Deliverable 1.4 (Version 09/07/2104):

VANESSA PROJECT FINAL REPORT

Grant Agreement number: 319116

Project acronym: VANESSA

Project title: Validation of Numerical Engineering Simulations: Standardisation Actions

Funding Scheme: FP7-NMP-2012-CSA-6

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Periodic report: 1st □ 2nd □ 3rd ☑ 4th Period covered: February 2013 to July 2014

Name, title and organisation of the scientific representative of the project's coordinator:

Professor Eann Patterson
School of Engineering, University of Liverpool

Tel: +44 (0)151 794 4665

E-mail: eann.patterson@liverpool.ac.uk

Project website address: http://www.engineeringvalidation.org/

1.0 SUMMARY

Engineering simulation is an essential feature of the design and manufacture of all engineered products at all scales. However such simulations are not routinely validated, at least in part because technology for rapid, cost-effect validations has not been available. Two previous projects, SPOTS and ADVISE led to the development of appropriate tools. The goal of the VANESSA project has been to establish a validation methodology and the associated calibration procedures within a standards framework and to promote the adoption of the methodology within the European industrial and scientific communities. A CEN Workshop Agreement on the validation of computational solid mechanics models has been developed through a series of public consultations and inter-laboratory studies (ILS). To encourage take up of this innovative approach to design validation by EU industrial base and to gain its international acceptance a series of knowledge exchange events have been organised. In addition, a package of technical and educational materials have been prepared and are available via the project website (www.engineeringvalidation.org) with links to media such as YouTube. The technical approach embedded in the validation process has the potential to stimulate improved quality control for the process chain from design, during production and certification, through to service and maintenance and its adoption would lead to a strengthening of the position of European industry.

I, as scientific representative of the coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):

☑ has fully achieved its objectives and technical goals for the period;

□ has achieved most of its objectives and technical goals for the period with relatively minor deviations.

□ has failed to achieve critical objectives and/or is not at all on schedule.

- The public website, if applicable

☑ is up to date

□ is not up to date

- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.4) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 3.2.3 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: Eann Patterson

Date: ....21...../ ......07....../ ....2014........

Contents

2.0 Project Objectives

The scientific and technical objectives of the project were as follows:

a) To conduct international inter-lab comparison (round-robin) exercises that will generate evidence that the reference material, for calibration of optical systems for strain field measurement, and the validation protocol, for computational solid mechanics models, form a solid basis for standardisation.
b) To prepare a CEN Workshop Agreement on validation of computational solid mechanics models using strain fields from calibrated measurement systems.
c) To raise awareness in the EU industrial base and international engineering community of the validation protocol through a programme of knowledge dissemination and exchange.

3.0 Work Progress and achievements during the period

The project was delivered on schedule and within budget with only minor changes in the allocation of both budget and resource between partners. There were no changes to the overall project budget and all deliverables have been submitted (see Table 1).

Table 1: Complete list of deliverables

Item	Description	Due	Status
D1.1	Six-month report	m7	Completed
D1.2	12-month report	m13	Completed
D1.3	IP Plan	m17	Completed
D1.4	Final report	m18	Completed
D2.1	PSC minutes: kick-off meeting	m2	Completed
D2.2	PSC minutes: month 4	m5	Completed
D2.3	PSC minutes: month 8	m9	Completed
D2.4	PSC minutes: month 12	m13	Completed
D2.5	PSC minutes: month 18	m18	Completed
D3.1	Calibration Inter-laboratory Study (round-robin) protocol	m3	Completed
D3.2	Validation Inter-laboratory Study (round-robin) protocol	m3	Completed
D3.3	Calibration Inter-laboratory Study (round-robin) report	m16	Completed
D3.4	Validation Inter-laboratory Study (round-robin) report	m16	Completed
D4.1	Draft unified calibration procedure	m4	Completed
D4.2	CWA Business Plan	m4	Completed
D4.3	Unified calibration procedure	m8	Completed
D4.4	CEN Workshop Agreement	m18	Completed
D5.1	Workshop proposal	m3	Completed
D5.2	Dissemination programme	m4	Completed
D5.3	Website constructed	m4	Completed
D5.4	1^{st} KE Workshop	m12	Completed
D5.5	CPD resources	m17	Completed
D5.6	2^{nd} KE Workshop	m18	Completed
D5.7	Publication report	m18	Completed

3.1 Work Package 2 – Supporting Action Co-ordination (WP Manager: UNIL)

Introduction

Work Package 2 dealt primarily with the administrative aspects of the project including the organisation and monitoring of progress to ensure deliverables and milestones were met in a timely fashion and in accordance with the DOW. This included the facilitation of meetings, brainstorming sessions and any other ad hoc duties required to ensure the smooth running of the project. In addition to the administrative aspects of the project, WP2 also included responsibility for ensuring that any Intellectual Property arising as a result of the project were protected from exploitation by third parties.

Task 2.1 Supporting Action Co-ordination (Task Leader: UNIL)

There is one task in WP2, Task 2.1 Supporting Action Co-ordination.

The following project beneficiaries have been involved in the task: UNIL (task leader), DD, EMPA, HPS, LTSM-UP, SNV, CRF & NNL.

Task Objective

a) The efficient and effective management of the project to ensure that the aims of the project are achieved, and that the project deliverables are available on schedule and within budget.

Progress

As co-ordinator of the project UNIL employed a Project Manager, on a part-time basis to handle administrative aspects of the project. This included the arrangement and documentation of project meetings, project communication, project promotion and reporting.

A private, secure blog was established at www.vanessaproject.wordpress.com to provide a channel for communication, disseminate information and for archiving project documentation. The blog will be maintained after the end of the project for a limited period of approximately six months for the benefit of the partners.

In addition to the above administrative tasks the protection of Intellectual Property was also under the remit of Task 2.1. Due to the overlapping nature of Work Package 1 & 2, the deliverable associated with this activity D1.3 is listed as an output of Work Package 1. To summarise; the basis of the project is produce a procedure for the validation of computational mechanics models and promote and encourage its uptake within the EU engineering community. For this reason, the majority of the documentation produced as outputs of the project has been made available publicly and as such it is anticipated there is little room for exploitation of this information for financial gain by third parties.

Progress of Task 2.1 was monitored via a series of deliverables in the form of minutes of the meetings of the Project Steering Committee which were scheduled and held throughout the life of the project.

Conclusions

Project meetings were held as planned in line with the proposal and as set out in the kick-off meeting with only minor changes to dates and times made, which were agreed upon by all partners. In order to minimise travel costs for all partners meetings were rotated around the consortium and/or combined with other project meetings, e.g. CEN Workshop 71 meetings, and were conducted in Liverpool (UK), Cardiff (UK), Zurich (CH), Patras (GR) and Munich (DE). The Project Steering Committee, responsible for all decision making is listed in Table 2.

Table 2 – Membership of Project Steering Committee

Beneficiary	PSC Representative	Deputy
UNIL	Eann Patterson	
DD	Thorsten Siebert	Hans Reinhard Schubach
EMPA	Urs Sennhauser	Erwin Hack
LTSM-UP	George Lampeas	
HPS	Alexander Ihle	Olaf Reichmann
SNV	Rolf Widmer	
CRF	Andrea Pipino	
NNL	Phil Ivision	Nassia Tzelepi

Deliverables associated with Task 2.1 have been submitted within the timeframes agreed upon. There was a minor delay to the submission of D2.2: PSC minutes: month 4 which was submitted in month 6 rather than month 5. This was as a result of the decision agreed upon unanimously by all parties at the kick-off meeting in Liverpool to move the PSC meeting for month 4 from Montpellier in late May to Brussels in mid-June to coincide with the CWA kick-off meeting at CEN HQ, which all consortium members were due to attend.

Although exploitation of Intellectual Property derived from the project is not anticipated due to the public nature of the work, project documentation and other project outputs, an IP plan has been produced (D1.3), which forms part of Work Package 1.

In the light of the standards nature of the VANESSA project all deliverables were formally approved by the PSC prior to submission to the EC.

