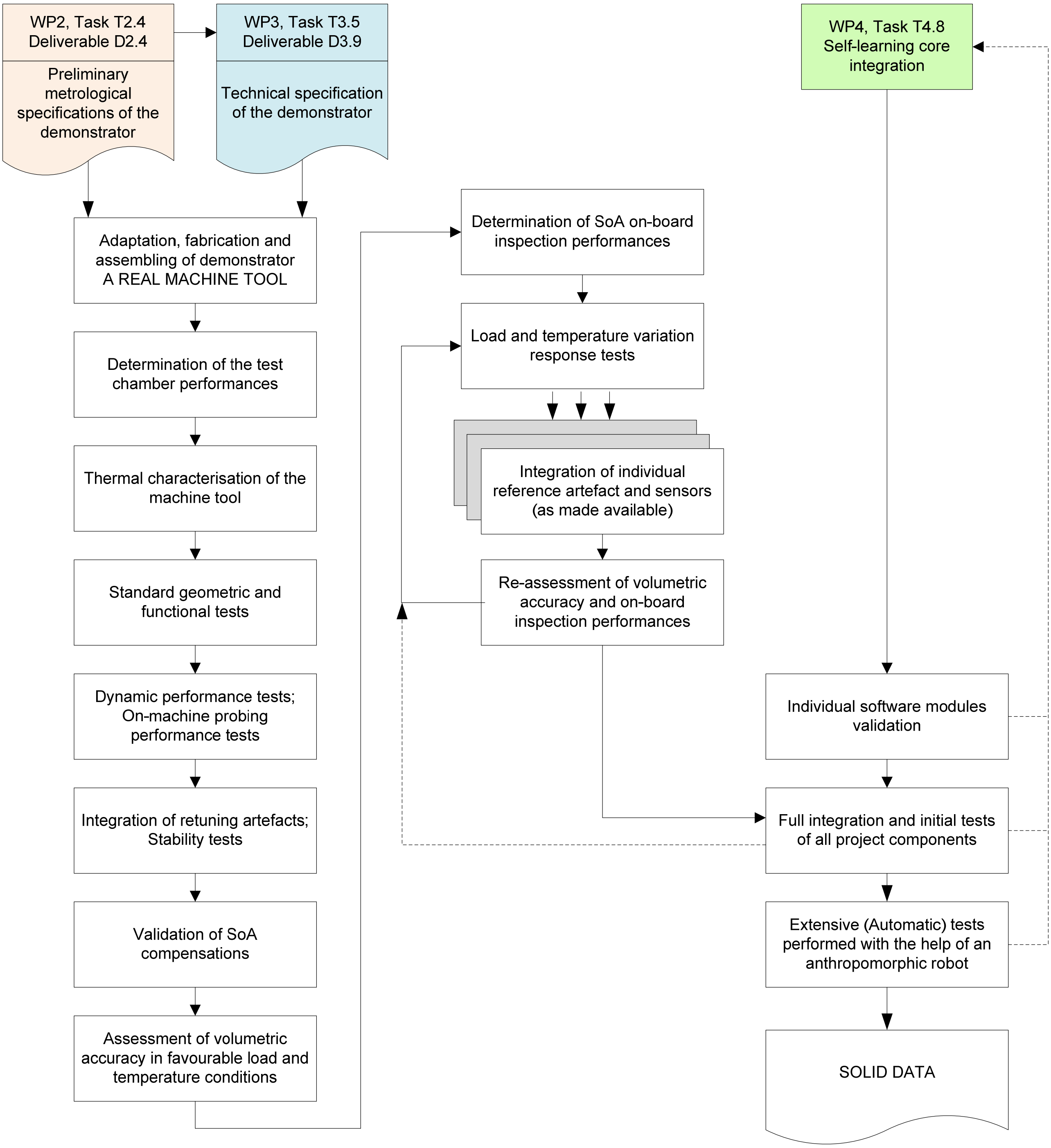


Figure 3.1 – SOMMACT project simplified validation flow-chart (adaptation of Figure 1.20 of the DoW)

3.1.1.2 SOMMACT project demonstrator

The SOMMACT project demonstrator prototype has been made available by end of March 2011. It complies with the requirements set forth in Deliverable D3.9 — *Technical specification of the demonstrator.*

The project demonstrator (see Figure 3.2) includes:

- A real, fully operational 5-axes machine tool including CNC, PLC, servomotors, drives and their interconnections;
- A suitable foundation;
- A “tool kit” combining reference artefacts and sensor systems capable to measure geometric variation of the machine tool structure (or of part of it);
- A thermally controlled test chamber capable to impose significant thermal environment variations (see Figure 3.3);
- Loading and unloading facilities for different masses;
- A self-centring probe;
- On-machine inspection facilities including touch trigger probe and measuring software.

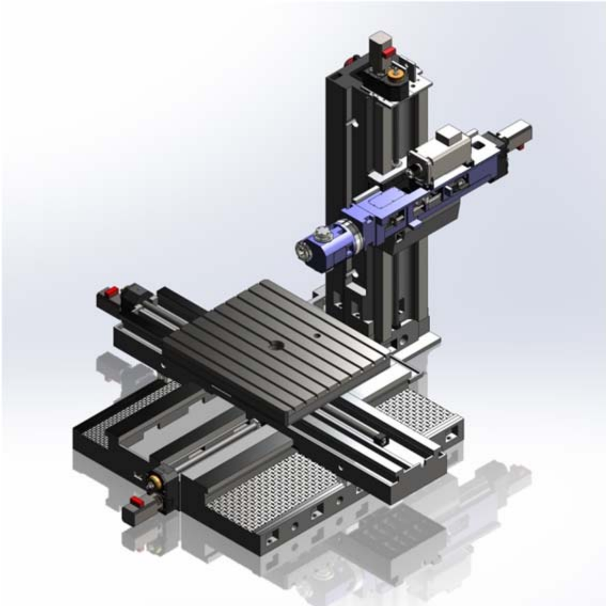


Figure 3.2 – 3D representation of the SOMMACT project demonstrator machine tool

Figure 3.3 – SOMMACT demonstrator test chamber with mass loading-unloading facilities

3.1.1.3 Mass variation tests

A preliminary test procedure was established and is outlined in Figure 3.4, where the expression: “applicable measurements” refers to the measurements that will be required for the specific purpose of the various tests that should be performed throughout the demonstration activities.

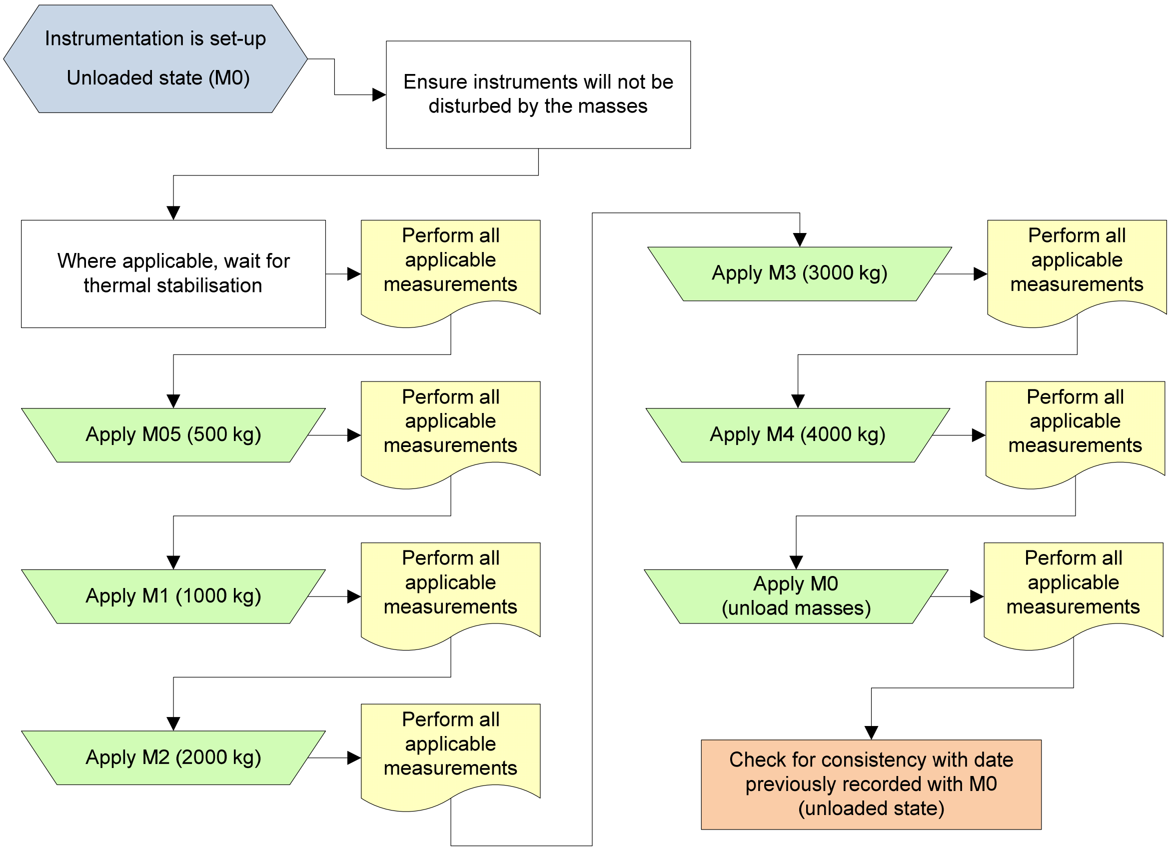


Figure 3.4 – Outline of mass variation test procedure

At the erection of the demonstrator system, considerations were made to the fact that the use of the 500 kg mass would have significantly lengthen the time required for the application of the procedure and would have increased the overall required Y-axis stroke. Furthermore, preliminary tests showed that the error motion variations corresponding to such load is very low. All tests were therefore performed applying different masses with 1 000 kg steps.

3.1.1.4 Combined mass variation and ambient temperature variation tests

These tests were conducted according to the sequence foreseen in section 14.4 of Deliverable D2.4. Figure 3.5 is the exact reproduction of Figure 17 of such document.

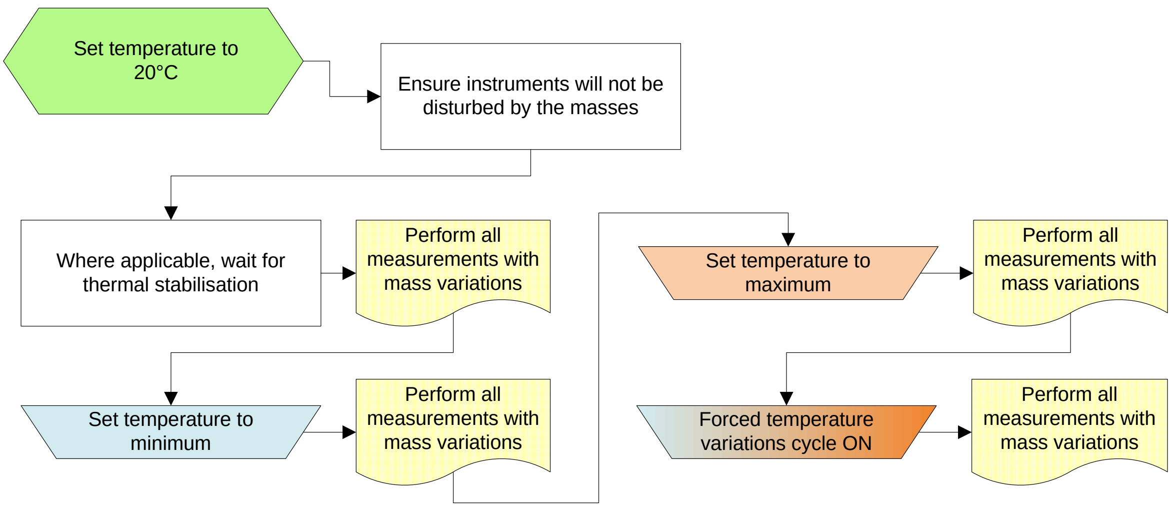


Figure 3.5 – Sequence for tests under combined mass and ambient temperature variations

Ambient temperature conditions are permanently monitored by the newly developed *TempSpy* system that is based on the application of 1-wire bus thermometers. The system can simultaneously collect data from up to 255 sensors.

The system provides for convenient graphical display of measured temperature data (see Figure 3.6) that are stored in the SLC database.

TempSpy recorded data are used by the SLC to derive <*Last_period*> ambient temperature trend analysis to be associated to all performed geometric errors measurements.

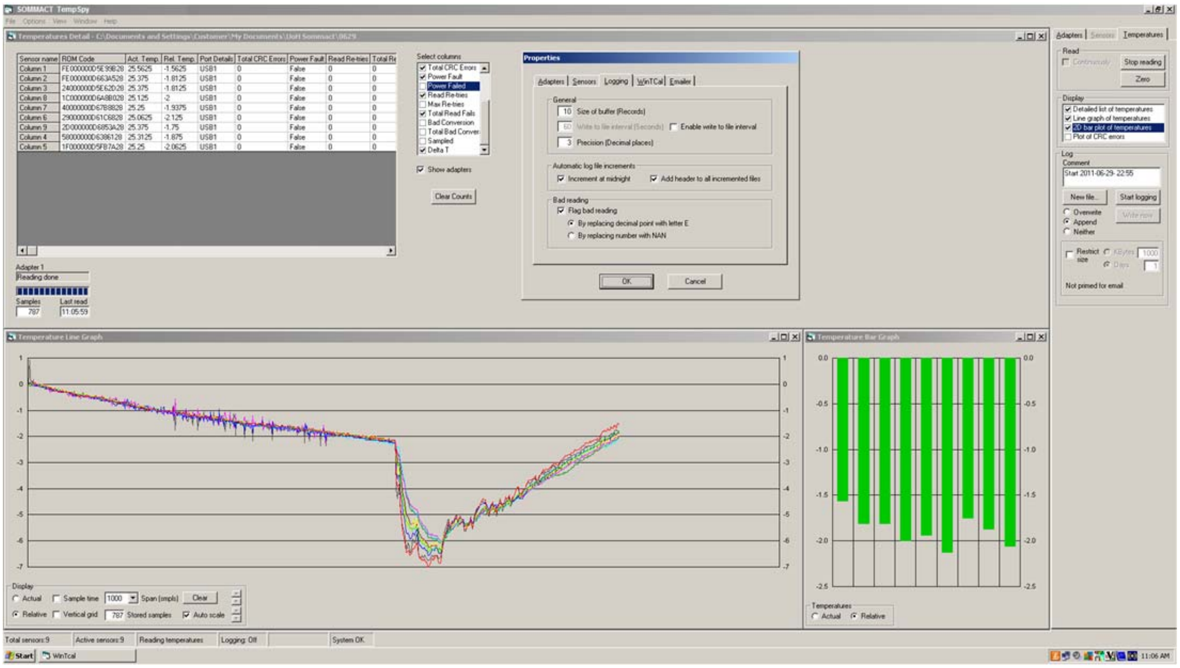


Figure 3.6 – Example of *TempSpy* screen shot

3.1.1.5 Design of measurement procedures

The proper definition and formal application of measurement procedures is an indispensable condition for the obtainment of robust measurement results.

At very early project stage, SUPSI and TTS developed supporting software tools that allow to:

- Define the specific error(s) to be measured;
- Specify sensors and/or measurement instruments to be applied and characterize them;
- Specify measurement conditions;
- Define measurement points sequence;
- Generate the part-program for automatic CNC execution;
- Perform, were applicable, automatic acquisition of measurement data.

3.1.1.6 Automatic execution of measurement procedures

SUPSI and TTS developed a specific software tool for the design of job lists that allow performing different measurement procedures in batch mode.