Deliverables and milestones

Item	Title	Responsibility	Date Due	Date Delivered
D2.1	PSC minutes: kick-off meeting	UNIL	2	2
D2.2	PSC minutes: month 4	UNIL	5	6
D2.3	PSC minutes: month 6	UNIL	9	9
D2.4	PSC minutes: month 12	UNIL	13	13
D2.5	PSC minutes: month 18	UNIL	18	18

3.2 Work Package 3 – Inter Comparison Studies (WP Manager: EMPA)

Introduction

The goal of the VANESSA project was to establish a validation methodology and the associated calibration procedures within a standards framework and to promote the adoption of the methodology within the European industrial and scientific communities. The scientific and technical project objective defining WP 3 was[1]:

[1] see VANESSA Description of Work, part B, page 4

(i) To conduct international inter-lab comparison (round-robin) exercises that will generate evidence that the reference material, for calibration of optical systems for strain field measurement, and the validation protocol, for computational solid mechanics models, form a solid basis for standardisation.

More specific, the objectives for WP3 were set as follows:

a) To prepare protocols, organise and collate the results from an international round robin exercise on a reference material for the calibration of strain measurement systems capable of measuring dynamic strain fields.

b) To prepare protocols, organise and collate the results from an international round robin exercise on a validation procedure for computational solid mechanics models.

c) To provide evidence that the reference materials for calibration and the validation protocol form a solid base for the proposed standardisation activity.

Preliminary work had established that *Interlaboratory Studies (ILS)* was a more accurate description of the activities than *round robins*, as the main goal was to promote the calibration and validation procedures and gain experience from different users. In order to achieve the objectives the following tasks were included in the Description of Work:

Task 3.1: Reference material for dynamic strain calibration (Task Manager: EMPA)

Task 3.2: Computational solid mechanics model validation (Task Manager: LTSM-UP)

The following sections contain the final reports for each of these tasks and are followed by 'Discussion and Conclusions' for the work package.

Task 3.1: Reference material for dynamic strain calibration (Task Leader: EMPA)

Introduction

The EU-funded FP7 project ADVISE led to the design of two reference materials for the calibration of measurement systems capable of measuring displacement and strain fields in engineering components subject to dynamic loading. A limited round-robin was had been conducted for both reference materials within the ADVISE consortium proving the applicability of the reference materials for calibration. In order to receive international acceptance a round-robin was conducted on an international scale with participation by organisations outside of the consortium.

The following project beneficiaries have been involved in the task: EMPA (task leader) UNIL, DD.

Task objective

The main objectives of Task 3.1 were derived from the WP3 objectives a) and c) above. The task involved the decision for a design and manufacturing of a physical reference material for loan to ILS participants, refinement of the protocol produced by ADVISE into a suitable format for a global ILS, promotion of the ILS, distribution of reference materials and distribution of documentation via the project website, followed by collation, interpretation and dissemination of the results.

Progress

This task was first concerned with the selection of one out of two reference materials that had been developed in the FP7 ADVISE project. In two brain-storming meetings in Liverpool and Ulm the type of reference material was selected using the rational decision making process – a cantilever machined from a thick plate of material, see Figure 1. Subsequently the dimension ratios of the cantilever beam were optimized to increase strain/displacement levels and reduce the resonance frequencies.

The two brain-storming meetings were also used to discuss and define the Calibration ILS protocol, based on earlier documents from the SPOTS and ADVISE projects. The Calibration ILS protocol (Deliverable D3.1) was established and published through the project website on which it remains available. It contains a step-by-step guidance through the calibration process for optical systems for strain and displacement measurement.

A set of 24 specimens of the Reference Material (RM) was manufactured by UNIL in house. Manufacture was carried out in two batches by UNIL and their quality assessed to achieve project Milestone MS1. They were provided in shipping boxes, Figure 2, for participants of the Calibration ILS. The specifications of the Reference Material are summarized in Table . The values provide evidence that the material is "sufficiently homogeneous and stable with reference to specified properties, which has been established to be fit for its intended use in measurement", as the International Vocabulary of Metrology defines a Reference Material [2].

The Calibration ILS protocol, reference materials and promotion strategy for the round robin on calibration for strain field measurement in dynamic loading were accepted at the PSC meeting in June 2013, providing confirmation of Milestone MS2.

The Calibration ILS was formally initiated at the second CEN workshop on September 4th, 2013, which was collocated with the BSSM conference in Cardiff, Wales. It was further promoted, among other means, by more than three dozen personalised invitation letters sent to engineers and researchers carefully selected by the VANESSA consortium and mainly from the industrial sector. Subsequently, an open invitation was issued via the project website and at conferences, followed by some 100 serial emails.

A first feed-back from the consortium was obtained during the first Knowledge Exchange Workshop in London on Nov 5th, 2013 which was used as input for the revision of the draft CWA dealt with in Work Package WP4.

[2] International vocabulary of metrology – Basic and general concepts and associated terms (VIM), 3rd edition, JCGM 200:2012

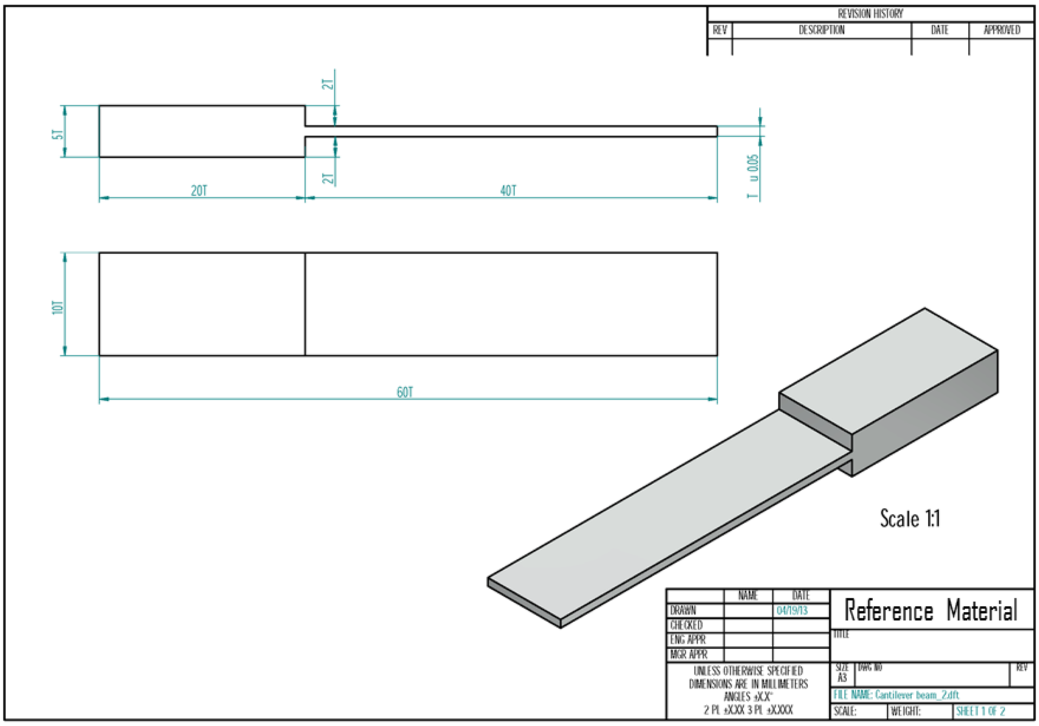

Figure 1: Drawing and 3D-rendering of the Reference Material. Note that the RM is parametric in *T*, the thickness of the cantilever.

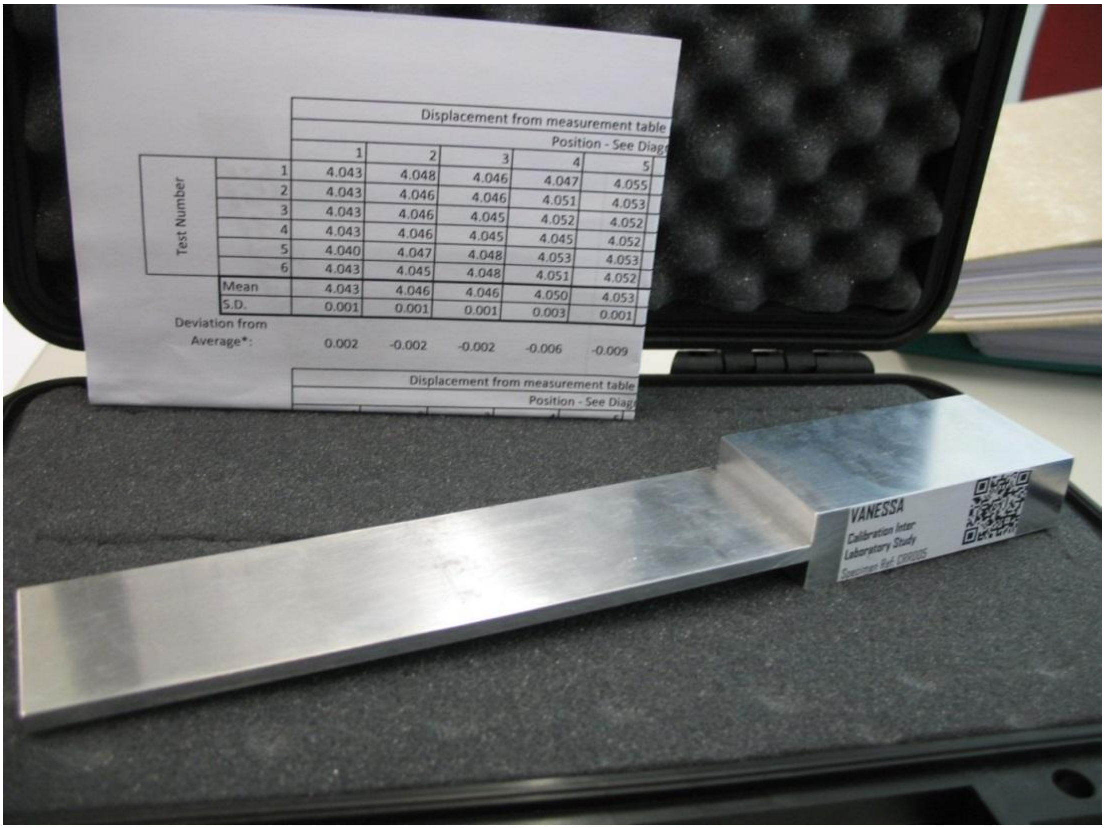

Figure 2: One exemplar of the Calibration Reference Material with QR identification tag, specification sheet and box for delivery to the ILS participants.

A total of 6 specimens were sent out to participants outside the consortium. The protocols and reports received from the participants of the Calibration ILS were collected and collated in the "Calibration Round-Robin Report" which constitutes Deliverable D3.3.

Three reports were obtained with quantitative results for dynamic loading with tip displacements of 6– 600 μm for mode 1, 2– 200 μm for mode 2, and a single report for mode 3 with 30 μm tip displacement. Digital Image Correlation (DIC) and Digital Speckle Pattern Interferometry (DSPI) were applied on the Reference Materials. Table summarizes the Reference Material identification, technique used, resonance frequencies, tip deflection, number of data points in the gauge area, and the uncertainty *u(d)*.

Table 3: Specifications of RM

Property	value	comments
Thickness reproducibility	4.000±0.012 mm	average of a batch of 10 specimen
Thickness variation	< 0.003 mm	max. std of 9 measurements across the face of a single specimen
Resonance frequency Mode 1	127.2±0.6 Hz	average of a batch of 10 specimen
Resonance frequency Mode 2	785.2±3.9 Hz	average of a batch of 10 specimen

Table 4: Results from calibration ILS using dynamic loading.

Property			
Identification	CRR004	CRR005	CRR010
Technique	DIC	DSPI	DIC
Mode 1 [Hz]	125.7	129.6	126.0
Mode 2 [Hz]	NA	796.0	796.0
Mode 3 [Hz]	NA	NA	2123.0
tip deflection		6.31 μm 1.99 μm	0.600 mm 0.200 mm 0.030 mm
Number of data points	625	111'220	1'258
u(d) [μm]	2.4	0.018 0.032	1.5 3.1 3.2

An example of experimental results for dynamic measurements is provided in Figure 3 (CRR005). The DSPI data for the shape of mode 1 is given as well as the deviation from the reference values.

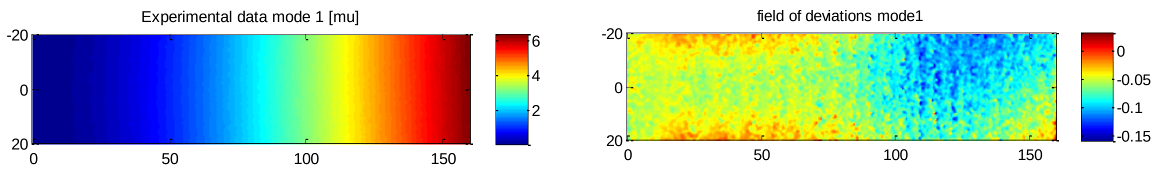

Figure 3: Experimental mode shape and field of deviations from reference value, scale given in μm.

Four reports were obtained with quantitative results for static loading with tip deflections of 0.23 to 4.7 mm. Table summarizes the Reference Material identification, technique used, tip deflection, number of data points on the gauge area, and uncertainty u(d).

Table 5: Results from calibration ILS using static loading

Property				
Identification	CRR006	CRR007	CRR008	CRR016
Technique	DIC	DIC	DIC	DIC
tip deflection [mm]	2.94 3.84 4.71	0.228 0.428 0.670 0.923 1.145	0.228 0.448 0.672 0.940 1.132	1.544
Number of data points	4647	48	200	429
u(d) [mm]	**0.0074** **0.0113** **0.0090**	0.0035 0.0108	0.0008	0.0081

An example of experimental results for static measurements is provided in Figure (CRR016). It shows experimental data and difference to the Reference Material data.

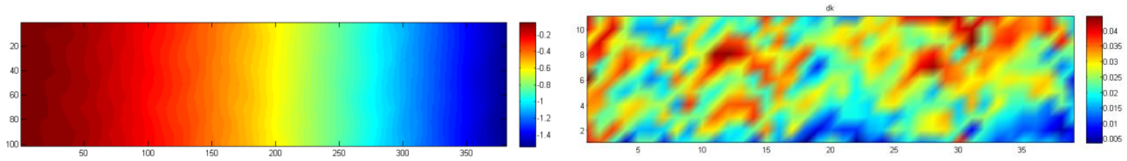

Figure 4: Out-of-plane displacement field in static loading from DIC experiment with static loading.

The feed-back on the Calibration ILS protocol high-lighted misprints in two formulae which were, however, irrelevant for the evaluation of the data. Further issues reported were:

- "I had problems calculating u_{cal}. Appendix C is not clear for me"
- "Our imaging camera does not have sufficient working distance to observe the full cantilever beam length (approximately 40 mm only observed)."
- "The RM was too small for my field of view, i.e. it did not cover 80% of the image."
- "Our LVDT transducer is not sufficiently reliable for us to trust its calibration."
- "We had a compliant loading rig and some uncertainty in the way in which the beam was deflecting (perhaps I may say uncertaintIES)."

A dedicated WP3 meeting was held in Patras on May 13-15, 2014 to discuss the issues raised by, and draw conclusions from, the Calibration ILS. The following recommendations were issued regarding the CEN Workshop Agreement.

- Use the RM preferably in the first resonant mode, since the second and third modes are difficult to excite with a loudspeaker.
- Allow for the use of a shaker and report the relative displacement of tip and root.
- Allow for the use of the RM for larger fields of view (FOV), e.g. by tiling repeated calibration measurements in the FOV.
- Simplify Appendix C on determining the measurement uncertainty and include the simplifications in the Appendix. Remove the parameters α and β – meant to describe systematic offset and slope of the measurement deviation – and use the field of deviations directly to determine $u(d)$.

These recommendations were reported to the CEN secretary and formed the basis for improving the CEN Workshop Agreement prior to its final form.

Deliverables and Milestones

Item	Description	Responsibility	Date due	Date delivered
D3.1	Protocol for round robin on calibration for strain field measurement in dynamic loading	EMPA	m3	m3
MS1	Reference materials available: Supply of reference materials for dynamic strain field measurement	UNIL	m4	m5
MS2	Calibration round-robin initiated: Protocol, reference materials and promotion strategy for round robin on calibration for strain field measurement in dynamic loading agreed	EMPA	m4	m4
D3.3	Calibration round-robin report	EMPA	m16	m16

Conclusions

The preparation of the Calibration ILS Protocol (D3.1), the organisation of the round robin and the collation of the results fulfil one of the three objectives of WP3. The conclusions from the round-robin provide evidence that the calibration protocol enshrined in the CEN Workshop Agreement (CWA) has a solid base, which is a second objective of WP3. Together these activities contribute very substantially to the achievement of one of the VANESSA project's three S & T objectives, namely 'to conduct international comparison (round-robin) exercises that will generate evidence that the reference material, for calibration of optical systems for strain field measurement, and the validation protocol for computational solid mechanics models, form a solid base for standardisation'. Finally, the widespread promotion of the calibration ILS or round robin has contributed to a second VANESSA S&T objective 'to raise awareness in the EU industrial base and international engineering community of the validation protocol' of which calibration is a vital feature.