Thanks to this very valuable tool it is possible, for example, to perform a pre-defined sequence of measurements while the temperature is forced to vary within a specified range.

The job list is executed in unmanned mode.

At the end of the execution of each individual measurement procedures, the SLC automatically stores the results in its database and, at termination of all procedures specified in the job list, sends the results as attachment to an e-mail message addressed to SUPSI, TTS and ALESAMONTI researchers.

3.1.1.7 Estimation of measurement uncertainty

Proper estimation of measurement uncertainty is a must.

To this purpose, INRIM provided specific training to SUPSI, TTS and ALESAMONTI researchers on the estimation of measurement uncertainty to be (i) associated to each individual measurement result and (ii) stored in the SLC database for subsequent processing (e.g.: similarity analysis to be applied by the Self-Optimising core).

3.1.1.8 Analysis of measurement results and conversion into compensation tables

A clear distinction is made between deviations measured by different sensors, sensors systems and/or measurement instruments, and the relevant error functions that can be derived or inferred from the analysis of such measured deviations, through the application of an appropriate mathematical model.

3.1.2 Traceable on-machine inspection capabilities

This objective is fully attained and documented in section 2.7 of Deliverable D5.6. The SOMMACT machine tool with numerically compensated geometric errors, equipped with adequate touch-trigger probe and relevant inspection software, provides on-machine inspection facilities that were typically available only on Coordinate Measuring Machines (CMM). Traceability is insured by the application of newly developed calibrated reference artefacts.

The SOMMACT demonstrator machine is equipped with a RENISHAW RMP600 wireless touch-trigger probe and with the DELCAM *PowerInspect OMV-PRO* measuring software.

The touch-trigger probe is used in conjunction with two available reference artefacts: a 3D reference ball beam (see Figure 3.7) and a 3-spheres squareness reference artefact (see Figure 3.8).

The mathematical models of the two reference artefacts are available and exactly represent the relative spatial coordinates of the artefacts reference spheres as defined in the relevant calibration certificate. The inspection software allows to:

- Select the features to be measured;
- Define relevant probing strategy;
- Simulate all the relative motions between the touch trigger probe and the workpiece;
- Generate the measurement part-program to be sent to the CNC;
- Retrieve individual probing points coordinates recorded by the CNC;
- Compare results to the mathematical model and generate the corresponding measurement report.

Figure 3.7 – The 3D reference beam directly applied to the demonstrator test masses

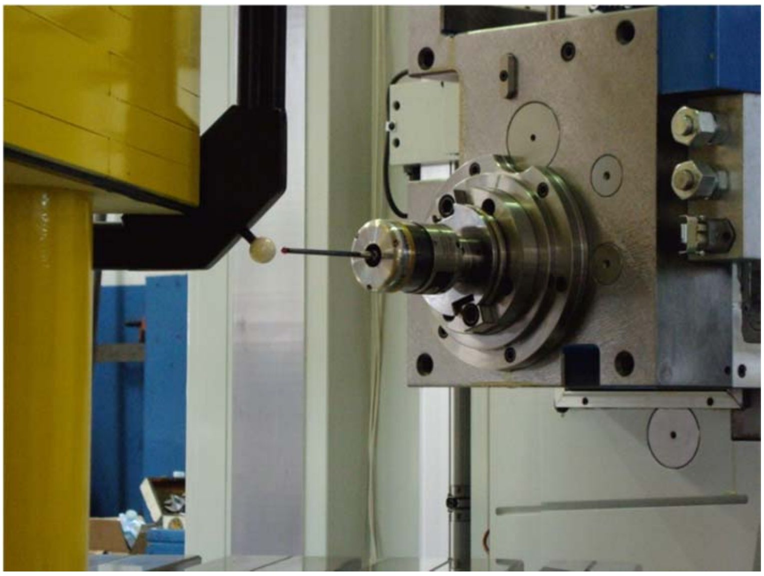


Figure 3.8 – RMP600 touch-trigger probe measuring the 3-spheres reference artefact

Very fast and effective measurements on reference artefacts can be performed through the application of the IBS PE newly developed ruggedized self-centring probe (see Figure 3.9).

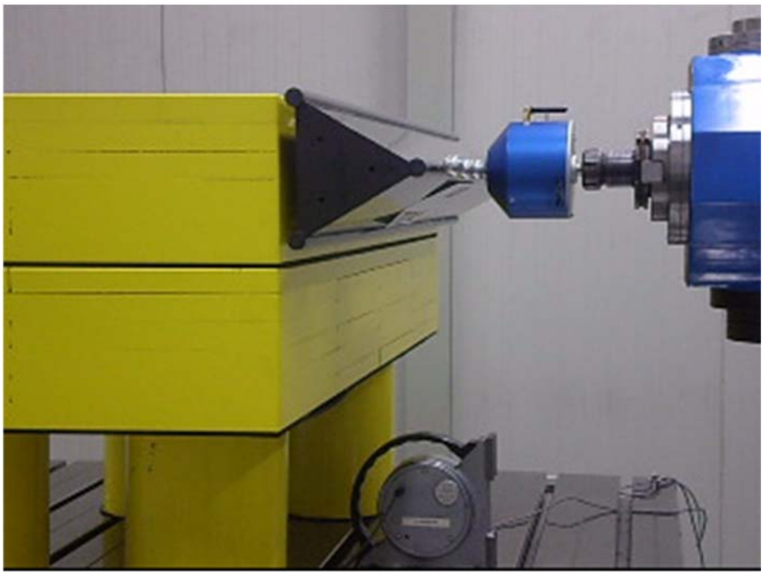


Figure 3.9 – The wireless self-centring probe on the SOMMACT demonstrator

The self-centring probe system allows to:

- Calibrate the orientation of the probe with respect to the machine tool coordinate system;
- Determine the position and orientation of the reference beam coordinate system;
- Generate the CNC part-program for the fully automatic measurement of the reference beam;
- Automatically acquire the deviations between the nominal spatial coordinates of each one of the reference beam spheres centres with respect to the nominal coordinates read from the reference beam Calibration Certificate;
- Perform direct evaluation of positioning errors along the axis under test, as well as the evaluation of straightness errors in two orthogonal planes.

3.1.3 Measurement of 6 degrees of freedom

A valuable tool kit of solutions has been integrated and validated on the SOMMACT demonstrator machine tool. It allows for multiple choices of equipment and methods to be applied to suit different machine types and sizes. Additional costs for the foreseen industrialized solutions are computed to be less than 10% of the overall machine costs. Most of the solutions that compose the tool kit are retrofittable to existing MTs, provided such MTs are equipped with recent CNCs.

This document briefly describes publishable information on some relevant SOMMACT tool kit components.

The description of solutions that have been the object of patent applications are minimised in order to ensure appropriate IPR protection.

3.1.3.1 Overview of linear axes error motions and relevant on-machine assessment solutions

An overview is provided on:

- SOMMACT tool kit solutions deemed to be applicable to individual axes of liner motion;
- Sensitivity of individual error motions to mass and temperature variations and
- Possible solutions that could be implemented in subsequent industrialised SOMMACT versions.

The identification of error motions of the machine tool axes of linear motion complies with ISO 230-1:2012 prescriptions (see Figure 3.10).

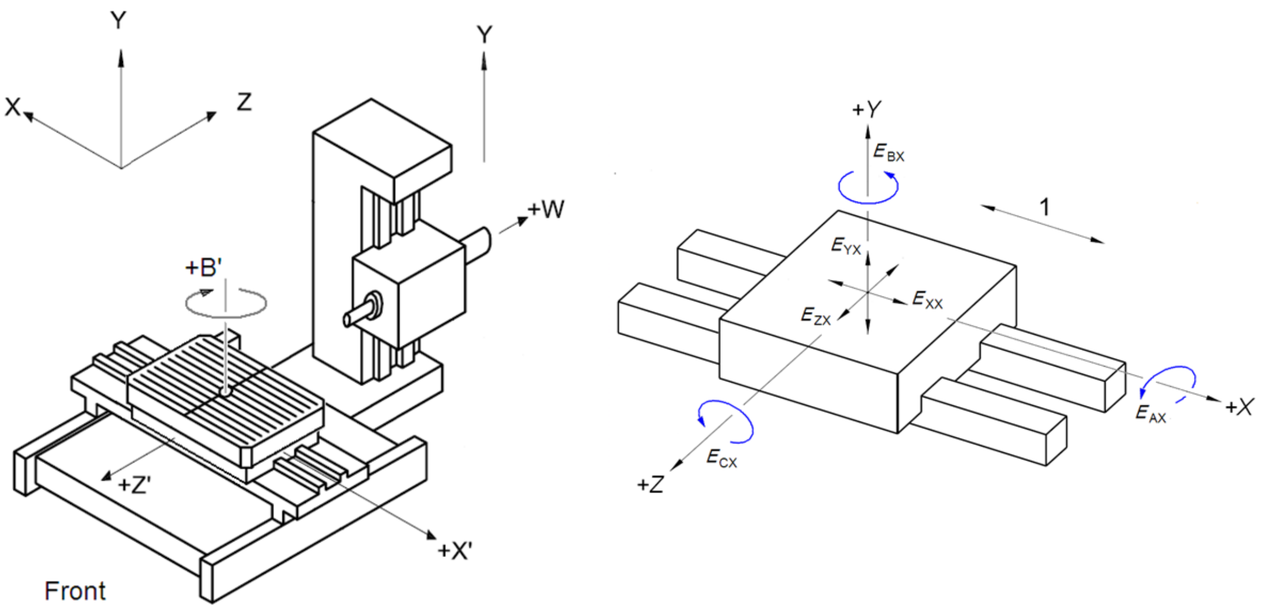


Figure3.10 – Axes identification and error motions nomenclature

In the following, considerations are provided for each individual SOMMACT demonstrator axes of motion.

3.1.3.2 X'-axis

This is the first linear axis in the SOMMACT demonstrator kinematic chain. Individual angular and translational error motions are discussed in Table 1.

Table 1 – X'-axis error motions overview

Error function and description	*Topic*	*Description and foreseen actions*
E_{XX} Positioning error motion	Applicable on-machine assessment	The existing linear positioning transducer will be stabilised for thermal influences applying a minimum of two PT100 thermometers. The BiSLIDER solution is tested here. Invariant scale tested on Y-axis is, in principle, also applicable.
	Sensitivity to:	Temperature variation: high. Mass variation: medium to low.
	Possible industrialised version solutions	(i) temperature stabilisation; (ii) invariant scale or (iii) *BiSLIDER*.
E_{ZX} Straightness in Z-axis direction	Applicable on-machine assessment	Inferred from (possible) yaw error motion measurements. Inferred from (possible) guides temperature measurements (tested on Y-axis).
	Sensitivity to:	Temperature variation: medium. Mass variation: medium to low.
	Possible industrialised version solutions	Inferred from (possible) yaw error motion measurements. Inferred from (possible) guides temperature measurements.
E_{YX} Straightness in Y-axis direction	Applicable on-machine assessment	Inferred from pitch error motion measurements.
	Sensitivity to:	Temperature variation: medium. Mass variation: high.
	Possible industrialised version solutions	Inferred from pitch error motion measurements.
E_{AX} Roll	Applicable on-machine assessment	Inclinometers with differential measurement between workpiece side and tool side.
	Sensitivity to:	Temperature variation: medium. Mass variation: high.
	Possible industrialised version solutions	Inclinometers with differential measurement between workpiece side and tool side
E_{BX} Yaw	Applicable on-machine assessment	Possible differential measurement with two linear positioning transducers (tested on Y-axis)
	Sensitivity to:	Temperature variation: medium to low. Mass variation: low.
	Possible industrialised version solutions	Differential measurement with two linear positioning transducers (depending on effective sensitivity resulting from final demonstration activities)
E_{CX} Pitch	Applicable on-machine assessment	Inclinometers with differential measurement between workpiece side and tool side.
	Sensitivity to:	Temperature variation: medium to low. Mass variation: high.
	Possible industrialised version solutions	Inclinometers with differential measurement between workpiece side and tool side

3.1.3.3 Z'-axis

This is the second linear axis in the SOMMACT demonstrator kinematic chain. Individual angular and translational error motions are discussed in Table 2.

Table 2 – Z'-axis error motions overview

Error function and description	*Topic*	*Description and foreseen actions*
E_{ZZ} Positioning error motion	Applicable on-machine assessment	The existing linear positioning transducer will be stabilised for thermal influences applying a minimum of two PT100 thermometers. Variations resulting from component deformations will be estimated from angular error motion measurements. Invariant scales (tested on Y-axis) and BiSLIDER solution (tested on X-axis) are, in principle, also applicable.
	Sensitivity to:	Temperature variation: high. Mass variation: medium to low.
	Possible industrialised version solutions	(i) temperature stabilisation; (ii) invariant scale or (iii) BiSLIDER.
E_{XZ} Straightness in X-axis direction	Applicable on-machine assessment	Inferred from (possible) yaw error motion measurements. Inferred from (possible) guides temperature gradients measurements (tested on Y-axis).
	Sensitivity to:	Temperature variation: medium. Mass variation: medium to low.
	Possible industrialised version solutions	Inferred from (possible) yaw error motion measurements. Inferred from (possible) guides temperature gradients measurements.
E_{YZ} Straightness in Y-axis direction	Applicable on-machine assessment	Inferred from pitch error motion measurements.
	Sensitivity to:	Temperature variation: medium. Mass variation: high.
	Possible industrialised version solutions	Inferred from pitch error motion measurements.
E_{AZ} Pitch	Applicable on-machine assessment	Inclinometers with differential measurement between workpiece side and tool side.
	Sensitivity to:	Temperature variation: medium. Mass variation: high.
	Possible industrialised version solutions	Inclinometers with differential measurement between workpiece side and tool side
E_{BZ} Yaw	Applicable on-machine assessment	Differential measurement with two linear positioning transducers (tested on Y-axis).
	Sensitivity to:	Temperature variation: medium to low. Mass variation: low.
	Possible industrialised version solutions	Differential measurement with two linear positioning transducers (depending on effective sensitivity resulting from final demonstration activities)
E_{CZ} Roll	Applicable on-machine assessment	Inclinometers with differential measurement between workpiece side and tool side.
	Sensitivity to:	Temperature variation: medium to low. Mass variation: high.
	Possible industrialised version solutions	Inclinometers with differential measurement between workpiece side and tool side

3.1.3.4 Y-axis

This is the third linear axis in the SOMMACT demonstrator kinematic chain. Individual angular and translational error motions are discussed in Table 3.

Table 3 – Y-axis error motions overview

Error function and description	*Topic*	*Description and foreseen actions*
E_{YY} Positioning error motion	Applicable on-machine assessment	The existing linear positioning transducer is stabilised for thermal influences applying three PT100 thermometers. Invariant scale is tested here.
	Sensitivity to:	Temperature variation: high. Mass variation: expected to be insignificant.
	Possible industrialised version solutions	(i) temperature stabilisation; (ii) invariant scale or (iii) BiSLIDER.
E_{ZY} Straightness in Z-axis direction	Applicable on-machine assessment	Inferred from yaw error motion measurements. Inferred here from guides temperature measurements.
	Sensitivity to:	Temperature variation: medium. Mass variation: expected to be insignificant.
	Possible industrialised version solutions	Inferred from (possible) yaw error motion measurements. Inferred from (possible) guides temperature measurements.
E_{XY} Straightness in X-axis direction	Applicable on-machine assessment	Inferred from pitch and roll error motion measurements.
	Sensitivity to:	Temperature variation: medium. Mass variation: medium.
	Possible industrialised version solutions	Inferred from pitch and roll error motion measurements.
E_{AY} Yaw	Applicable on-machine assessment	Inclinometers with differential measurement between workpiece side and tool side. Also compared here with differential measurement with two linear position transducers.
	Sensitivity to:	Temperature variation: medium to high. Mass variation: medium (column tilt is be affected whereas roll variation is very small).
	Possible industrialised version solutions	Inclinometers with differential measurement between workpiece side and tool side.
E_{BY} Roll	Applicable on-machine assessment	Would need measurements with two camera-based taut wire inclinometers (Possibly implemented at a later stage).
	Sensitivity to:	Temperature variation: expected to be low. Mass variation: expected to be insignificant.
	Possible industrialised version solutions	Application of two camera-based taut wire inclinometers or inferred from initial calibration (depending on effective sensitivity resulting from final demonstration activities).
E_{CY} Pitch	Applicable on-machine assessment	Inclinometers with differential measurement between workpiece side and tool side.
	Sensitivity to:	Temperature variation: medium to high. Mass variation: medium (column tilt is affected whereas pitch variation is very small).
	Possible industrialised version solutions	Inclinometers with differential measurement between workpiece side and tool side

3.1.3.5 W-axis

SOMMACT project focuses on the minimization of the effect of mass variation and ambient temperature variation on a three axes machine tool.

In typical milling/boring operations, the W-axis is not used for stringent-tolerance machining: it is positioned at the proper extension then machining is performed moving the Z-axis.

During demonstration activities, the W-axis was used as a very convenient component to allow for programmed variation of (apparent) tool length.

Error functions associated with W-axis were measured and compensated for using state-of-the-art compensation facilities available on the CNC but no attempt was made to investigate the full volumetric effect of W-axis error functions.

3.1.3.6 B'-axis

B'-axis error motions were measured and compensated for using state-of-the-art CNC facilities but it is here recalled that the stabilization of the effect of variable mass and ambient temperature variation on B'-axis was not included in the SOMMACT project scope. Information on such variations, collected during project execution, is expected to constitute an important set of data to be considered in the subsequent industrialisation phase.

During final demonstration activities, the B'-axis was used as an auxiliary device is very effective for the determination of some error motions associated with axes of linear motion.

3.1.3.7 Determination of relative position and orientation between axes of linear motion

In addition to the determination of the 18 error functions associated with Z'-, X'- and Y-axis, full characterisation of the machine tool geometric performance requires additional information on three squareness deviations (orientations) and three parameters identifying drifts in the effective zero position of individual axes.

Squareness between some axes of linear motion is inferred by keeping relevant error motions variations under control (e.g. E_{AY} and E_{AZ} for Y-and Z-axes squareness). Such angular error motions are measured by inclinometers that are referred to the same independent local constant: gravity.

Squareness is periodically re-verified using redundant measurements (where available) and re-tuning artefacts in association with the touch-trigger probe and in association with the ruggedized version of the self-centring probe. Partial (local) information on linear axes squareness is also inferred using specifically designed measurement sequences employing the B'-axis.

Axes relative zero position drifts are kept under control by periodical in-process measurement of reference spheres fixed to the workpiece coordinate system. (e.g. the centre coordinates of one or more reference spheres permanently connected to one side of the B'-axis rotary table are measured using the touch-trigger probe.

3.1.3.8 Development, integration and validation of the embedded reference beam

The integration of a reference beam with multi-degree-of-freedom sensors in the SOMMACT demonstrator is an exemplary solution selected from the number of suggested tool kits. In the corresponding measurements with this demonstrator, it had to be shown that it is possible to deduce low order changes of correctable errors of machine motion.

The final choice of a 3D reference beam (stable in length, straightness and twist) and of long term stable camera sensors was based on:

- The available space on and inside the demonstrator machine: this space is limited to cross sections of little more than 100 mm x 100 mm along the X-axis slide ways; this makes it necessary to use 3D reference structures and not 1D structures as all degrees of freedom "must be transmitted to this small cross section". 1D structures would, in this case, not allow rotations to be referenced.
- The need for the most stable sensors found in SOMMACT: the most stable sensors were, as reported in Deliverable D3.3, cameras which image two ball targets (one ball attached to the reference beam and one to the machine slide way).

The 3D reference beam of carbon fibre composite rods (see Figure 3.11) rests on three supports attached to the X-axis slide way; the fixing to these supports is kinematic and thus introduces only minor forces into the beam as a consequence of deformations of the machine.

Figure 3-11 – Embedded reference beam integrated to the demonstrator X-axis

Measurements of displacements on the left side relative to the right side of the beam are in first order free from influences of translations and rotations of the beam; only relative deformations are measured.to the X-axis slide way just in front of the slide way, by four camera sensors (see Figure 3.12)

Figure 3-12 – Left ad right side camera sensors

The camera sensors were installed fixed to the slide way at either end of the reference beam. It was thus possible to detect deformations in the slide way which are, to a large percentage, representative for roll, pitch, yaw, straightness and errors of position of the X-motion. Cross talks from deformations of the X-axis slide way due to motion in Z-axis are included too in these measured deformations.

It was verified that linearized changes of errors of the machine geometry can be obtained - correct to within 20%.

The system registers weight influences, including non-rigid body errors and temperature influences. Independent measurements were used to proof this.

The reference beam, as it is integrated into the demonstrator, is commercially problematic as it is hand-made and thus very costly. As well imperfections in the hand weaving are unavoidable, and may influence the long term stability. Therefore experiments are still underway to find stable and cost effective industrial solutions.

The approach to use half-timbered-house structures has yielded already very good stability while being reasonably easy to make in industrialized processes; this encourages to apply such structures for machine-integrated reference systems.

3.1.3.9 Development, integration and validation of the BiSLIDER solution

The *BiSLIDER* consists of two independent reading heads separated by a spacer and it allows to:

- Compensate for the linear error after an initial calibration in a reference state;
- Detect the variation of the linear scale error function from the measured function in the reference state by observing the variation of the difference of readings of the two position sensors from state to state;
- Recover from the new state to the reference state;
- Compensate for the linear error in the reconstructed reference state.

This novel solution has been the object of a patent application jointly filed on 2012-08-22 by INRIM and ALESAMONTI.

3.1.3.10 Development, integration and validation of the KinLoc solution

This multi-degree of freedom measuring device uses a novel sensing methodology that provides non-contact detection of short range relative motion with good stability and economic hardware.

The device has been applied to the SOMMACT demonstrator to validate it as a viable solution having high sensitivity in all degrees-of-freedom enabling measurement between reference frame components or structural elements directly.

The device makes use of slotted photo-micro sensors combined with a novel dual shutter method to give high-resolution detection of displacement and increased immunity to the main error sources that adversely affect this type of sensor.

A patent application for this novel solution is being filed by the University of Huddersfield.

3.1.4 Dynamic update of volumetric compensation tables

This objective is fully attained and it is effectively applied on the project demonstrator machine tool that is equipped with a FIDIA CNC where updating of compensation tables is performed in quasi-real time, subject to operator’s confirmation. Further research activities, to be performed after SOMMACT project termination, will provide the MT manufacturers and users with a standalone unit capable to provide:

- Assistance to the acquisition of MT axes error data interfacing available industrial sensors, sensor systems and measuring equipment (see Figure 3.13);
- Simplified definition of the MT kinematic chain;
- Prediction and 3D visualization of the single or cumulative effect of individual errors on the MT volumetric performance;
- Automatic computation of error compensation files that are formatted for direct interpretation by different CNCs and
- Support to the validation of the effectiveness of the applied compensations.

3.1.4.1 Assistance to the determination of geometric errors

SUPSI has developed, made available and tested software tools with the specific purpose to help researchers to design experiments including selection of:

- Error functions to be measured;
- Relevant (possibly combined) axes travels;
- Position of axes that are not under test;
- Equivalent tool length (where applicable);
- Measurement conditions (e.g. mass);
- Measurements step (freely selectable for each axis under test);
- Unidirectional or bi-directional measurements;
- Number of repetitions.

This very valuable software tool (see Figure 3.13) automatically generates the part-program corresponding to the measurement procedures, including features to help the operator properly preparing the measurement set-up.

The part-program is generated and automatically transferred to the CNC, ready for execution on operator's request. Bi-directional communication between the IPC and the CNC is operational.

Automatic acquisition of NIVELTRONIC inclinometers readings is operative. It is performed through specific PROFIBUS analogue-digital converters that are integrated into the IPC.

The automatic acquisition of LE401 radio transmission inclinometer is performed through USB connection between the inclinometer display/receiver and the IPC.

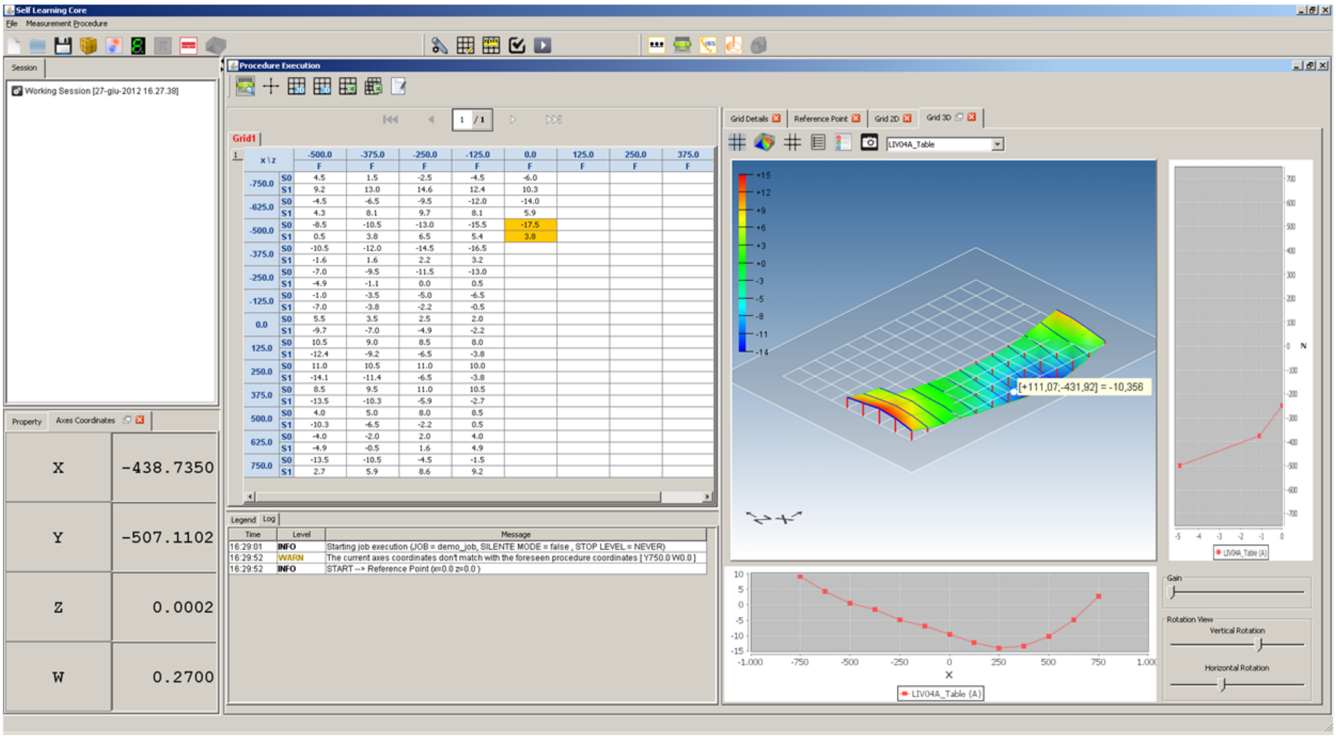


Figure 3.13 – Screen shot of SUPSI specifically developed software for assisted DoE and corresponding measurement results evaluation

3.1.4.2 Extrapolation of machine tool non-rigid body behaviour

Thanks to the excellent cooperation between researchers from ISM-3D, SUPSI, TTS, FIDIA and ALESAMONTI, a very effective software tool has been developed to (i) automatically extrapolate the non-rigid behaviour of the demonstrator cross table and (ii) automatically infer linear, quadratic and cubic additional error compensation components to be applied to the newly developed CNC compensation algorithms.

Extensive tests performed on the SOMMACT project demonstrator showed that the non-rigid component of geometric errors is very significant (see example in Figure 3.14, 3.15 and 3.16).

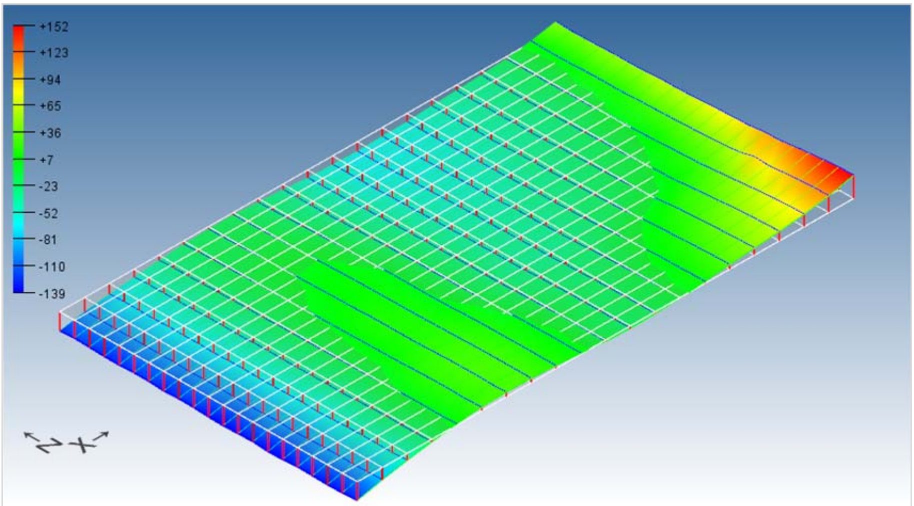


Figure 3.14 – E_{AX} and E_{AZ} measurement data, 4 000 kg mass; min = - 139 μrad; max = 152 μrad

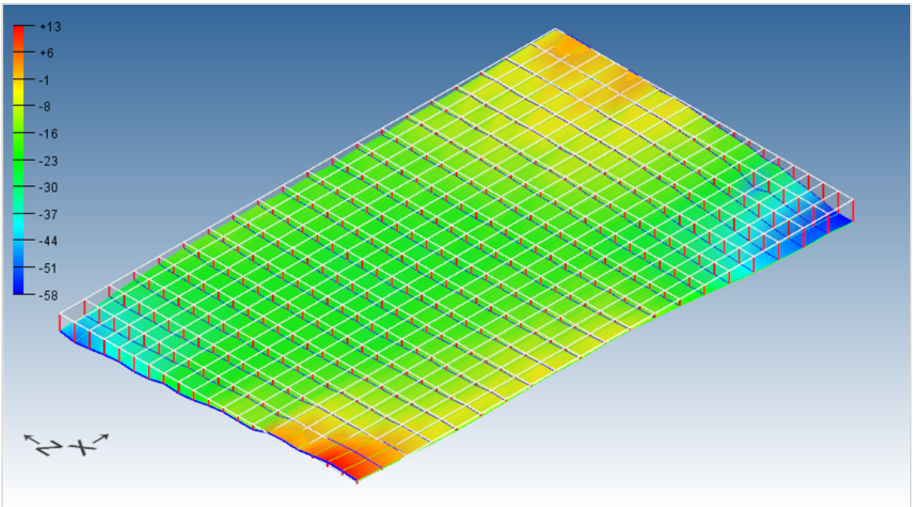


Figure 3.15 – Residual E_{AX} and E_{AZ} errors resulting from the application of rigid-body model: min = - 58 μrad; max = 13 μrad

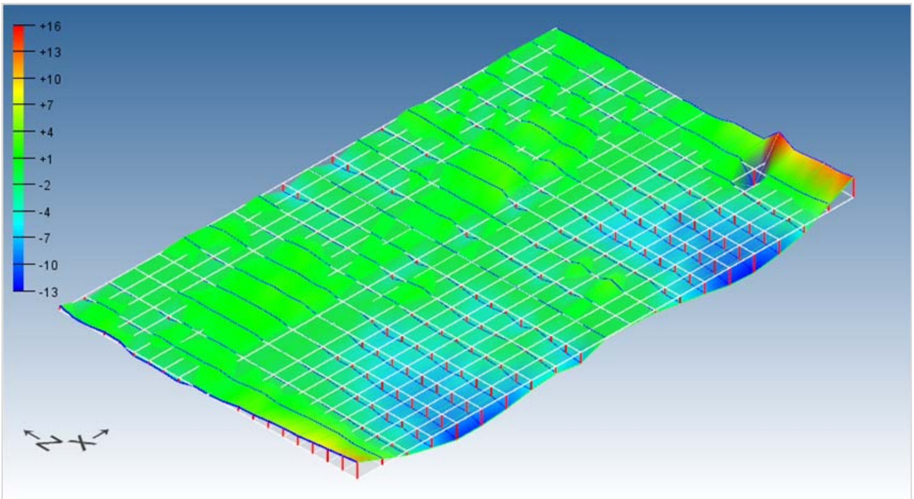


Figure 3.16 – Residual E_{AX} and E_{AZ} errors resulting from the application of non-rigid body model: min = - 13 μrad; max = 16 μrad

3.1.5 Standardisation of compensation tables

The main objective was to promote international standardisation on: (i) machine tool geometric error functions and parameter definition, identification and terminology, insuring uniformity in different industrial fields, (ii) data format for the presentation of different measuring and sensors systems output and (iii) data format for volumetric compensation tables.