Task 3.2: Computational solid mechanics model validation (Task Leader: LTSM-UP)

Introduction

The FP7 EU funded project ADVISE[3] led to the publication of an innovative *Guide for Validation of Computational Solid Mechanics Models*[2]. A successful but limited amount of testing of the methodology described in this guide had been performed by the members of the ADVISE consortium. In VANESSA, the appropriateness of this validation procedure as part of a regulatory process for validation of computational solid mechanics models was systematically investigated.

The following project beneficiaries were involved in the task: LTSM-UP (task leader), UNIL, DD, EMPA, HPS, CRF, NNL.

Task objectives

The main objectives of Task 3.2 have been:

a) To prepare protocols, organise and collate the results from an Inter-Laboratory-Study (ILS) appropriate to a validation procedure of a generic computational model;

[3] *Advanced Dynamic Validations using Integrated Simulation and Experimentation*, Project No. SCP7-GA-2008-218595, see www.dynamicvalidation.org

b) To provide evidence that the validation protocol (together with the calibration protocol derived in Task 3.1) forms a solid base for standardisation.

Progress

In order to achieve its objectives, Task 3.2 activities were initially focused on the design of the ILS exercise for validation of computational solid mechanics models and the preparation of the corresponding Validation ILS protocol. The Validation ILS Protocol aims at evaluating the effectiveness of a methodology for the validation of computational solid mechanics simulation models using full-field optical measurements of strain and, or displacement. An overview of the methodology is presented in Figure 4.

The process for validating models of structural components using full-field measurement data from optical methods is described in detail in the protocol. Dimensionality of data fields derived by simulation or experimentation is reduced by the use of image decomposition based on feature vectors, which contain the coefficients of the shape descriptors, such as Fourier descriptors or orthogonal polynomials, employed to describe the data field. This approach enables a simple comparison of data-rich fields from a computational model and a validation experiment to be made utilising the uncertainty to assess the acceptability of the correlation.

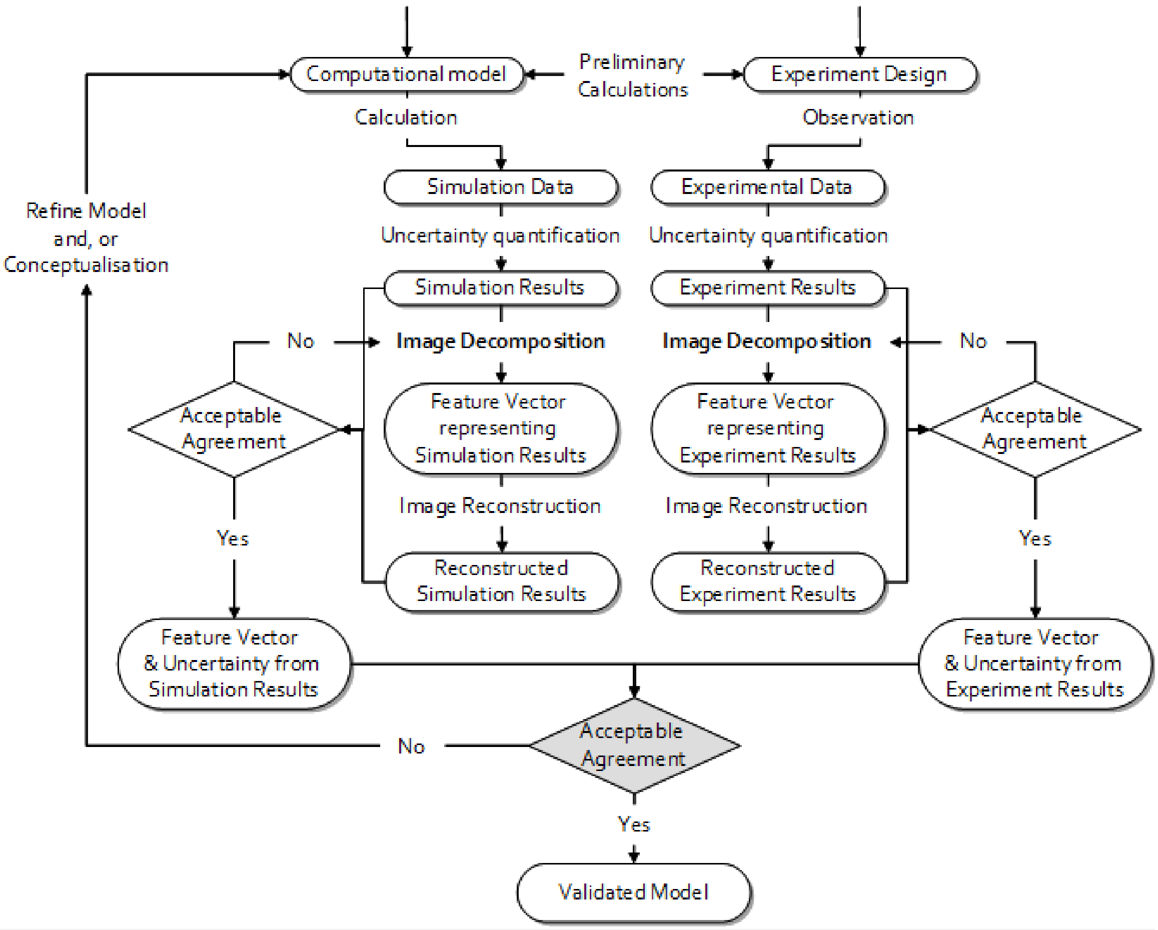

Figure 4: Flow chart for the validation process using image decomposition.

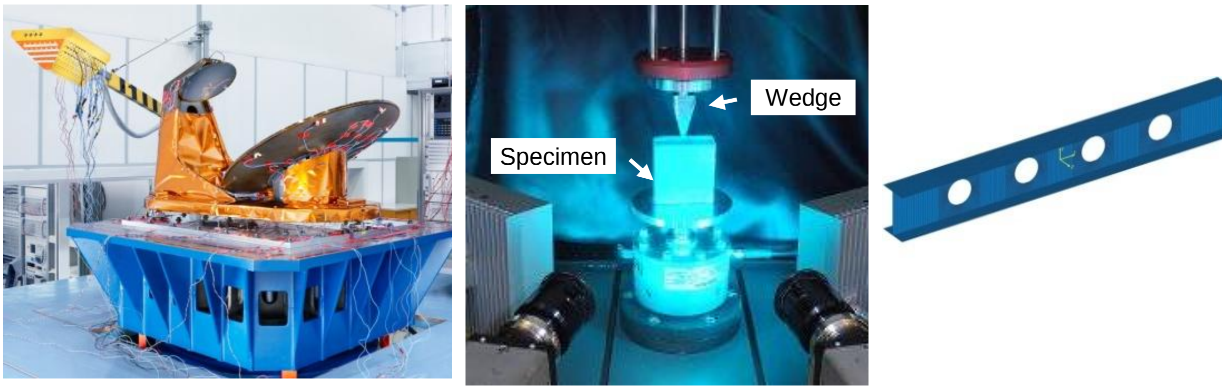

Figure 5: Case studies for the Validation ILS. Left: Full CFRP space antenna reflector; centre: wedge indenter deforming a rubber block (experimental arrangement); right: I-beam with holes under 3-point bending (simulation model).

The Validation ILS protocol included three case-studies to which the validation methodology could be applied. Their definition was based on two brain-storming meetings of VANESSA participants, and a strong emphasis was put on using industrially relevant components. More specifically, the three case-studies shown in Figure 5 were:

a) a thermo-mechanical analysis of an antenna reflector,

b) a wedge indenter deforming a rubber block,

c) an I-beam with open holes in the web under three-point bending loading.

A step-by-step application of the validation process and the recording of results was provided in the protocol. Displacement and / or strain plots in 'tiff' format were provided for use in the validation process. An image decomposition software package, which could be used for image decomposition, together with an Excel file for the visualization of the results were developed by UNIL and were made available for the ILS participants.