This objective has been fully attained.

It was found that dissemination of SOMMACT project outcomes needed extended effort on the standardisation field in order to make sure existing standards would: (i) consider project expected advancements and (ii) specify text procedures that allow for the application of numerical compensation of geometric errors.

Specific activities have been devoted to the development of the following standards:

ISO 230-2 – Part 2: *Determination of accuracy and repeatability of positioning numerically controlled axes.* Mr. Renato OTTONE is the project leader for the revision of this International Standard. A new Annex including the determination of accuracy and repeatability assessment using SOMMACT developed reference ball beams and sensors nests (self-centring probe) has been included. The DIS version of the document was submitted to public ballot and received 100% of approval. The next step will be FDIS (Final draft international standard)

ISO 10791 (all parts) — *Test conditions for machining centres*. Participation to the editing committees for the revision of this series of International standards was actively pursued (and accepted by ISO TC39/SC2) in order to ensure that the specification of individual geometric tests for machining centres will not contain procedures that might be conflicting with expected SOMMACT project outcomes.

ISO 3070 (all parts) — *Machine tools — Test conditions for testing the accuracy of boring and milling machines with horizontal spindle*. This series of International Standards directly concerns the machine tool types that constitute the SOMMACT project preferred application scope.

During the ISO TC39/SC2 meeting that was held in Berlin on 2011-10-10/14, where the participation of Dr. Andrew LONGSTAFF from the University of Huddersfield was well appreciated, we succeeded to convince the subcommittee members to proceed to the revision of this series of International Standards. The project leadership for the development work has been attributed to Dr. Gianfranco MALAGOLA and to Mr. Renato OTTONE, both from ALESAMONTI. The WD (working draft) version of the document was prepared in due time and discussed at the ISO TC39/SC2 meeting that was held in Hangzhou, China, on May 2012.

On EC invitation, standardization activities within the SOMMACT project have been presented as “success stories” at the seminar *Standardisation in Research and Innovation*, held in Brussels on 2011-11-10 and at the sectorial workshop *Standards Supporting Energy Efficiency in Manufacturing Processes*, held in Brussels on 2012-06-05.

3.1.5.1 IMS

The IMS MATECS-MTP initiative (Deliverable D6.5) was published in due time on the Intelligent Manufacturing System (IMS) website in quest for extended partnership and was promoted at the IMS meeting that was held in Lugano, CH, by end of June 2010.

Thanks to specific promotion performed during subsequent ISO TC39/SC2 meetings, we convinced the Korean delegates to pursue the steps needed to ensure the active participation of Korea, thus reaching the minimum threshold of three IMS regions.

The Memorandum of Understanding (MOA) was signed in May 2012.

The IMS MATECS-MTP initiative became an operative IMS project with the participation of the following IMS regions: (i) Europe with Italy (ALESAMONTI and INRIM) and The Netherlands (IBS PE), (ii) Switzerland with SUPSI and (iii) Korea with DOOSAN INFRACORE

3.1.6 Self-optimisation of the geometric compensation

The assessment of the attainment of this objective requires the availability of data to be collected over a reasonable time span. Such data will be made available during the execution of the on-going IFaCOM project.

The SOMMACT demonstrator MT is now undergoing industrialization activities devoted to transform it from a test bench, specifically addressing the validation of geometric errors compensation, to a fully operational MT to be used to produce ALESAMONTI's machine tools structural components. These industrialization activities are expected to be concluded by March 2013.

3.1.7 Assistance to decision making

The developed system provides the functionalities for:

a) Applying immediate action in the presence of unforeseen events (detected, for example, by plausibility checks);
b) Requesting execution of retuning or full recalibration procedures if the machine state is outside the previously learned scenarios;
c) Predicting periodical maintenance needs based on the observation of the machine tool geometric performance degradation.

A specific graphical interface has been developed to predict the machine tool geometric errors that would result from the application of different choices, as selected by the operator (see Figure 3.17).

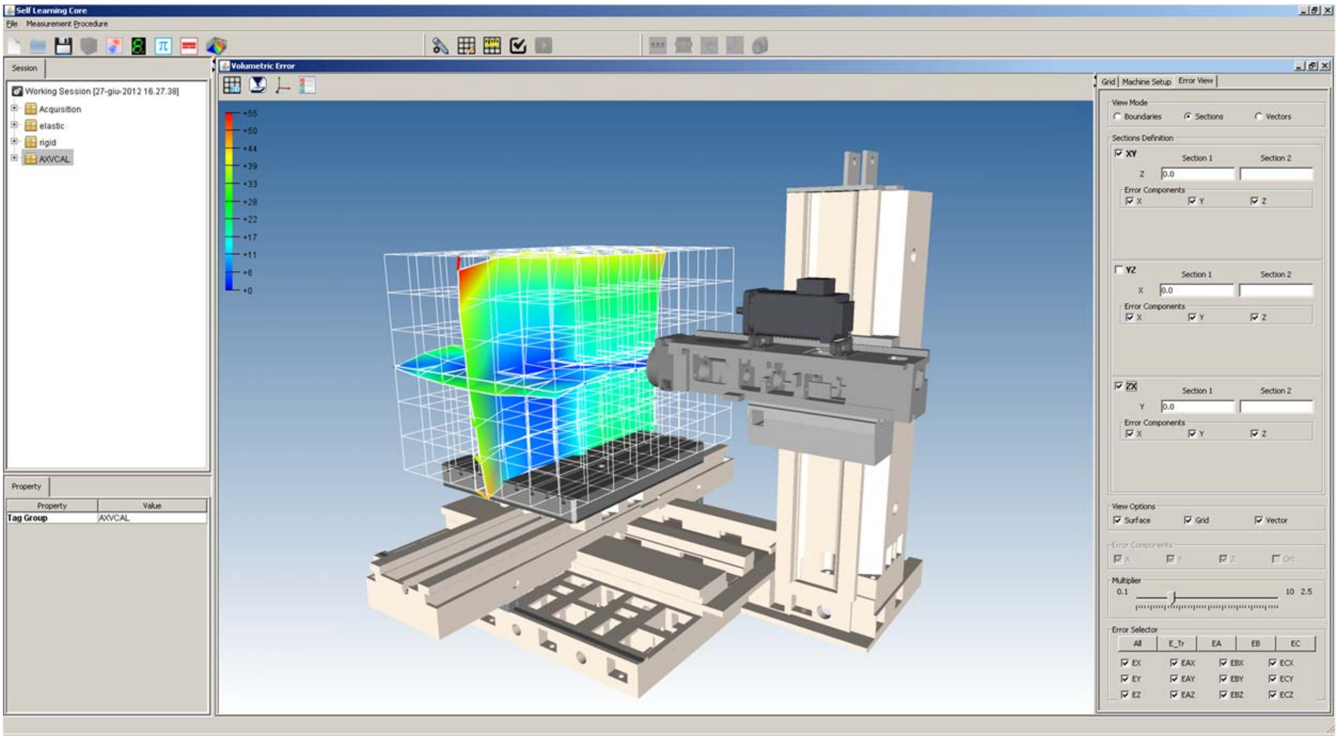


Figure 3.17 – Prediction of workpiece geometric errors

4 Potential impact

4.1 The metal cutting machine tool market

Data and some of the texts reported in this sub section are extracted from the following sources. Relevant links are provided for the convenience of the reader:

- CECIMO, The association of European Machine Tool Builders Associations; http://www.cecimo.eu/machine-tools/dataastatistics/latesttrend.html
- The German Machine Tool Builders Association 2011 report (issued on 05/2012). http://www.vdw.de/web-bin/owa/bw_zeige_ordner?p_verz_id=283&p_sprache=e

Machine tools are capital-intensive investment goods with a high value-added and know-how input.

Advanced machine tools produced in Europe are sought after all over the world. Apart from the European market, they are marketed successfully in the growing markets such as China, Russia, India and Brazil, but also in developed economies like Japan, South Korea and Taiwan (see Figure 4.1)

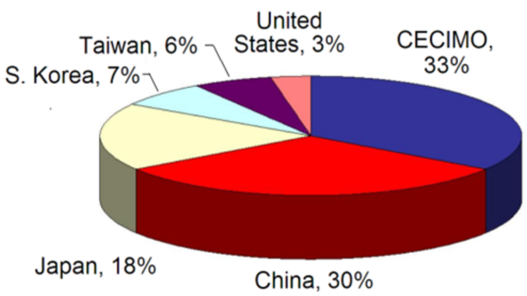


Figure 4.1 – Target markets of machine tools produced in Europe (Source CECIMO)

CECIMO represents approximately 1500 industrial enterprises in Europe; over 80% are SMEs.

Machine tool production in Europe, worth more than 11 billion € p.a., has great relevance for EU manufacturing. Three out of the world top ten metal cutting machine tools producing countries are European (see Figure 4.2).

A very cautious estimate would consider that machining performed on MTs installed in Europe is worth more than 200 billion € p.a. European machine tools provide customers with sophisticated production technology. Owing to continuous progress in product development, state-of-the-art MTs made in Europe allow customers to remain competitive on their markets.

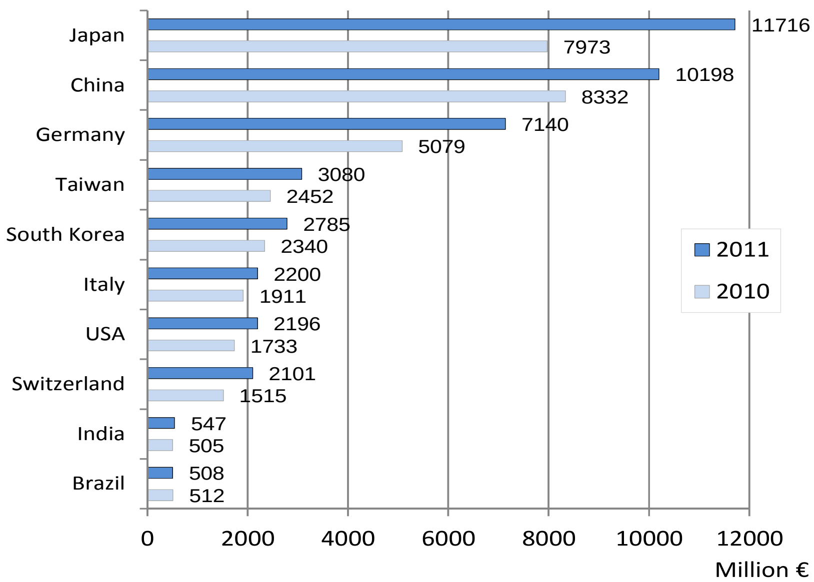


Figure 4.2 – Metal cutting MT production (Source VDW)

4.2 Impact expected from the industrial application of SOMMACT outcomes

- At least, 100% of improvement of product quality;
- 20-30% reduction of total manufacturing time for small and single-batch production;
- 15-20% increase of machine availability;
- Strong drive toward “zero defects” target;
- 70% reduction of workpiece moving phases;
- 15-20% increase in acceptable operating temperature conditions.

4.3 Socio-economic impact

SOMMACT supports the transformation of the machine tool industry to strengthen Europe’s ability to compete in terms of high added-value for the end users as cost-based competition is not compatible with the goal of maintaining the Communities social and sustainability standards.

European machine tool builders will increase the knowledge-based content of their products and the service-related content of their revenues will increase.

European end users – that are mainly SMEs – will produce significantly better quality parts with an increased productivity thus increasing their competitive advantages and protecting jobs.

4.4 Environmental impact

SOMMACT units will significantly reduce energy consumption by (i) reducing manufacturing time (20-30% for small and single-batch production) and (ii) reducing workpiece displacement phases (70%). Energy consumption for rework will also be greatly reduced.

Significant overall reduction of waste and energy consumption will also derive from improved product quality that will spread benefits through the whole subsequent

4.5 Dissemination activities

Dissemination activities carried out during the project’s duration have been in line with the activities foreseen in the Dissemination Plan and are reported in the following.

4.5.1 Scientific dissemination

The School of Computing and Engineering at the University of Huddersfield (UoH) has many Master of Science courses, a number of which involve metrology and manufacturing. Two courses in particular have already incorporated some SOMMACT philosophy and initial work outcomes.

The first course, *Development of Dimensional Measurement*, run by Dr. Simon FLETCHER, discusses the evolution of dimensional measurement applied to manufacturing industry including large volume metrology for machine tools and CMM calibration. The course is continually evolving to incorporate more consideration of temperature-related effects on measurement uncertainty and traceability for calibration and inspection in non-temperature controlled environments. The new approaches made by the SOMMACT project to addresses this issue provide a much needed boost to the discussions on potential solutions.

The second course, *Manufacturing Systems Automation*, run by Dr. Andrew LONGSTAFF, includes automated manufacturing on machine tools with in-depth discussion of both on-machine probing and CMM quality control and SPC issues. SOMMACT shows the potential for full traceable inspection, extending the scope for automation and efficiency in small batch production.

Scientific dissemination started with a very brief SOMMACT project outline presented by Dr. BALSAMO of INRIM at the Collège International pour la Recherche en Productique (CIRP) at the Paris January 2010 meeting. The objective of the presentation was to inform the very high level scientific attendance that the project had started.

Dr. MALAGOLA presented general information on SOMMACT project activities at the Quality Bridge forum, held in conjunction with BIMU 2010 machine tool trade fair (October 2010, Milan, Italy).

Dr. BALSAMO of INRIM presented the BiSLIDER application at the CIRP meeting that was held in Hong Kong, China, during August 2012.

Prof. SILVESTRI of SUPSI presented a scientific paper at euspen meeting held in Como, Italy in May 2011.

4.5.2 Website

The project website was registered at an early stage, under www.sommact.eu

Different sections are available:

- Project's description with basic information:
  - Scope,
  - Team description: Information related to the SOMMACT consortium partners;
- Documents:
  - Press: Reporting and links to articles that were published in local and national newspapers,
  - Scientific documents: Reporting and links to presentations;
  - Deliverables: Public deliverables and publishable summary of all project deliverables,
  - Technical articles: Reporting and links to articles that were published in specialised technical magazines.

Figure 4.3 – SOMMACT website home page

The project website will undergo deep revision in order to make it become the main channel for the dissemination and exploitation of SOMMACT project outcomes. The support of professionals outside the SOMMACT consortium is foreseen.

4.5.3 Newsletter

Three newsletters have been published on August 2011, December 2011 and June 2012.

A newsletter is planned to be published by beginning of 2013.

4.5.4 Leaflet and Roll-Up

A leaflet with an introduction to the project and contact information has been produced for EMO 2009 Exhibition. The leaflet can be downloaded from the website.

Three roll-ups with brief information on the project have been produced. The image and content of leaflet and the roll-up can be downloaded from the website.

4.5.5 Articles on technical magazines

Many different articles have been published on hard copy and/or electronic format on technical magazines (in English, Spanish and Italian); some of them are reported here:

MACHINERY.CO.UK

Article on May 3, 2010

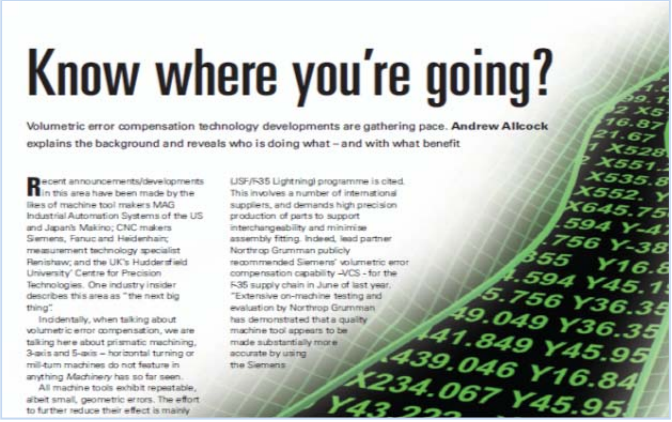
MACHINARY, the magazine for production engineers, is published in the UK.

Its reading is recommended.

Volumetric compensation of machine tool errors made the cover story of its May 2010 paper edition.

The article is also available on-line at:

http://www.machinery.co.uk/article/24197/volumetric-error-compensation-in-machine-tools.aspx



Know where you're going?

Volumetric error compensation technology developments are gathering pace. Andrew Allcock explains the background and reveals who is doing what – and with what benefit

Recent announcements/developments in this area have been made by the likes of machine tool makers MAG Industrial Automation Systems of the US and Japan's Makino; CNC makers Siemens, Fanuc and Heidenhain; measurement technology specialist Renishaw; and the UK's Huddersfield University' Centre for Precision Technologies. One industry insider describes this area as "the next big thing".

Incidentally, when talking about volumetric error compensation, we are talking here about prismatic machining, 3-axis and 5-axis – horizontal turning or mill-turn machines do not feature in anything *Machinery* has so far seen.

All machine tools exhibit repeatable, albeit small, geometric errors. The effort to further reduce their effect is mainly

USF/F35 Lightning) programme is cited. This involves a number of international suppliers, and demands high precision production of parts to support interchangeability and minimise assembly fitting. Indeed, lead partner Northrop Grumman publicly recommended Siemens' volumetric error compensation capability –VCS - for the F-35 supply chain in June of last year. "Extensive on-machine testing and evaluation by Northrop Grumman has demonstrated that a quality machine tool appears to be made substantially more accurate by using the Siemens

Figure 4.4 – MACHINARY.CO.UK – May 2010

Canal INOVA Asturias

"La metrologia da fiabilidad a la industria" (*Metrology provides reliability to industry*)

Article on April 13, 2010

Canal INNOVA Asturias is an on-line channel that is sponsored by the "Club Asturiano de la Innovación", Spain.

ISM-3D is a member of this Association.

The article can be downloaded at:

http://proyectos.elcomerciodigital.com/blogs/innova/2010/04/13/la-metrologia-da-fiabilidad-a-la-industria/

innova

PRINCIPAL

La metrología da fiabilidad a la industria

Ism 3d investiga nuevas tecnologías y modelos de medición con los que ha conseguido mejorar el proceso de fabricación industrial para que sea «mas preciso y fiable»

L. A. gijón

La metrología es la tecnología de la medición que afecta a todo el desarrollo y la ejecución en un proceso de medición industrial. Según José Antonio González, uno de los socios fundadores de Ingeniería y Servicios de Metrología 3D existen dos tipos de metrología industrial, que abarcan muchos parámetros físicos. Se usa, por ejemplo, en las instalaciones industriales para medir caudales, masa o la temperatura en hornos. La metrologia dimensional es la que mas peso tiene y se utiliza para medir distancias, ángulos o parámetros geométricos como rectitudes.

Figure 4.5 – INNOVA Asturias – Apr 2010

INNOVARE

Article on January 2011 issue.

SOMMACT project starts experimental phase

by Gianfranco Malagola.

The article can be downloaded at

http://www.sommact.eu/portal/wp-content/plugins/download-monitor/download.php?id=52

LE PMI SANNO INNOVARE

IL PROGETTO SOMMACT INIZIA LA FASE SPERIMENTALE

SOMMACT (www.sommact.eu) è un progetto di ricerca finanziato dalla Commissione Europea nell'ambito del 7° Programma Quadro per la Ricerca e lo Sviluppo Tecnologico ed è coordinato da ALESAMONTI con la partecipazione di API Varese

Figure 4.6 – INNOVARE Magazine, January 2011

4.5.6 Workshops and Seminars

The project and its objectives have been presented during several events and in particular during meetings with:

- Mechanical enterprises board of UNIONMECCANICA VARESE, Italy.
- Following a presentation at INSUBRIA's University in Varese, Italy.

Presentations were also made at:

CMM Club Italia

This is an Italian non-profit organisation, that aims at spreading the culture of three-dimensional metrology. At the 20° INTERSEC Seminar that took place on April 24, 2010 in Turin (Italy), the annual event organized by CMM Club Italia, two SOMMACT related papers were presented:

Dr. Gianfranco MALAGOLA (ALESAMONTI), *Sala metrologica o CMM in linea di produzione?* – Discussion on whether to perform dimensional measurements in QC laboratories or with a CMM installed in the production line;

Dr. Aldo PONTERIO (ALESAMONTI), *Riduzione degli effetti delle variazioni della temperatura ambiente sull'accuratezza volumetrica delle macchine utensili* – Presentation on the reduction of ambient temperature effects on the volumetric accuracy of machine tools.

ISO

International Standard Organisation

Standardisation concerning machine tool geometric error functions and parameters is essential to disseminate SOMMACT project outcomes and to promote interoperability,

A NWIP (New Work Item Proposal) outline was presented by Mr. Renato OTTONE (ALESAMONTI) to ISO TC39/SC2 at the meeting that was held in Seoul, Korea on May 2010. The proposal was very favourably appreciated by delegates from Australia, Germany, Japan, Korea, Switzerland, the United Kingdom and the United States.

Figure 4.7 – NWIP presentation at ISO

The NWIP has been accepted. ISO/TR 16907, Machine tools — numerical compensation of geometric errors has reached the Committed Draft (CD) level. The project leader for the development is Renato OTTONE (ALESAMONTI).

IMS

Intelligent Manufacturing System

Cooperation on standardisation issues is also sought under the IMS umbrella.

The corresponding IMS MATECS Initiative proposal was published at an early stage on the www.ims.org website with the specific purpose to seek for partners from other IMS regions (see deliverable D6.5).

The initiative was promoted by Dr. Jamal EL CHAAR (SUPSI) and Mr. Renato OTTONE (ALESAMONTI) at the IMS meeting that was held in Lugano, CH, on 2010-06-28. The IMS MATECS MTP project is now operative.

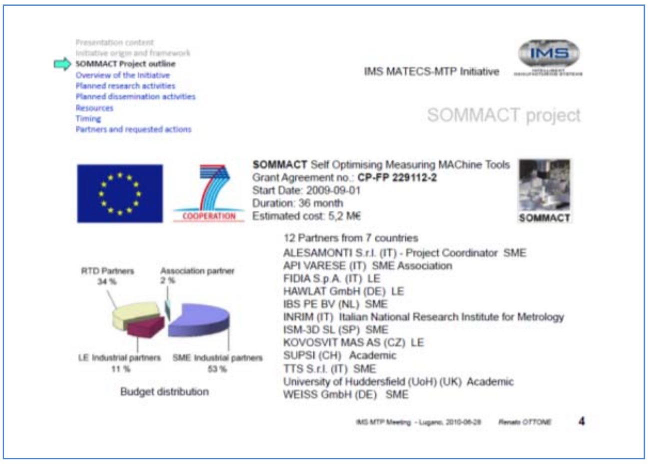


Figure 4.8 – MATECS-MTP presentation at IMS

Quality Bridge Forum

Workshop in parallel with BIMU /SFORTEC 2010 machine tool trade show that was held in Milan, Italy, on 2010-10-5/9

A brief presentation on ISO/FDIS 230-10 – *Test code for machine tools – Part 10: Determination of the measuring performance of probing systems of numerically controlled machine tools* was made by Mr. Renato OTTONE (ALESAMONTI).

Dr. Gianfranco MALAGOLA made a very appreciated presentation of SOMMACT goals and updated the audience on the current status of the on-going research and development activities.

Figure 4.9 – Presentation at Quality Bridge, Oct 2010

Yekaterinburg Forum

"Technical re-equipment of engineering plants of Russia. Special Laser, Optical and Nanotechnology" scientific-industrial Forum.

The forum was held in Yekaterinburg, Russia on 2010-10-19/21, in conjunction with the machine tool trade show.

Mr. Fabio MONTI (ALESAMONTI) made a very appreciated presentation of the SOMMACT project concepts and expected outcomes.

SOMMACT has crossed the Urals Mountains!

Figure 4.10 – Yekaterinburg forum

4.5.7 Trade Fairs

EMO 2009, Milan, Italy

Wide range dissemination of the project concepts started during EMO 2009 world machine tool exhibition, held in Milan, Italy, on 2009-10-5/10.

The show was attended by more than 120 000 visitors coming from 99 countries, with a foreign attendance of 41% of total. 69 visitors were registered as being interested in receiving the project e-mail newsletter.

A roll-up panel and leaflets clearly informed that what was shown, was the state-of-the-art starting point for the SOMMACT project.

ALESAMONTI made available a machine tool equipped with a robot, performing a demonstration cycle showing: (i) simulated machining operations, (ii) on board measurement with a very accurate touch trigger probe and (iii) calibration cycle using a reference beam made on purpose by ISM-3D and the existing version of the self-centring probe provided by IBS PE

Emphasis was devoted to clarify that the self-centring probe itself was the industrial outcome of the MT-CHECK research project, funded by the EC under the 5th Framework Programme.

METAV 2010, Düsseldorf, Germany

This European machine tool exhibition was held on 2010-02-23/27 and was attended by more than 44.000 visitors (92% from Germany).

The SOMMACT project roll-up was shown at the ALESAMONTI booth.

BIMU/SFORTEC 2010, Milan, Italy

This Italian machine tool exhibition was held on 2010-10-5/9 and was attended by more than 60.000 visitors (95% from Italy).

The SOMMACT project roll-up was shown at the ALESAMONTI booth. Dr. Gianfranco MALAGOLA (ALESAMONTI) and Mr. Renato OTTONE (ALESAMONTI) made SOMMACT related presentations at the parallel QUALITY BRIDGE Congress (see 3.6).

EMO 2011, Hannover, Germany

EMO Hannover 2011 (19 to 24 September), with its 2.037 exhibitors from 41 different nations, has confirmed its international reputation as an unparalleled showcase for innovations. At the end EMO Hannover attracted some 140,000 visitors from more than 100 countries. Many visitors took an interest in SOMMACT concepts.

http://www.sommact.eu/portal/?p=284

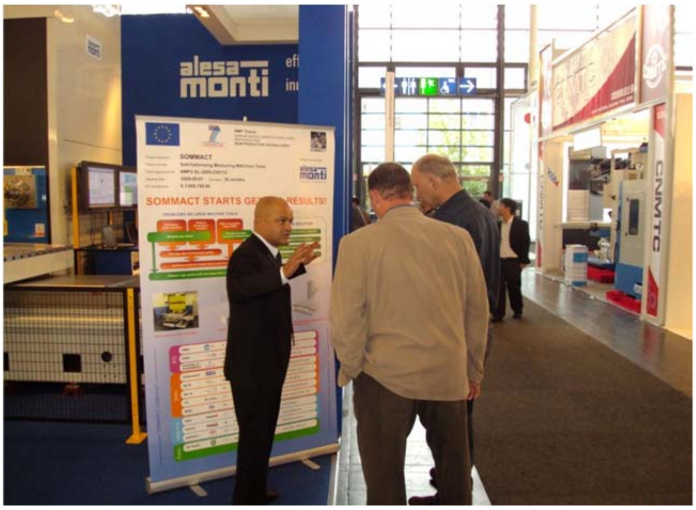


Figure 4.11 – SOMMACT concept shown at EMO 2011

Aerospace Turin 2011

SOMMACT concepts dissemination at AEROSPACE & DEFENCE meeting in Torino - Italy - October 26-27, 2011.

Project concepts and expected outcomes were the object of a dedicated presentation at ALESAMONTI's booth.

http://www.sommact.eu/portal/?p=298

Figure 4.12 – SOMMACT dissemination at AEROSPACE & DEFENCE, Turin 2011

BIMU/SFORTEC 2012, Milan, Italy

Held between October 2 and October 6, 2012, this event — that ranks amongst the most significant exhibitions within the machine tool sector — showed the offering of 1160 exhibitors over an area of 90000 m^2.

It was attended by approximately 59000 visitors, including some 2900 foreign visitors mainly coming from Switzerland, Germany, France, Spain, Serbia and Taiwan.

Figure 4.12 – SOMMACT concept shown at BIMU 2012

4.5.8 Press conferences

2010 — SOMMACT End of Year 1 Meeting Press Conference

On occasion of the SOMMACT end of year 1 meeting, held in Solbiate Olona, (VA), Italy, on 2010-11-16/17, a press conference was called out by a proper invitation.

A press folder with information about SOMMACT has been prepared and delivered to journalists who took part to the conference.

The speakers at the press conference were: Mr. Dimitrios KARADIMAS - EC Project Technical Advisor, Dr. Alessandro BALSAMO – INRIM, Head of the Precision Engineering Programme, Dr. Gianfranco MALAGOLA – ALESAMONTI, Plant Director and Dr. Franco COLOMBO – President of CONFAPI VARESE.

Figure 4.13 – Speakers at SOMMACT End of Year 1 Meeting press conference

2012 — SOMMACT Final Meeting Press Conference

The last press conference took place on occasion of the Final Meeting, on 3rd of July 2012, at ALESAMONTI – Barasso, Italy.

After the press conference, the SOMMACT project prototype machine was presented.

Press conference speakers were (from left to right):

Dr. Gianfranco MALAGOLA, ALESAMONTI;

Dr. Alessandro BALSAMO, INRIM;

Dr. Frédéric GOUARDERES, EC SOMMACT Project Officer and

Mr. Dimitrios KARADIMAS, EC SOMMACT Project Technical Advisor;

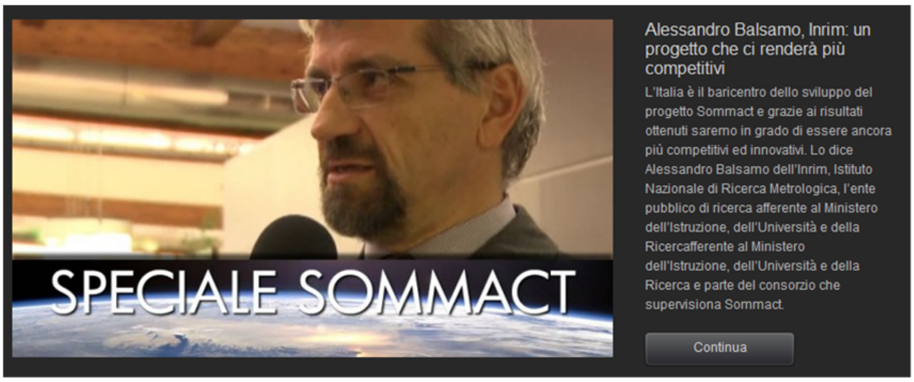
Figure 4.14 – Speakers at SOMMACT Final Meeting press conference

4.5.9 Press

Some 20 articles related to the SOMMACT project were published in local and national Italian newspapers.