The Validation ILS was formally launched at the second CEN workshop on September 4th, 2013, in Cardiff, Wales. The initial focus of the promotional campaign of the validation ILS to the international engineering community consisted of personalised invitations to engineers and researchers involved in computational solid mechanics simulations, mainly from the industrial sector, who were carefully selected by the VANESSA consortium. More specifically, in a first promotion round, 34 personalized invitations were sent, while in a second round another 36 personalized invitations were e-mailed. In addition, the consortium reached out to engineering bodies such as NAFEMS and other organisations such as BSSM in order to bring attention to the study of the wider engineering community. The study was further promoted via both internal and external websites and via social media (Twitter and Wordpress blogs). Subsequently, an open invitation was issued via the project website and at conferences, followed by some 100 serial emails, including the participants of the 1st Knowledge Exchange Workshop, which took place at the British Museum in London on November 5th 2013.

The feedback received from the international engineering community comprised 18 completed Validation ILS protocols, as well as comments about the validation methodology and the ILS protocol from 3 participants who did not complete the ILS protocol. In Table , a collation of the main comments received from the Validation ILS participants is presented.

The collection of the completed validation ILS protocols was followed by collation, interpretation and dissemination of the results. The collected feedback comprises comments referring to the validation methodology and the ILS process; remarks on the implementation of the methodology; and comments about the three case-studies provided in the Validation ILS.

Table 6: Collation of major comments received from the Validation ILS participants

Participant	**Case study used**	**Main comment**
1	Wedge indenter	Methodology is easy to follow and software is adequate
2	I-beam with open holes	Globally, this validation methodology is a useful tool to assess the FE models
3	Wedge indenter	No major comment
4	I-beam with open holes	No major comment
5	Antenna reflector	A lesson learned is the importance of same ROI for measurement and simulation.
6	I-beam with open holes	The right selection of the ROI is most important
7-A	Antenna reflector	The provided geometry (full-field) is not suitable for the decomposition methods available in the software
7-B	Wedge indenter	It is important that both the experimental and the simulation images are based either on the deformed or on the original object shape
8	I-beam with open holes	No major comment
9-A	Antenna reflector	This example has a complicated geometry and requires the 3 data sets to be masked to equivalent ROI.
9-B	I-beam with open holes	Overall the main problem has been the apparent misalignment of the DIC/Model region of interest. The only 'acceptable' case is the one (UX Side) which has the least high ordered shape.
9-C	Wedge indenter	For the larger displacements it is obvious that the sample rotated as shown by the tapered dark blue edges.
9-D	3 point bend of ceramic beam (participant exemplar)	ESPI is used to measure the response of the material under test which is compared with a computer model in which the boundary properties are adjusted until the model output matches the ESPI measurements.
10-A	Antenna reflector	No major comment
10-B	I-beam with open holes	No major comment
10-C	Wedge indenter	No major comment
11	I-beam with open holes	The whole validation procedure is easy to follow
12	I-beam with open holes	This is an interesting exercise to see if image decomposition is a valuable and valid approach for comparing simulated and experimental data sets without the usual requirements of accurate coordinate transformation and scaling, and may in some instances be useful.
13	N/A (*)	Overall a solid validation methodology but requires DIC equipment for its implementation, which we do not have available.
14	N/A (*)	I found it extremely easy to use, and a really useful tool, which would be really effective both in the university research and industrial field.
15	N/A (*)	From what I have seen it looks to be a powerful and useful method for validation of FE models, using full field data rather than just comparing individual point results or profiles.

(*) N/A: these participants did not return a completed protocol but only their comments.

Many comments about the validation methodology were received, most of which were positive, revealing that the methodology provides an easy-to-follow useful tool to assess the FE models and validate simulations using full-field experimental data. The impression received from the engineering community is that the validation methodology is novel, not widely known or applied, and changes or adjustments in the traditional approaches to establishing model credibility would be required before its adoption.

Some of the comments resulted in suggestions for changes in the CWA; these comments included 'the importance of using a common basis for the measurand maps from experiment and model', 'the need of employing normalised orthogonal shape descriptors' and the 'importance of the goodness of the displacement or strain field reconstruction to the original data field'. Some remarks on the implementation of the ILS methodology were received, the most important being the requirement of a perfect match between the Region of Interest (ROI) selected in the experiment and the simulation. Minor comments were also received about features of the three case studies, which did not affect the validation methodology or its implementation, nor raised issues related to the CWA.

Deliverables and Milestones

The Task 3.2 relevant deliverables were successfully delivered in time and a corresponding Milestone was achieved:

Item	Description	Responsibility	Date due	Date delivered
D3.2	Validation round-robin protocol: Protocol for round robin on validation of computational solid mechanics models	LTSM-UP	m3	m3
MS3	Validation round-robin initiated: Protocol, materials and promotion strategy for round robin on validation of computational solid mechanics models agreed	LTSM-UP	m4	m4
D3.4	Validation round-robin report	LTSM-UP	m16	m16

Conclusions

The completion of the ILS protocols by the participants demonstrated successfully the effectiveness of the proposed methodology for the validation of computational solid mechanics simulation models using full-field optical measurements of strain and/or displacement. Furthermore, evidence was provided, that the validation protocol (together with the calibration protocol) form a solid base for the VANESSA standardisation activity.

The participation of the engineering community in the inter-laboratory study and especially the contribution of organisations outside of the project consortium that supported this ILS activity resulted in an increase of the awareness about the validation methodology. The dissemination of the ILS activity results are expected to lead to the proposed validation methodology and the related CWA gaining further international acceptance.

Discussions and Conclusions on Work Package 3

The goal of the VANESSA project was to establish the validation methodology and the associated calibration procedures within a standards framework and to promote the adoption of the methodology within the European industrial and scientific communities. To this end two international Inter Laboratory Studies were conducted in Work Package 3.

A Calibration ILS and Validation ILS protocol were established, published and promoted through the project website. Both ILS protocols provided a step-by-step guidance for the calibration and validation processes, respectively. The Calibration ILS was based on the Cantilever Reference Material, while the Validation ILS provided three test cases with industrial relevance. These were made available for both ILS as data sets and physical systems (bending and indentation tests) together with dedicated image decomposition software based on MatLab.

The Calibration ILS and Validation ILS were initiated at the BSSM Conference in Cardiff, Wales, in September 2013 and were promoted, among other means, by personalised invitation to engineers and researchers. Participants included representatives from instrument manufacturers, measurement service providers, and aircraft industries. Results and feed-back from participants outside and inside of the consortium were collected, collated and interpreted. The results were disseminated through the project website [4].

Work package 3 has achieved all its objectives, and all four deliverables are available in the public domain. The conclusions from the Inter Laboratory Studies provided evidence that the validation protocol enshrined in the CEN Workshop Agreement (CWA) has a solid base, which was an objective of Work Package 3. Together, these activities contributed substantially to the achievement of one of the VANESSA project's three science and technology objectives, namely 'to conduct international comparison (round-robin) exercises that will generate evidence that the reference material, for calibration of optical systems for strain field measurement, and the validation protocol for computational solid mechanics models, form a solid base for standardisation'.

Finally, the widespread promotion of the validation ILS contributed to a second VANESSA S&T objective 'to raise awareness in the EU industrial base and international engineering community of the validation protocol'.

3.3 Work Package 4 – Standard Preparation (WP Manager: SNV)

Introduction

The goal of the VANESSA project was to establish the validation methodology and the associated calibration procedures within a standards framework and to promote the adoption of the methodology within the European industrial and scientific communities. Successful accomplishment of this goal required achievement of the following scientific and technical objectives:

a) To conduct international inter-lab comparison (round-robin) exercises that will generate evidence that the reference material, for calibration of optical systems for strain field

b) To prepare a CEN Workshop Agreement on validation of computational solid mechanics models using strain fields from calibrated measurement systems.

c) To raise awareness in the EU industrial base and international engineering community of the validation protocol through a programme of knowledge dissemination and exchange.

Objectives

Work Package 4 has been concerned primarily with the achievement of the second of these project objectives. Specifically, the objectives of Work Package 4 were:

a) To integrate the work on the calibration of strain fields in static, planar components with recent work on calibration of displacement and strain fields in dynamic, three-dimensional components; and
b) To prepare a CEN Workshop Agreement on validation of computational solid mechanics models using strain fields from calibrated optical measurement systems.

In order to achieve these objectives WP 4 included the following tasks:

4.1: Integration of SPOTS and ADVISE outputs (Task Manager: UNIL)

[4] http://www.engineeringvalidation.org/?VANESSA_home:Inter-Laboratory_Studies

4.2: Preparation of CEN Workshop agreement (Task Manager: SNV)

The following sections contain the final reports for each of these tasks and are followed by 'Discussion and Conclusions' for the work package.