4.5.10 Web TV

Thanks to the valuable support of API VARESE, SOMMACT project related information are hosted on the CONFAPI VARESE Web TV system.



Currently, the palimpsest of the web TV foresees a double offer: (i) an institutional ("TGWEB") Newscast, with journalist in study and filmed contributions and (ii) an index book of close examination ("Focus") with information contemplated as that devoted to the conference of the project.

The web television can be visualized on a common PC endowed with the software Real Player (freely downloadable on the Internet).

www.confapivarese.tv

5 Contacts

The SOMMACT consortium partners are listed in Figure 5.1 and direct link to their website is available through the project website www.sommact.eu

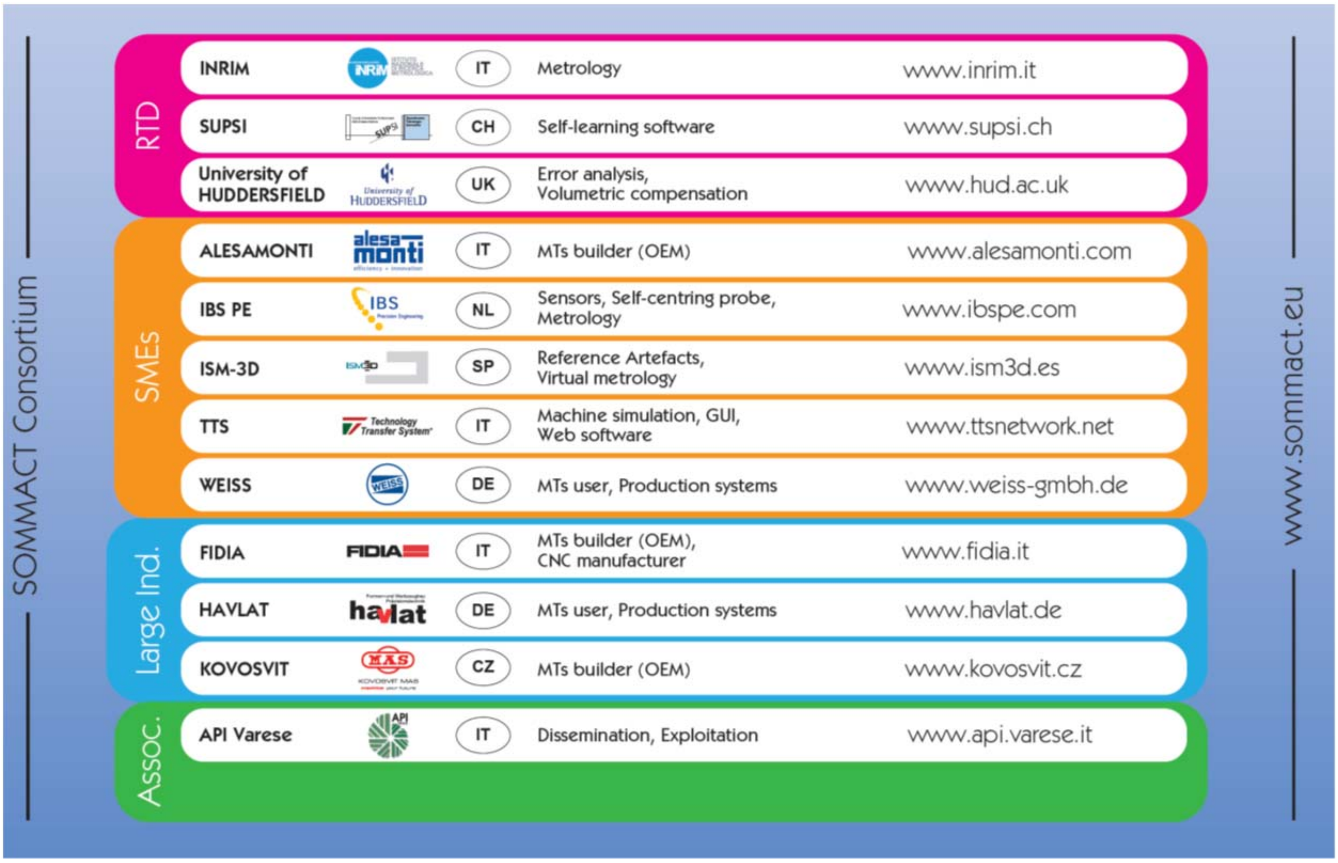


Figure 5.1 – SOMMACT consortium partners

Table 5.1 provides useful contact information within each partner organisation.

Table 5.1 – Contact list

Partner	Contact person	e-mail address
ALESAMONTI s.r.l.	Gianfranco MALAGOLA	g.malagola@alesamonti.com
API VARESE	Matteo CAMPARI	ufficiostudi@api.varese.it
FIDIA S.p.A.	Enrico TAMBURINI	e.tamburini@fidia.it
HAVLAT GmbH	Rico DAEHNERT	r.daehnert@havlat.de
IBS PE BV	Guido FLORUSSEN	florussen@ibspe.com
INRIM	Alessandro BALSAMO	a.balsamo@inrim.it
ISM-3D SL	Eugen TRAPET	trapet@ism3d.es
SUPSI	Giuseppe LANDOLFI	giuseppe.landolfi@icimsi.ch
TTS s.r.l.	Diego ROVERE	rovere@ttsnetwork.com
University of Huddersfield	Simon FLETCHER	s.fletcher@hud.ac.uk
WEISS GmbH	Uwe WEISS	u.weiss@weiss-gmbh.de

6 Use and dissemination of foreground

6.1 Section A (public)

6.1.1 Scientific dissemination

At present, no scientific (peer reviewed) publication relating to the foreground of the project has been produced so Template A1 is not applicable. An article on SOMMACT concept is being prepared for publication in CIRP Annals.

6.1.2 Dissemination to target audiences

Table A2: List of dissemination activities

NO.	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
1	Presentations	INRIM	SOMMACT Self Optimising Measuring Machine tools	21/01/2010	CIRP Paris, France	Scientific community (higher education, Research)	100	N/A
2	Presentations	INRIM	Stabilising the performance of linear en-coders: the BiSLIDER	24/08/2012	CIRP Hong Kong, China	Scientific community (higher education, Research)	100	N/A
3	Presentations	ALESAMONTI	Riduzione degli effetti della temperatura ambiente sull'accuratezza volumetrica delle macchine utensili	24/04/2010	INTERSEC 20 Turin, Italy	Scientific community (higher education, Research)	30	Italy
4	Presentations	ALESAMONTI	Sala metrologica o CMM in linea di pro-duzione?	24/04/2010	INTERSEC 20 Turin, Italy	Scientific community (higher education, Research)	30	Italy
5	Presentations	ALESAMONTI	SOMMACT Self Optimising Measuring Machine tools	14/05/2010	ISO TC339 Seoul, Korea	Scientific community (higher education, Research)	22	ISO member bodies
6	Presentations	ALESAMONTI	IMS MATECS Initiative	28/06/2010	IMS, Lugan0, Switzerland	Policy makers	45	IMS member regions
7	Workshop	ALESAMONTI	Stato di avanzamento del progetto SOMMACT	06/10/2010	Quality Bridge BIMU 2010 Milan, Italy	Industry	28	Italy
8	Presentations	ALESAMONTI	SOMMACT project concept	19/10/2010	Yekaterinburg Russia	Industry	95	Russia
9	Conference	SUPSI	Compensating high precision positioning machines	24/05/2011	EUSPEN Cernobbio, Italy	Scientific community (higher education, Research)	48	European countries

NO.	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
10	Presentations	ALESAMONTI	Standardisation activities within the SOMMACT project	10/09/2011	DG RTD Brussels	Scientific community (higher education, Research) – Industry – Policy makers	55	EC
11	Workshops	ALESAMONTI	Standards supporting energy in manufac-turing processes: the SOMMACT project case	05/06/2012	DG RTD Brussels	Scientific community (higher education, Research) – Industry – Policy makers	45	EC
12	Exhibitions	ALESAMONTI	EMO 2009	05/10/2009	Milan, Italy	Industry	120000	90 countries
13	Exhibitions	ALESAMONTI	METAV 2010	23/02/2010	Düsseldorf, Germany	Industry	44000	92% Germa-ny. Other EC
14	Exhibitions	ALESAMONTI	BIMU 2010	05/10/2010	Milan, Italy	Industry	60000	95% Italy. Other EC
15	Exhibitions	ALESAMONTI	EMO 2011	19/09/2011	Hannover, Germany	Industry	140000	99 countries
16	Exhibitions	ALESAMONTI	AEROSPACE & DEFENCE Meeting	26/10/2011	Turin, Italy	Industry	95	Europe, USA
17	Conference	API VARESE	SOMMACT Kick-off Meeting Press Conference	26/10/2009	Solbiate Olona, Italy	Industry, Medias	38	Italy
18	Conference	API VARESE	SOMMACT End of Year 1 Press Conference	16/11/2010	Solbiate Olona, Italy	Industry, Medias	45	Italy
19	Conference	API VARESE	SOMMACT Final Meeting Press Conference	03/07/2012	Barasso, Italy	Industry, Medias	55	Italy
20	Publication	ALESAMONTI	TECHNOLOGIE INDUSTRIALI SOMMACT: Misura e corregge gli errori geometrici.	10/12/2009	Italy	Industry	2000	Italy
21	Publication	ALESAMONTI	RMO RIVISTA DI MECCANICA Auto-ottimizzazione del sistema	15/01/2010	Italy	Industry	1000	Italy
22	Publication	ISM-3D	Canal INOVA Asturias La metrologia dà fiabilidad a la industria	13/04/2010	Spain	Industry	3000	Spain
23	Publication	The University of Huddersfield	MACINERY CO , UK Know where you're going?	15/05/2010	Great Britain	Industry	20000	Great Britain
24	Publication	ALESAMONTI	MACCHINE UTENSILI Macchine utensili a prova di errore	12/03/2012	Italy	Industry	3000	Italy
25	Publication	ALESAMONTI	INNOVARE - Un'eccellente PMI alla gui-da di un progetto europeo	15/01/2010	Italy	Industry	120000	Italy
26	Publication	ALESAMONTI	INNOVARE – Il progetto SOMMACT inizia la fase sperimentale.	04/06/2010	Italy	Industry	120000	Italy

NO.	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
27	Publication	ALESAMONTI	INNOVARE – La partecipazione ad un progetto europeo	15/02/2011	Italy	Industry	120000	Italy
28	Publication	ALESAMONTI	INNOVARE – La normazione nei progetti di ricerca – L'esperienza di SOMMACT	15/04/2012	Italy	Industry	120000	Italy
29	Publication	ALESAMONTI	INNOVARE – Lo sfruttamento dei risultati nei progetti di ricerca – L'esperienza di SOMMACT	15/07/2012	Italy	Industry	120000	Italy
30	Publication	ALESAMONTI	ECONOMIA E FINANZA Da Barasso a Bruxelles. La meccanica è in rete	04/07/2012	Varese, Italy	Industry – Civil society	5000	Italy
31	Publication	ALESAMONTI	IL SOLE 24 ORE La maxi-fresatrice che si autocorregge	13/08/2012	Italy	Industry – Civil society	500000	Italy

6.2 Section B – Exploitable foreground – PUBLIC

6.2.1 Patent applications

1. INRIM and ALESAMONTI filed a Patent Application under PCT rule on 2012-08-22 with the title: "Apparatus and method for the stabilisation of linear position encoders".
2. The University of Huddersfield is preparing a Patent Application under PCT rule with the title: "Apparatus and method for accurate measurement using differential light obscuration in transmissive photomicrosensor"

NOTE: These Patent Applications have been input as "Others" for the on-line form because not all required data are available.

Table B1: List of application for patents, trademarks, registered designs, etc.

Type of IP Rights	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	Yes			Apparatus and method for the stabilisation of linear position encoders	INRIM and ALESAMONTI
Patent	Yes			Apparatus and method for accurate measurement using differential light obscuration in transmissive photomicrosensor	The University of Huddersfield

6.2.2 Description of exploitable results

The main objective of exploitation is to create revenues and/or provide social benefits. This section identifies and characterise the expected results coming from the project which have commercial/social significance and that can be exploited as a stand-alone product, process, service, etc. These results in principle need further R&D, prototyping, engineering, validation etc. before they become commercially exploitable. In this section are comprised also exploitable R&D results, such as products, processes, methods, services, etc. which are new, improved or less costly.

Here follows a preliminary list of results:

Table 6.1 – List of preliminarily identified exploitable results

No	Exploitable Results	Partner(s) reporting on the specific Result
1	Metrological solutions for MT errors characterisation and compensation	ISM-3D
2	Application of inclinometers to MT	ALESAMONTI
3	Reference artefacts for machine tools (MT) coordinate metrology	ISM-3D
4	Ruggedized self-centring probe with calibration system	IBS PE
5	*BiSLIDER* solution/stabilisation of position transducers	INRIM / ALESAMONTI
6	Application of camera-based systems to MT	ISM-3D
7	Methods and procedures for MT error measurement and compensation	UoH
8	On-machine inspection methods and procedures	ALESAMONTI
9	Enhanced volumetric compensation strategies	FIDIA
10	Self-learning and self-optimising systems	SUPSI
11	Pre- normative documents on numerical compensation of machine tool errors	ALESAMONTI
12	Low cost sensor for measurement of short range motion in 5 DoF	UoH

On 2012-08-22, INRIM and ALESAMONTI have jointly deposited a Patent Application on the "*BiSLIDER* solution" (Result No 5).

The University of Huddersfield is proceeding to deposit a Patent Application on the "*KinLoc* solution (Result No 12).

6.2.2.1 Results characterisation

The objective of the characterisation is to provide an assessment of the results in a way that their relevance in commercial terms can be understood.

To characterize each Exploitable Result the partner(s) identified in Table 6.1 has (have) filled the predefined tables that were discussed during the ESS seminar held on 2011-02-01/02. The predefined table's content is reported in this section mainly maintaining the original ESS seminar time-frame reference but specific adaptation has been applied in some cases in order to provide correct and updated information.

Quantitative information (e.g. market size, price, time to market) has been considered of particular value, even when it is only approximate, or provided as a range of values (e.g. less than 10 M€, or 50 k€ -100 k€). In the cases where it has not been possible to provide quantitative estimations, qualitative information has been provided instead.

It has also been considered very valuable to identify partners, potential customers and competitors (at least conceptually). For the latter, a rough prediction of the speed of reaction to the introduction of each result on the market has been provided in Deliverable D6.3b (Confidential).

Non confidential information related to each individual exploitable result is reported in Table 6.2.