Task 4.1 – Integration of SPOTS and ADVISE Outputs (Task Leader: UNIL)

Introduction

The SPOTS project[5] led to the publication of a guideline for the calibration of optical systems for strain measurement[6] and the design of a corresponding reference material. This work is gaining acceptance following its endorsement by VAMAS TWA26 and a number of calibrations have been published[7,8]. The SPOTS guideline is limited to static or pseudo-static loading cases and for planar or locally plane surfaces. The subsequent ADVISE project[9] sought to remove both of these limitations and resulted in two viable designs for the reference material required in the calibration process. This task has been focussed on integrating the SPOTS and ADVISE approaches to provide a unified procedure for the calibration of optical instruments capable of measuring strain fields for use in the validation of computational solid mechanics models. The process of integration involved a number of brain-storming sessions with partners involved in both projects in order to arrive at a common methodology that was acceptable to the engineering community and could serve as the basis for the proposed standard.

The following project beneficiaries have been involved in the task: UNIL (task leader), DD, EMPA & CRF.

Task Objective

To integrate the work on the calibration of strain fields in static, planar components with recent work on calibration of displacement and strain fields in dynamic, three-dimensional components.

Progress

The ADVISE project had resulted in two designs for Reference Materials for use in the calibration of optical systems capable of measuring out-of-plane strain or displacement fields, i.e. a membrane that could be excited at resonant frequencies and a cantilever that could be either excited at resonant frequencies or loaded statically. Consequently, the first step in this task was to select one of these Reference Materials as the preferred design. The cantilever design was adopted because it was easier and cheaper to manufacture, it allowed cyclic, transient and static loading and it enabled the possibility of in-plane calibrations.

After the Cantilever Reference Material had been selected, work commenced on drafting a unified protocol for the use of the SPOTS Reference Material and Cantilever Reference Material (Figure 7) for calibration of optical systems for use in measuring in-plane strain and out-of-plane

[5] SPOTS, *Standardisation project for optical techniques of strain measurement*, GROWTH Project No. G6RD-CT-2002-00856.

[6] Patterson, E.A., Hack, E., Brailly, P., Burguete, R.L., Saleem, Q., Siebert, T., Tomlinson, R.A., & Whelan, M.P.,2007, 'Calibration and evaluation of optical systems for full-field strain measurement', *Optics and Lasers in Engineering*, 45(5):550-564.

[7] Whelan, M.P., Albrecht, D., Hack, E., Patterson, E.A., 2008, 'Calibration of a speckle interferometry full-field strain measurement system', *Strain*, 44(2):180-190.

[8] Sebastian, C., & Patterson, E.A., 2014, Calibration of a digital image correlation system, *Experimental Techniques*, doi. 10.1111/ext.12005.

[9] ADVISE, *Advanced Dynamic Validations using Integrated Simulation and Experimentation*, Project No. SCP7-GA-2008-218595.

displacements. A substantial number of commonalities were identified including the methodology for providing traceability, the uncertainty budgeting, the guidance on manufacturing, the comparison of measured and predicted values, the assessment of deviations. This resulted in the production of a draft unified methodology as deliverable D4.1 on-time in month 4 and a final unified calibration procedure (deliverable D4.3) in month 8. This unified methodology formed the core of the protocol for the inter-laboratory study (ILS) on calibration (deliverable D3.1) and has evolved, with feedback from the ILS, into the description of the calibration procedure provided in the CEN Workshop Agreement (deliverable D4.4).

The beneficiaries in this task held a number of meetings which coincided with project progress meetings in order to brain-storm on the major issues and also used on-line meetings to develop and edit the unified calibration procedure.

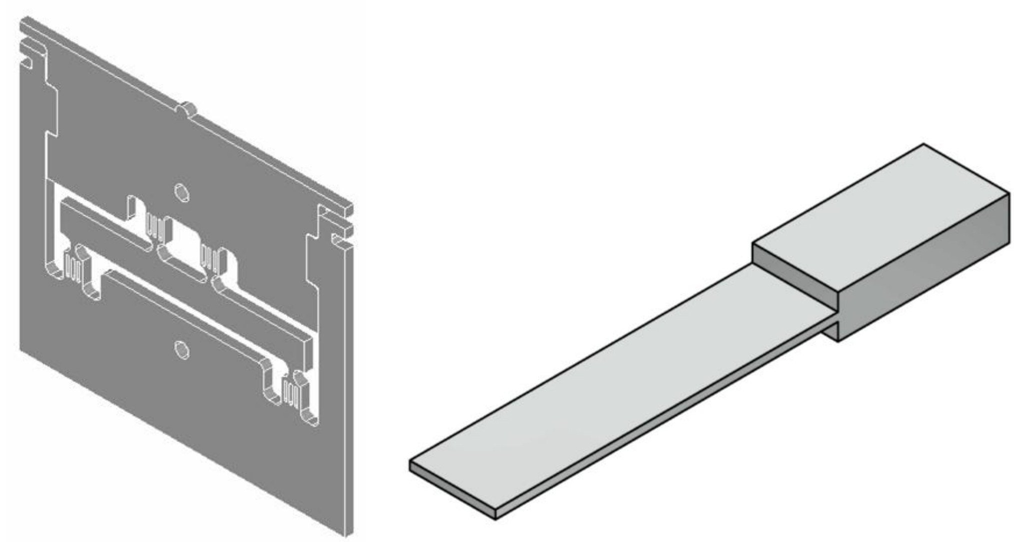

Figure 7 – SPOTS Reference Material (*EU Community Design Registration 000213467*) (*left*) and Cantilever Reference Material (*right*) intended for calibration.

Conclusions

The development of a unified calibration procedure based on the outputs from the SPOTS and ADVISE projects has been completed on schedule. The two deliverables from the task, which were the draft (D4.1) and final (D4.3) unified calibration procedures were produced in months 4 and 8 of the project. A decision was taken to adopt the cantilever design of Reference Material for out-of-plane displacement measurement systems, rather than the membrane design also developed in the ADVISE project, based on the ease of manufacture and diversity of loading options. The unified calibration procedure formed the basis of the protocol used in the Inter-Laboratory Study (ILS) on calibration (deliverable D3.1) and, as a consequence of feedback from the ILS, evolved into the procedure described in the CEN Workshop Agreement (deliverable D4.4) that will be published shortly by CEN.

Deliverables and Milestones

Item	Title	Responsibility	Date due	Date Delivered
D4.1	Draft unified calibration procedure	UNIL	4	4
D4.3	Unified calibration procedure	UNIL	8	8

Task 4.2 - Preparation of CEN Workshop Agreement (Task Leader: SNV)

Introduction

This task involved the preparation of a business plan, organization and preparation of a CEN Workshop Agreement on the subject of validation of computational solid mechanics models using strain fields from calibrated measurement systems. The workshop involved three meetings that were organized as part of this task. The task involved the preparation of the standardization work based on the outputs from the SPOTS and ADVISE projects as well as from tasks 3.1, 3.2 and 4.1 in this project.

The following project beneficiaries have been involved in the task: SNV (task leader), UNIL, EMPA, DD, LTSM-UP, HPS, CRF, NNL

Task Objective

To prepare a CEN Workshop Agreement on validation of computational solid mechanics models using strain fields from calibrated optical measurement systems.

Progress

A business plan (D4.2) was produced at the beginning of the project which followed the process prescribed in the directives for CEN Workshop Agreements (CWA). The business plan was submitted to CEN and initiated the Workshop 71 on the Validation of Computational Solid Mechanics Models. A kick-off meeting was held at CEN HQ in Brussels on June 12th, 2013 .

In order to reach a wide range of experts, one CWA meeting was held at the "BSSM 9th International Conference on Advances in Experimental Mechanics", one meeting was held as webinar and the last meeting was held immediately prior to the "Third International Workshop on Validation of Computational Mechanics Models "

Prior to each meeting a draft of the CWA was published on the CEN website and comments were invited from the general public. This resulted in approximately 50 comments which were discussed at the CWA meetings and a consensus reached on amendments to the CWA. This cycle of consultation, discussion and consensus was repeated three times before finalizing the document which was unanimously accepted at the final CWA meeting in Munich on June 11th, 2014. The CWA has been submitted to CEN for formal publication.

Efficient communication between the partners was achieved by holding Skype meetings and using a private blog as a document repository which enabled the consortium to meet the given time schedule for all of the milestones and deliverables.

Conclusions

The task to prepare a CEN Workshop Agreement on validation of computational solid mechanics models using strain fields from calibrated optical measurement systems, which was widely supported, has been completed on time and within budget.

A wide range of organizations were consulted and have contributed during the preparation of this agreement. They were drawn from the following economic sectors: aerospace; automotive;

instrument manufacturing; nuclear power; research institutes and universities. These contributions are acknowledged in the foreword to the CEN Workshop Agreement.

Deliverables and Milestones

Item	Title	Responsibility	Date Due	Date Delivered
D4.2	CWA Business Plan	SNV	4	4
D4.4	CEN Workshop Agreement	SNV	18	18

Discussion and Conclusions on Work Package 4

This work package was concerned with accelerating the standardization process and achieving project S&T objective (b), i.e. the preparation of a CEN Workshop Agreement on validation of computational solid mechanics models using strain fields from calibrated measurement systems. The first task involved the common partners from the SPOTS, ADVISE and VANESSA projects working together to integrate the outputs from the SPOTS and ADVISE projects in a coherent set of reference materials and associated methodologies for calibration of strain field measurement systems. This work underpinned the protocols for the inter-lab comparisons (project S&T objective (a)). The second and more substantial task was the generation of a CEN Workshop Agreement, which has been successfully achieved and incorporates the validation and calibration procedures developed. The process of public consultation followed in developing the CWA made a considerable contribution to raising awareness in the EU industrial base and the international engineering community of the validation protocol (project S&T objective (c)).

3.4 Work Package 5 – Knowledge Exchange (WP Manager: DD)

Introduction

The goal of Work Package 5, Knowledge Exchange, was to raise participation of the EU industrial base and international scientific community in the development and use of the standardisation processes being pursued in Work Packages 3 and 4. The importance of this work is based on the need of a constant exchange and discussion of the process of standardisation within the engineering and scientific community in order to achieve the best result and acceptance.

In particular the objectives of this work package were set as follows:

a) to promote the round robins and standardisation actions being undertaken in the project;

b) to disseminate the knowledge associated with the project to the EU industrial base; and

c) to engage in knowledge exchange with the international engineering community in order to achieve excellence in the standards work and to accelerate their international acceptance.

There were three routes through which the dissemination was performed. Each of these routes was incorporated in a task.

Task 5.1: A series of international workshops was organised to stimulate participation from leading researchers and end-users in the field of validation of engineering simulations

Task 5.2: Dissemination through conferences, exhibitions plus trade and scientific publications to promote awareness and knowledge of the activity

Task 5.3: Generation of an external website to promote the project activities and to host on-line resources plus the establishment of an intra-net to support collaboration within the project

The following sections contain the final reports for each of these tasks and are followed by 'Discussion and Conclusions' for the work package.

Task 5.1 – Knowledge Exchange Workshops (Task Leader: UNIL)

Introduction

The core activity of the task was to organise two knowledge exchange workshops in which invited speakers would discuss the latest developments in the validation of computational mechanics models, the associated technologies and the implications for engineering practice. The awareness of the developments in the validation of computational models would be promoted both by the workshops themselves and by the advertising campaign associated with achieving a good attendance at the workshops.

The following project beneficiaries have been involved in the task: UNIL (task leader), DD, EMPA, LTSM-UP, CRF & NNL.

Task Objectives

a. To disseminate the knowledge associated with the project to the EU industrial base; and
b. To engage in knowledge exchange with the international engineering community in order to achieve excellence in the standards work and to accelerate their international acceptance.

Progress

Two one-day stand-alone knowledge exchange workshops have been organised under the titles 2nd and 3rd International Workshop on Validation of Computational Mechanics Model. The first workshop in the series had been organised by Professors Shan Fu and Eann Patterson at Shanghai Jiao Tong University, China, in October 2011 prior to commencement of the VANESSA project. The second and third workshops were held at the British Museum in London on November 5th, 2013 and at the Neues Rathaus in Munich on June 12th, 2014 respectively. Reports on these two workshops have been submitted as deliverables D5.4 and D5.6 respectively, and the pdf files of the presentations made at the workshops can be found on the project website at www.engineeringvalidation.org. A special issue of the Journal of Strain Analysis for Engineering Design is being organised under the title 'Advances in validation of computational mechanics models' and will contain papers based on a selection of the presentations from both workshops plus two papers reporting the Inter-Laboratory Studies. A brief overview of the workshops is provided here.

Both workshops were organized in three sessions each consisting of an invited keynote presentation and two submitted presentations followed by a panel discussion. The keynote presentations were of 40 minutes duration, the remaining presentations of 20 minutes each and the panel discussion at least 30 minutes in duration, which provided time for some high-level debate on the issues raised by the presentations. In London, the first session was focussed on 'Solid Mechanics Model Validation' with contributions on the proposed VANESSA protocol, civil engineering structures and uncertainty quantification for aerospace structures. The second session in London was on 'Acceptable Evidence for Engineering Decisions' with a contribution from a philosopher on what constitutes evidence, from the nuclear industry on sparse data and from the aerospace industry on principal component analysis for validation. The third session was on 'Fluid Mechanics Model Validation' and included an overview on the challenges for validation in CFD, the use of Bayesian averaging for quantifying turbulence and an example of validation for a non-Newtonian fluid flow. The discussions at this workshop provided valuable insight and context for the preparation of the CEN Workshop Agreement on Validation of Computational Solid Mechanics Models.

The workshop in Munich consisted of a first session on 'Mechanics Model Validation' with speakers focussing on aerospace and automotive applications as well as the connections to multi-scale modelling. The second session was on 'Making Decisions using Mechanics Models' with inputs from a philosopher on 'How not to make decisions with computer simulations' as well as contributions on complex non-linear systems. The third sessions was focussed on 'Designing with High-Fidelity Models' with contributions on design-to-fabrication, aero-engine structures and CAD design of airframes. The discussion at this workshop confirmed the need for the standards development in this area and also focussed on the opportunities in engineering practice provided by high fidelity simulations.

The attendance at the workshops was approximately 50 and 40, respectively, with representation from industry, academia and national labs from a number of countries, so that dissemination of knowledge to the EU industrial base was achieved. In order to strengthen the dissemination component of this task a special session on 'Credibility of Computational Solid Mechanics Models' has been organised at the 11th World Congress on Computational Mechanics in Barcelona on July 25th, 2014. In this session the project beneficiaries presented five papers in which exemplars demonstrating the application and advantages of the validation protocol were described.

Deliverables and Milestones

Item	Description	Responsibility	Date due	Date delivered
D5.1	Workshop proposal: Proposal for two KE workshops including outline programmes, promotion and dissemination plan	UNIL	m3	m3
D5.4	1st KE workshop: First knowledge exchange workshop held	UNIL	m12	m10
D5.6	2nd KE workshop: Second knowledge exchange workshop held	UNIL	m18	m17

Conclusions

The proposed programme of knowledge exchange workshops has been completed on schedule and reported in deliverables D5.4 and D5.6. An additional knowledge exchange event has been planned at a major international conference on computational mechanics modelling. These events have allowed the project beneficiaries to engage in knowledge exchange activities with international engineering community as presented by the delegates attending the workshops from 10 countries. As a result of these exchanges, particularly at the London workshop, the quality of the CWA document has been improved through the insights and understanding of relevance gained. In addition, the acceptance of the approach to validation described in the CWA document has been accelerated and the potential opportunities identified for advancing engineering practice through the exploitation of high fidelity validated models. The task has achieved its objectives of disseminating knowledge of the validation procedures to the EU industrial base both through attendance at the workshops of representatives from the aerospace, automotive, bioengineering, civil engineering, materials, nuclear and space industries and through the advertising of the events through a number of websites, such as NAFEMS and EURASEM, and the promotion of the workshops via personal emails to hundreds of engineers across Europe.

TASK 5.2: Dissemination to the EU Engineering Community (Task Leader: DD)

Introduction

This task was focusing on the promotion of the round robin, CEN workshop agreements and knowledge exchange workshops activities to the EU engineering community and the dissemination of the outputs. The main groups addressed were the scientific community as well as the EU industrial base. The dissemination was achieved through publication in the trade and professional literature, a presence at major conferences and exhibitions, and through liaison with European and international industrial and professional bodies.

The following project beneficiaries have been involved in the task: DD (task leader), UNIL, EMPA, LTSM-UP, CRF & NNL.