Table 6.2 — Results characterisation

Result No 1: Metrological solutions for MT errors characterisation and compensation	
Describe the innovation content of result	1. Easy to use external artefacts and methods for the MT user to be able to update correction tables in short time intervals. 2. Low cost Reference Structures (artefacts) for offline calibration, providing better accuracy to MT. 3. Add-on solutions for machine integration for the MT builder to update correction tables in short time intervals or in real time.
Who will be the customer?	MT builders, MT users
What benefit will it bring to the customers?	Higher accuracy by frequent updating of correction values.
When is the expected date of achievement in the project (Mth/yr)?	Jan 2012: MT-specific (SOMMACT-specific) external reference artefacts. September 2012: machine integrated reference structures.
When is the time to market (Mth/yr)?	December 2012.
What are the costs to be incurred after the project and before exploitation?	50 k€ for commercial samples' making and calibrating of external artefacts, web page, leaflets, dissemination events, efforts for sales people contacting.
What is the approximate price range of this result / price of licences?	5 k€ -10 k€ € for external artefact 5 k€ for artefact-related software 20 k€ for an internal ref structure for 1 machine axis and integration support.
What is the market size in M€ for this result and relevant trend?	The same estimation of the total market volume as for inclinometers (Result No 2) yields here. The question is how we are able to develop the acceptance of the market for the offered additional value. Sales foreseen: 0 M€ within 1 year, 1,5 M€ within 5 years, 5 M€ within 10 years.
Who are the partners involved in the result?	ISM-3D, ALESAMONTI (the artefacts are sole property of ISM-3D with free use for ALESAMONTI)
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	ISM-3D, WEISS, HAVLAT, ALESAMONTI
Have you protected or will you protect this result? How? When?	The concept is not patentable. Specific solutions using integrated reference structures may be patentable. Specific design features of artefacts may be patentable. We have to see, how these reference structures evolve during the rest of the project.
Result No 2: Application of inclinometers to MT	
Describe the innovation content of result	Excellent inclinometers (electronic levels) exist and are well used as independent measuring instruments for adjusting/testing machine tool functional surfaces. Research is being conducted (in cooperation with inclinometers manufacturers) to evaluate/validate their long term stability and to study/apply solutions to make them withstand vibrations in order to allow their (permanent) application on machine tools. The effective innovation will result from their integration (application method, measurement signal interpretation and correlation to mass variation and temperature variation) within the SOMMACT project tool kit.
Who will be the customer?	Virtually all machine tool builders

What benefit will it bring to the customers?	The benefits (for MT users) are the main expectations from SOMMACT outcomes: – 100% of improvement of product quality; – 20-30% reduction of total manufacturing time for small and single batch production; – 15-20% increase of machine availability; – Strong drive toward “zero defects” target; – 70% reduction of workpiece moving phases; – 15-20% increase in acceptable operating temperature conditions.
When is the expected date of achievement in the project (Mth/yr)?	February 2012
When is the time to market (Mth/yr)?	October 2012 Marketing will be independently performed by inclinometers manufacturers but real benefits will practically only come from the application of SOMMACT outcomes. Time to market of possibly simplified versions of SOMMACT outcomes is expected to be February 2013
What are the costs to be incurred after the project and before exploitation?	Estimated additional costs of 50 k€ for industrialisation of simplified version.
What is the approximate price range of this result / price of licences?	Cost-of-good-sold increase is estimated to be not relevant. No licensing policy is expected to be applied. MT manufactures (other than SOMMACT partners) will be able to get enhanced inclinometers on the market but they will have to go through all learning phase regarding the effective application (that will need to involve also the CNC manufacturers and/or providers of IPC systems).
What is the market size in M€ for this result and relevant trend?	Some 19 G€/year (estimated world metal cutting MT production). NOTE. We expect this application could be retrofitted to existing machines, thus significantly extending the market size.
Who are the partners involved in the result?	ALESAMONTI is carrying out the relevant research activity on inclinometers. FIDIA, SUPSI and TTS are involved in the integration within the CNC and the SLC.
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	ALESAMONTI and FIDIA (as MT manufacturer and also as CNC manufacturer).
Have you protected or will you protect this result? How? When?	This result will not be formally protected (it cannot be patented). Protection is expected from the inherent initial difficult response from competition.
Result No 3: Reference artefacts for MT coordinate metrology	
Describe the innovation content of result	Different ball beams for full and high point density compensation/error assessment, calibrated and stable in 3D or 2D (depending on model); available for self-centring probes, 2D camera probes and standard touch trigger probes.
Who will be the customer?	Machine tool builders and service providers.
What benefit will it bring to the customers?	Fast error measurement, modularity, flexibility, low price: 20% of price of Laser Tracer (ETALON), 35% of price of 6dof (RENISHAW) and of ETALON machine tool calibrating system, but almost the same accuracy as the LaserTracer, in practice.
When is the expected date of achievement in the project (Mth/yr)?	Jan 2012
When is the time to market (Mth/yr)?	Jan 2013
What are the costs to be incurred after the project and before exploitation?	50 k€ for commercial samples’ making and calibrating of external artefacts, web page, leaflets, dissemination events, efforts for sales people contacting
What is the approximate price range of this result / price of licences?	20k€: kit with 2 artefacts of different size, software, camera sensor, fixtures.

What is the market size in M€ for this result and relevant trend?	The same estimation of the total market volume as for inclinometers yields here. The question is how we are able to develop the acceptance of the market for the offered additional value. Sales foreseen: 0,4 M€ within 2 years, 2 M€ within 5 years, 6 M€ within 10 years.
How this result will rank against competing products in terms of price / performance?	<20% of price of competing product LaserTracer, 30% of price of competing products 6dof of RENISHAW and API, 50% of competing product Laser Interferometer plus level plus straightedge. It is superior to all other products up to 500 mm axis length of the machines to be calibrated; it is better applicable on machines up to 1m; same performance on machines between 1 m and 3 m axis length, from 5 m length on not applicable. It is inferior to LaserTracer for very accurate machines.
Who are the competitors for this result?	ETALON, RENISHAW, API. If successful, more competitors may emerge: KOBA, AfM, copying the product.
How fast and in what ways will the competition respond to this result?	May be competitors start to copy concepts within 3 years after marketed successfully by SOMMACT members. We have at least a 5 year lead, however, the market awareness improvement performed by SOMMACT partners works as well in favour of the late comers.
Who are the partners involved in the result?	ISM-3D, software and hardware, concept/technology.
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	MT makers, MT service providers.
Have you protected or will you protect this result? How? When?	The concepts are not patentable as already existing in similar form, particularly from the side of ISM-3D and its affiliates. Protection is expected from the inherent initial difficult response from competition.
Result No 4: Ruggedized self-centring probe with calibration system	
Describe the innovation content of result	Tactile probes (i.e. RENISHAW) exist, but need multiple spatially distributed points to obtain the 3D position of a ball. A self-centring probe determines such 3D ball position more accurately and in a single spatial point, making measuring times much shorter. Unique is the possibility to measure a machine dynamically, on-the-fly; tactile probes cannot do this (=static only). The new SOMMACT probe can do the same fast machine measurement, but it will be: - less expensive/lower cost/price, - wireless. - non-contact.
Who will be the customer?	MT users and builders.
What benefit will it bring to the customers?	Machine accuracy can be determined faster and more accurate. It will be easy to operate to make the system suitable for machine operators too; to make machine metrology available for anybody and not only for experts like in current situation. Because of cost reductions, machines will be measured more often and meeting tight work piece tolerances will become less difficult/possible. Machines can be improved by compensation or simply strategically selected by “machine accuracy ranking”.
When is the expected date of achievement in the project (Mth/yr)?	End of project: 1-9-2012
When is the time to market (Mth/yr)?	Approximately 9 months after successful testing of the proto-type
What are the costs to be incurred after the project and before exploitation?	150 k€
What is the approximate price range of this result / price of licences?	15 k€
What is the market size in M€ for this result and relevant trend?	15 M€ and we expect this to increase as 5-axis machining gets more and more important.
Who are the partners involved in the result?	IBS PE develops the (inductive) probe themselves, no partners involved. The probe application is combined with the artefacts of partner ISM-3D.
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	Machine tool, automotive & aerospace, the “high-precision” industries (mould & die, optics, medical prostheses, turbine blades, impellors etc.).

Have you protected or will you protect this result? How? When?	Yes, the intention is to arrange this probe under the existing patent EP 1491287.
Result No 5: *BiSLIDER* solution/stabilization of position transducers	
Describe the innovation content of result	Existing position transducers accuracy is strongly affected by thermo-mechanical distortions inherent to the transducers themselves and to their supporting structure. Such distortions are always present in machine tools applications and are mainly associated to temperature variations and non-rigid behaviour of machine components. The *BiSLIDER* goal is not primarily to compensate for scale errors, rather to stabilise the scale measurements over time, in spite of possible thermo-mechanical (local) expansion / compression. If good error compensation is achieved by other means (e.g. by comparison with an interferometer) – possibly providing traceability – prior to the application of any *BiSLIDER* concept, then the *BiSLIDER* stabilisation extends the benefit of this compensation over time with a reference measurement system that can even be retro-fitted.
Who will be the customer?	Virtually all machine tool builders.
What benefit will it bring to the customers?	Significant enhancement of finished part quality. For example, for a thermal gradient of 15 °C (very likely to exist in machining shops, adding daily and seasonal ambient temperature variations) the corresponding error of indication (directly transmitted to the workpiece accuracy) would be as big as 0,15 mm/m. The biSLIDER application would reduce the resulting error by more than 90%.
When is the expected date of achievement in the project (Mth/yr)?	March/April 2012
When is the time to market (Mth/yr)?	March/April 2013
What are the costs to be incurred after the project and before exploitation?	Cost for industrialisation for HEIDENHAIN scales (the most popular) is estimated to be approximately 50 k€. Cost-of-good-sold should be less than 100 €
What is the approximate price range of this result / price of licences?	Price range is estimated to be 500 € (subject to specific marketing analysis).This price refers to the *BiSLIDER* alone. The application will require an additional standard slider costing the MT manufacturer approximately 500 €. Price for lump-sum licence would range at around 1 M€ with very small likelihood. Licence to SOMMACT partners willing to produce and apply the *BiSLIDER* will be negotiated starting from 10% of the product selling price.
What is the market size in M€ for this result and relevant trend?	The market size is evaluated only on machine tools axes length over 2 m. The very preliminary estimation (assuming 5% of produced MT to have 1 axis over 2 m and the average price/machine to be 300 k€) would yield an approximately 10.000 units/year corresponding to 5 M€/year. The trend will depend on accurate single product pricing as a price reduction could extend the possible application by an order of magnitude.
Who are the partners involved in the result?	INRIM and ALESAMONTI.
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	ALESAMONTI and FIDIA are considering applying it on their MT.
Have you protected or will you protect this result? How? When?	The invention has been protected by a Patent Application jointly filed on 2012-08-22 by INRIM and ALESAMONTI with the title: "*Apparatus and method for the stabilization of linear encoders*"
Result No 6: Application of camera-based systems to MT	
Describe the innovation content of result	Use of cameras as low-cost 2D displacement sensors in reference structures, inbuilt into machines. Substitutes more expensive sensors; very stable measurement values for machine deformations (differential) relative between reference beams and structural components and/or slide ways of machine. For the use of cameras as sensors for measurement of external

	reference artefacts on MT: see "artefacts". Here we refer only to the use of cameras as parts of machine-inbuilt reference systems.
Who will be the customer?	Machine tool builders, machine tool maintenance services
What benefit will it bring to the customers?	Lower cost for the additional hardware and simple integration result in a lower threshold when a customer has to decide to implement this solution. The sensors and reference beams can be retro-fitted. Note that in SOMMACT camera sensors are in many cases only one of many alternatives to other sensors used.
When is the expected date of achievement in the project (Mth/yr)?	Integration in test rig in ISM-3D in May 2011, in demonstrator in ALESAMONTI in July 2011, proven until Sept 2012 ("achievement").
When is the time to market (Mth/yr)?	March 2013
What are the costs to be incurred after the project and before exploitation?	20 k€ corresponding to partial costs for prototype machine tool making, web page, leaflets, trade shows, efforts for sales people contacting and training
What is the approximate price range of this result / price of licences?	The sensors as such are negligible in cost; the implementation of the simplest thinkable solution with reference beam will be in the order of 20 k€ (1 reference beam plus 2 camera sensors).
What is the market size in M€ for this result and relevant trend?	The camera sensors form part of the entire SOMMACT-concept and here again they are part of the compensation tool kits. The same estimation of the total market volume as for inclinometers yields here. The question is how we are able to develop the acceptance of the market for the offered additional value. Trying to judge the value of the camera sensors alone, we expect an estimated 0,2 M€ within 2 years, 0,5 M€ within 5 years, 3 M€ within 10 years
Who are the partners involved in the result?	ISM-3D (software and hardware, concept/technology), ALESAMONTI (implementation)
Who are the industrial partners interested in the result (partners, sponsors, etc. …)?	MT makers, MT users, MT service providers
Have you protected or will you protect this result? How? When?	No decision has been taken yet on this subject.
Result No 7: Methods and procedures for MT error measurement and compensation	
Describe the innovation content of result	1. Robust methods and procedures for applying traditional and state-of-the-art equipment for machine tool error identification and compensation in line with new standards resulting from the SOMMACT project. 2. New methods and procedures for measurement and correction of non-rigid errors using traditional and state-of-the-art equipment.
Who will be the customer?	Machine tool builders, end users and service providers
What benefit will it bring to the customers?	Increasing the opportunity of in-house implementation of machine tool performance improvement strategies. Increased machine tool accuracy, and the associated advantages of improved quality, particularly for machines susceptible to non-rigid errors and heavy components.
When is the expected date of achievement in the project (Mth/yr)?	April 2012
When is the time to market (Mth/yr)?	Marketing of some procedures can begin immediately after validation in the project and then increased incrementally as the range of equipment and scope of the validated procedures increases with SOMMACT machine integrations.
What are the costs to be incurred after the project and before exploitation?	Estimated 30 k€ for formalisation of documentation and industrialisation of software tools.
What is the approximate price range of this result / price of licences?	The result shall be marketed to complement general MT calibration services and extend existing training courses currently delivered by UoH. Possible price of 2 k€ for training and documentation and 1 k€ for potential software tools (to be developed).
What is the market size in M€ for this result and relevant trend?	The methodologies can be implemented generally as well as on SOMMACT machines. Estimated market from a service perspective is 0,3 M€ initially, increasing with the on-going trend for tighter tolerances on machined parts.

Who are the partners involved in the result?	Specific SOMMACT procedures were developed and implemented in cooperation between ALESAMONTI, FIDIA, INRIM, ISM-3D and the UoH. SUPSI and TTS dedicated significant research activities to the efficient integration of such procedures within the SLC.
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	MT users and builders.
Have you protected or will you protect this result? How? When?	The methods and procedures will not be formally protected. Any software tools and documentation may be protected.
Result No 8: On-machine inspection methods and procedures	
Describe the innovation content of result	On-machine inspection is not currently widely applied on the bases that, if the MT geometry is not accurate enough, on-machine inspection is not necessarily fit for the purpose and is usually only applied for limited in-process measurements. Within SOMMACT, it will be combined with: (i) enhanced MT accuracy, (ii) ad-hoc developed reference artefacts and (iii) methods and procedure for traceability assessment and measurement uncertainty estimation.
Who will be the customer?	Machine tool users, especially for large machine tools. Methods and procedures are applicable (in principle) to machine tool configurations not initially addressed by SOMMACT
What benefit will it bring to the customers?	– Strong drive toward "zero defects" target; – 70% reduction of workpiece moving phases; – Monitoring of MT geometric performances.
When is the expected date of achievement in the project (Mth/yr)?	Initial results expected by end of year 2011 with some practical, limited applications at HAVLAT and WEISS
When is the time to market (Mth/yr)?	Limited version marketing (with end users other than HAVLAT and WEISS) could reasonably start by second half of year 2012 on selected customers with the basic aim to obtain early stage market feedback. The pricing of the limited version shall be established to simply cover relevant additional application expenses.
What are the costs to be incurred after the project and before exploitation?	Estimated additional costs of 50 k€ for industrialisation of simplified version, including application analysis costs to support the very beneficial expected dissemination resulting from marketing activities of RENISHAW (for high accuracy touch probes) and DELCAM. Significant positive dissemination will also come from ISM-3D marketing of reference artefacts.
What is the approximate price range of this result / price of licences?	This result shall be marketed to complement general MT adjustment/calibration services and shall complement DELCAM measuring software training courses. The result shall be initially proposed at an additional price of some 3 k€/customer (note that the customer will possibly use the acquired technology to be applied on more than one machine tool)
What is the market size in M€ for this result and relevant trend?	Initial market will be limited to selected customers with large machine tools. 20 applications during the first 3 years are a reasonable estimate.
Who are the partners involved in the result?	Research mainly involves ALESAMONTI, using ISM-3D artefacts to address traceability issues.
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	ALESAMONTI and FIDIA, in conjunction with MT adjustment / calibration services offering. ISM-3D will be able to offer high-level training on methods and procedures, complementing the sale of reference artefacts.
Have you protected or will you protect this result? How? When?	No specific protection is envisaged for this result. The publication of ISO 230-10:2011 (developed under the leadership of the SOMMACT project technical coordinator) will actually foster wide dissemination of the concept. It is considered that such dissemination will be beneficial to the market and will improve effective SOMMACT global outcome exploitation chances.

Result No 9: Enhanced volumetric compensation strategies (software and service)	
Describe the innovation content of result	Volumetric compensation is based on error tables determined when the machine is built or when some important component is changed. At present the construction of these tables is a very demanding operation. The SOMMACT result will allow automatizing the tables building process, thus dramatically reducing the measuring time while using an increased number of sensors for error determination. At the same time a greater number of error functions will be determined, establishing a relation between several dof errors and axes positions.
Who will be the customer?	Customers will be all FIDIA's potential customers, that is: machine tool end users
What benefit will it bring to the customers?	– Operating with more precise machines, – Reducing machining set-up time; – Optimizing and tuning the compensation parameters in quasi-real time.
When is the expected date of achievement in the project (Mth/yr)?	M30
When is the time to market (Mth/yr)?	As a stand-alone result, it will be easily exploitable after 3-6 months after the project end
What are the costs to be incurred after the project and before exploitation?	Mainly industrialisation, training (commercial and technical) and commercial dissemination.
What is the approximate price range of this result / price of licences?	It can be sold as an option of the CNC/machining system. Based on currently sold VAC solutions, the price range will be between 10 k€ and 15 k€, according to the size of the machining system.
What is the market size in M€ for this result and relevant trend?	From FIDIA's point of view, the target market is in the end the precision cutting machine sector, which according to the 2010 World Machine Tools survey, even with the economic and financial crisis consists in about 10 G€ in Europe (30 G€ Worldwide). With respect to 2008, the sector suffered for a 30% contraction due to the crisis, but first indicators in 2010 show a slow recover (+10% in 2010 with respect to 2009).
Who are the partners involved in the result?	Research activities involved FIDIA, ISM-3D, ALESAMONTI, SUPSI and TTS. FIDIA is the exclusive owner of the foreground related to the design and implementation of the new strategies into the FIDIA CNC.
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	High Speed Milling machine tools end users in the field of mould & dies manufacturing and aerospace.
Have you protected or will you protect this result? How? When?	No, as far as FIDIA is concerned
Result No 10: Self-learning and self-optimising systems (combining software and hardware solutions)	
Describe the innovation content of result	Currently existing machine tools provide a static geometrical compensation; SLC will provide a quasi-real time compensation of the geometrical errors, supporting the MT common user in updating compensation tables on NC and therefore enhancing the machine performance. Existing on-board metrological systems are calibrated only at commissioning or at subsequent, rarely performed and expensive recalibrations, SOMMACT will propose a new metrology system enabling periodic machine recalibration: SLC will play an important role, predicting optimal recalibration time basing on learned experiences. SLC will offer adaptability and self-learning capabilities, both as a self-contained system and as integrated into a

	production management system. SLC will also provide a correlation among data on calibration, workpiece features, environment and sensors measurements.
Who will be the customer?	Machine tool builders and Numerical Control Builders.
What benefit will it bring to the customers?	– Self-optimization: continuous improvement of the machine accuracy, ensuring no performances degradation. – Assessment of the machine capability to meet machining and measuring accuracy specifications (under certain environmental and loading conditions). – Assistance to decision making: execution of retuning or full recalibration procedures if the machine state is outside the previously learned scenarios; – Prediction of periodical maintenance, based on observation of the geometric performance degradation.
When is the expected date of achievement in the project (Mth/yr)?	Initial results are expected by mid-year 2011. Major results are expected during test phase in which it will be possible to integrate software with the rest of the system (IPC, sensors, CNC, etc.). Therefore the major results are expected by the end of the project (06/2012)
When is the time to market (Mth/yr)?	Even if SUPSI has no market purposes, preliminary version of the SLC marketing could start after a large period of tests (2012-2013) on a small set of customers in order to obtain early stage market feedback.
What are the costs to be incurred after the project and before exploitation?	It is difficult to evaluate at this stage the costs that will be required to industrialize the sw. It will strongly depend on the results of the test phase.
What is the approximate price range of this result / price of licences?	Currently no additional costs are expected for third party licences. The choice of the software applications (DBMS, development libraries, etc.) has been done taking into account the possibility to use them for free, both during the project development and in any commercial exploitation of the results. Therefore the expected price range will depend only on the receptivity of the market that will be evaluated after the test phase.
What is the market size in M€ for this result and relevant trend?	Not known at present
Who are the partners involved in the result?	SLC research involves all partners of the projects, due to its nature. Main partners in the software development are SUPSI and TTS, which carry on also the integration activities with the following partners: (i) ALESAMONTI - integration of the SLC within the SOMMACT system; (ii) FIDIA - communication with CNC; (iii) INRIM and ISM-3D - integration of the mathematical models within the SLC logics;
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	ALESAMONTI and TTS. Both partners are directly interested to the results, for possible future sales of the software within the SOMMACT system.
Have you protected or will you protect this result? How? When?	It is not expected to protect SLC with a patent but the source code will be protected by a copyright and not freely distributable licence. The binaries (SLC application) will be protected with a licensing mechanism with activation on demand and limited in time.
Result No 11: Pre- normative documents on numerical compensation of MT errors	
Describe the innovation content of result	Standardisation of machine tool error functions and parameters is a strategic goal and is addressed at the world level within ISO Support from IMS is also sought. Standardisation will mainly concern: (i) MT error function and parameters definition, identification and terminology insuring uniformity in different industrial fields, (ii) data format for the presentation of different measuring systems and sensors systems output, (iii) data format for volumetric compensation tables, (iv) definition of CNC functions required to apply (standardised) volumetric compensation tables.
Who will be the customer?	Worldwide metal cutting manufacturing processes and end users of the corresponding products.
What benefit will it bring to the customers?	This result will facilitate trade and worldwide societal benefit will derive from improved efficiency and quality in metal cutting manufacturing processes and

	their products.
When is the expected date of achievement in the project (Mth/yr)?	By the end of the project, the standard is expected to have reached the CD (Committee Draft) stage.
When is the time to market (Mth/yr)?	ISO/TR 16907 is expected to be published by end of year 2014
What are the costs to be incurred after the project and before exploitation?	Some 25 k€ /year during 2 years after the project end.
What is the approximate price range of this result / price of licences?	Not applicable
What is the market size in M€ for this result and relevant trend?	Worldwide production of metal cutting manufacturing processes is cautiously estimated to be some 400 G€ / year
Who are the partners involved in the result?	ALESAMONTI and IBS PE
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	ALESAMONTI image will (and already does) directly benefit from disseminating its significant involvement in the standardisation activity. Early knowledge on standardisation trends will provide competitive advantages to ALESAMONTI, FIDIA, IBS PE and ISM-3D.
Have you protected or will you protect this result? How? When?	Not applicable

Result No 12: Low cost sensor for measurement of short range motion in 5 DoF	
Describe the innovation content of result	Combining a type of low cost dual slotted photo-resister with dual shutter method to give high resolution detection of displacement and increased immunity to main error sources. A mechanical arrangement of said sensors designed to give short range, non-contact measurement of up to 5 degrees of freedom. This can be used to measure small structural deflections affecting machine tool accuracy, and possibly other systems as well. Current stability of the sensor is likely to preclude long term measurement.
Who will be the customer?	Machine and robotic system builders and users interested in monitoring short term structural deflection.
What benefit will it bring to the customers?	Detection of motion in up to 5 DoF between nominally static elements. This may help detect strain or relative orientation. The sensor can be contactless for force sensitive applications. It is expected that the resolution will be good, probably in the sub-micron range for displacement and sub arc-second for angle. It is expected that the system will be low cost with variation depending mostly on the requirement of the analogue to digital conversion and mechanical mounting.
When is the expected date of achievement in the project (Mth/yr)?	Practical demonstration by April 2012
When is the time to market (Mth/yr)?	Possibly 6-9 months after successful testing of the main prototypes.
What are the costs to be incurred after the project and before exploitation?	Cost will be heavily dependent on the design of the hardware interface for specific applications rather than the sensor system. However it is expected to be very low.
What is the approximate price range of this result / price of licences?	Yet to be defined but likely to be very low, perhaps circa €1k. It may be influenced by the final measurement performance and particular hardware interface design.
What is the market size in M€ for this result and relevant trend?	To be investigated. There are no known comparable commercial systems against which to make an estimate.
Who are the partners involved in the result?	UoH as inventor and developer.
Who are the industrial partners interested in the result (partners, sponsors, etc…)?	UoH and possibly IBS.
Have you protected or will you protect this result? How? When?	If positive outcome from demonstration and sufficient market can be foreseen then formal protection may be sought in the future.

6.2.3 IPR and exploitation claims

Table 6.3 — Partners IPR and exploitation claims on each identified exploitable result

Result \ Partner	ALESAMONTI	API VARESE	FIDIA	HAVLAT	IBS PE	INRIM	ISM-3D	KOVOSVIT	SUPSI	TTS	UoH	WEISS
1 – Metrological solutions for MT errors characterisation and compensation	F U		U			B	B F M O	Not active anymore within the SOMMACT project	U O	U O	F U O	
2 – Application of inclinometers to MT	F M U		U				O		U O	U O	B U O	
3 – Reference artefacts for MT coordinate metrology	U		U	U	B U	B	B F M O		U	U	U O	U
4 – Ruggedized self-centring probe	U		U		B F MU O		UO				U O	
5 – *BiSLIDER* solution	F M U (L)		U	U		B F L	U O				U O	
6 – Application of camera-based systems to MT	U		U				B F M				O	
7 – Methods and procedures for MT error measurement and compensation	B F U O		B F U O		B	B F	B F L O		U O	U O	B F U O	
8 – On-machine inspection methods and procedures	B F U O		B F U O	U		F	B F O				B U O	U
9 – Enhanced volumetric compensation strategies	U O		B F U L O			B F	B F O		U O	U O	B F U O	
10 – Self-learning and self-optimising systems	U		U						B F L O	B F U L O	U O	
11 – Pre- normative documents on numerical compensation of machine tool errors	B F U O		U		B F O						B F U O	
12 – Low cost sensor for measurement of short range motion in 5 DoF	U				U		U				F U L	

Table 6.3 reports the willingness of the partners to exploit the results by:

- M making them and selling them;
- U using them internally to make something else for sale and/or, for academic partners, including them in their relevant courses;
- L to licence them to third parties,
- O to provide services such as consultancy, etc.

The table also reports the partner's intention of claiming Intellectual Property Rights on the Background (B) or Foreground (F) Information. The first is all the information (excluding foreground information) brought to the project from existing knowledge, owned or controlled by project partners in the same or related fields of the work carried out in the research project. The second is information including all kind of exploitable results generated by the project partners or third parties working for them in the implementation of the research project.

6.2.3.1 *Clarifications on IPR and exploitation claims*

The following clarifications are provided under the supervision of the SOMMACT project technical coordinator, have been approved by relevant partners and represent the common agreement between SOMMACT consortium partners.

Result No 1: Metrological solutions for MT errors characterisation and compensation

ISM-3D, INRIM, the UoH and ALESAMONTI were the main contributors to this result.

ISM-3D will freely embed the related foreground into its products and services offering.

The UoH is claiming the possibility of using such result and providing services on it and this is accepted by all other involved partners.

ALESAMONTI, FIDIA and TTS will freely embed the related foreground into their products and services offering.

SUPSI will include this result into its academic activities and will include such result into its planned exploitation of result No 10 – *Self-learning and self-optimizing system*.

Result No 2: Application of inclinometers to MTs

ALESAMONTI is the main contributor to this result and manifested his intention to check on the opportunity to dedicate, after SOMMACT project termination, additional resources to the design, development and making of specific apparatus for the efficient permanent integration of inclinometers to MT.

FIDIA, ISM-3D, SUPSI, TTS and the UoH will be free to embed the SOMMACT project foreground related to this result into their products and services offering.

Result No 3: Reference artefacts for MT coordinate metrology

ISM-3D is the main contributor to this result. He is also the manufacturer. The use of the result by SOMMACT project partners will benefit from the application of special prices by ISM-3D.

Result No 4: Ruggedized self-centring probe with calibration system

IBS PE is the sole contributor to this result. He is also the manufacturer. Project users will refer to such owner.

Result No 5: *BiSLIDER* solution / stabilisation of position transducers

This result has been generated by ALESAMONTI and INRIM. The relevant Patent Application has been jointly filed and they have stipulated a specific exploitation agreement.

Result No 6: Application of camera-based systems to MT

ISM-3D is the main contributor to the result and manifested its intention to dedicate, after SOMMACT project termination, additional resources for the industrialisation of the relevant foreground. Project partners will refer to ISM-3D.

Result No 7: Methods and procedures for MT error measurement and compensation

This is a soft result made of knowledge and software. Five partners were mainly contributing to it. Six SOMMACT project partners will freely use the relevant foreground to embed it into their products and services offering and ISM-3D will also be allowed to consider granting non-exclusive licence to third parties.

Result No 8: On-machine inspection methods and procedures

Four partners are contributing to this result. The exploitation is meant for internal uses and for embedding such result into products and services offering. INRIM is contributing with foreground without exploitation wishes.

Result No 9: Enhanced volumetric compensation strategies

Four partners are contributing to this result. FIDIA will embed this result into its own CNC. The claim for licensing derives from the fact that the software that is embedded into the CNC is typically sold as a licence to the buyer.

ALESAMONTI, ISM-3D and the UoH will freely embed this result into their products and services offering.

SUPSI and TTS will freely embed the concepts associated to this result into their service offering.

INRIM is contributing with background and foreground without any exploitation plans.

Result No 10: Self-learning and self-optimising systems

SUPSI and TTS are the main contributor this result. Both have the ambition to include this result into their services offering. Their close relationship will allow them to easily reach agreement on exploitation.

The source code and related binaries will be protected by a copyright and not freely distributable licence. The SLC will be protected with a licensing mechanism with activation on demand and limited in time.

ALESAMONTI and FIDIA will freely use the SOMMACT demonstrator SLC software.

Result No 11: Pre-normative documents on numerical compensation of machine tool errors

Three partners are contributing to this result. It has social significance and could generate indirect benefits to the partners and beyond.

Result No 12: Low cost sensor for measurement of short range motion in 5 DoF

The UoH is the inventor and the developer of this result. SOMMACT project partner wishing to use this result will refer to the UoH.

7 Report on societal implications

Replies to this section are reported in the on-line document.

8 Final report on the distribution of the European Union financial contribution

This report will be submitted to the Commission within 30 days after receipt of the final payment of the European Union financial contribution.