Task Objectives

c. Promotion of the round-robins, CEN workshop, knowledge exchange workshops to the EU engineering community and
d. Dissemination through publication in the trade and professional literature, a presence at major conferences and exhibitions, liaison with European and international industrial and professional bodies.

Progress

From the beginning of the project, the dissemination of the round robins and workshops has been pursued. The first presentation of the project was given in month 3 at an International Conference on Applications for Image based Measurements. During the duration of the project, so far 22 presentations have been made in five different European countries:

- Conferences with publications (15 presentations in international conferences, including 2 special sessions on major conferences in the fields of experimental and computational mechanics)
- Workshops (2 Knowledge Exchange workshops)
- Industrial exhibitions (3 exhibitions focusing on NDT Material Testing and Aero Space Engineering)
- Seminars (1 seminar on high performance structures in lightweight construction)
- Lecture (1 AIAS Summer school)
- Journal Manuscripts (1 manuscript under review; 2 in preparation; special issue in preparation)
- Industrial and professional bodies (promotion of CEN and knowledge exchange workshop through NAFEMS and EURASEM websites; participation in BSSM meetings and demonstration of calibration and validation methodologies)

The presentations were focussed on the round robins (inter laboratories studies ILS) the workshops (CEN and knowledge exchange) and the overall project progress and results.

Deliverables and Milestones

Item	Description	Responsibility	Date due	Date delivered
D5.2	Dissemination programme: Programme of dissemination through publication in literature and attendance at conference and exhibitions	DD	m4	m4
D5.7	Publication report: Publications on project outputs in trade & professional literature	DD	m18	m18

Conclusions

The constant interaction with the EU engineering community during the project was an important component of the project and was necessary to engage a wide range of industrial and scientific community in the process of developing the standardisation process. By spreading the information through international conferences, workshops, industrial exhibitions and journals, discussions with different communities were held throughout the duration of the project. These interactions helped the development of the standardisation process, by including suggestions and ideas to improve the process from professional engineers and increasing the awareness and acceptance. The high degree of dissemination activity can be seen from the average of more than 1.2 dissemination actions per month over the project duration.

Task 5.3: On-line Resources (Task Leader: EMPA)

Introduction

This task was concerned with the establishment of an intra-net to aid the exchange of information between partners and a public website to promote the activities of the project. The SPOTS and ADVISE project websites were integrated so as to provide a 'one-stop shop' for information on calibration and validation of strain field data in engineering components. Two Round Robins (or Inter-Laboratory Studies) were promoted, among other means, through the website, and their results are disseminated now. Further, on-line resources for professional development of engineers on the subject of validation of computational solid mechanics models are provided on the website.

The following project beneficiaries have been involved in the task:
EMPA (task leader) and UNIL.

Objectives

a) To promote the round robins and standardisation actions being undertaken in the project;

b) To disseminate the knowledge associated with the project to the EU industrial base; and

c) To engage in knowledge exchange with the international engineering community in order to achieve excellence in the standards work and to accelerate their international acceptance.

Progress

The intra-net was established as a private blog under http://projectvanessa.wordpress.com/, organized in Work Packages. It was regularly used to exchange information, discuss draft documents, distribute documents, and occasionally used to conduct a PSC vote.

The website was constructed at http://www.engineeringvalidation.org. It was constantly updated according to the progress of the project and presently includes the following topics:

- VANESSA home
  - project description
  - CEN workshop
  - Inter-Laboratory Studies
  - background material
  - publications
  - contact us
  - stakeholders
- Events
- Knowledge Exchange
  - 1st KE Workshop
  - 2nd KE Workshop
- Continued Professional Development
  - Podcasts
  - Validation Process Flowchart

While the sub-topics "Inter-Laboratory Studies", "calibration ILS" and "validation ILS", were used to promote the Round Robins that were conducted in Work Package 3, they now include a link to the ILS reports.

The topic CEN workshop contains material relevant for the standardization action conducted towards a CEN workshop agreement in Work Package 4.

The topic "Knowledge Exchange" contains the program and presentations of the two Knowledge Exchange Workshops held in London and Munich, respectively, for which the speakers provided the slides of their talks to remain available online.

Continued Professional Development contains a set of three podcasts which were recorded in m12 and form part of the CPD: (i) on the VANESSA CEN Workshop Agreement, (ii) on calibration and (iii) on validation. In addition a flowchart was generated to explain calibration, validation and the tools available for comparing large data sets. The flow-chart is shown in Figure 8. Each box links to a video-snippet explaining the content.

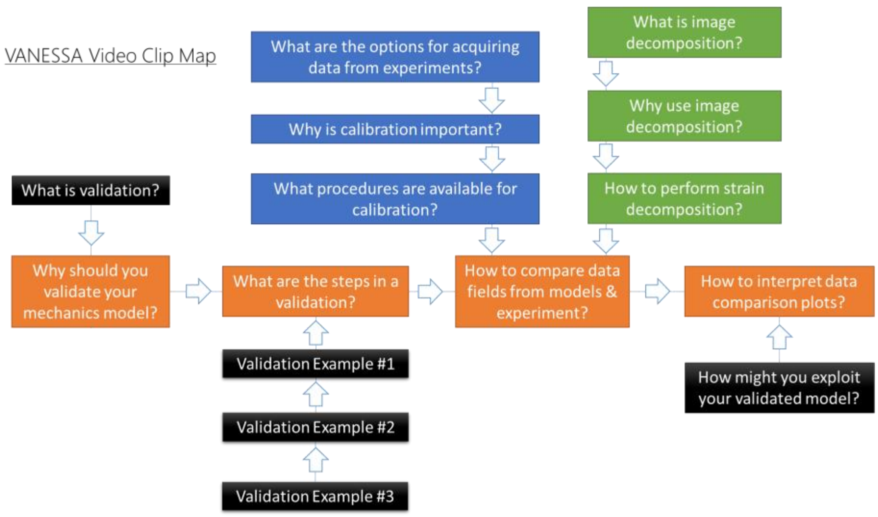

Figure 8: Flowchart explaining the essentials of a validation process.

Deliverables and Milestones

Item	Description	Responsibility	Date due	Date delivered
D5.3	Website constructed: Construction of project internet and intranet web sites; project description on website	EMPA	m4	M5
D5.5	CPD resources available: On-line resources for continuing professional development available on website	EMPA	m17	m17
MS8	Website integration, Demonstration of integration of SPOTS, ADVISE and VANESSA websites	EMPA	m8	m8
MS9	On-line resources, Plan for on-line resources agreed	EMPA	m8	m8

Conclusions

The Task 5.3 deliverables D5.3 and D5.5 were completed on schedule; and achievement of Milestones M8 and M9 was approved by the PSC at its Cardiff meeting on Sep 5, 2013. The website contains project relevant documents and material for the Continued Professional Development. The task has achieved its objectives of promoting the round robins and standardisation actions being undertaken in the project, disseminating the round robin results, and providing on-line resources for CPD on the subject of validation of computational solid mechanics models for the international engineering community.

Discussion and Conclusions on Work Package 5

The goal of this work package was to raise the awareness and participation of the EU industrial base and international scientific community in the development and use of the standardisation processes. Three routes of dissemination were followed. Within the two held knowledge exchange workshops an international community was addressed and the quality of the CWA document could be improved by the input of attendees at the workshops of representatives from the aerospace, automotive, bioengineering, civil engineering, materials, nuclear and space industries. A third workshop was held at a major international conference on computational mechanics modelling. The number of attendances and the quality of the discussions showed the high interest and demand of development of the standardisation process. Selected papers from the workshops will be published as a Special Issues of a peer-reviewed international journal.

Beside the organisation of dedicated events and workshops a continued effort has been made to promote and disseminate the round robins and standardisation actions. Here the interaction with the EU engineering community has been made by presentations at international conferences, exhibitions focusing on industrial community, journal manuscripts and through industrial and professional bodies. With an average of more than 1.2 dissemination actions per month over the whole project, this route was quite successful and increased the awareness beyond the end of the project. It is planned to continue the dissemination via conference and journal papers.

An intra-net was established as a private blog. Here all relevant information was posted and collected to exchange information, discuss draft documents, distribute documents, and occasionally used to conduct a PSC vote.

The project website was established and updated during the entire project with the newest relevant information. It has supported the promotion of the round robins and standardisation actions being undertaken in the project, dissemination of the round robin results, and the provision of on-line resources for Continued Professional Development on the subject of validation of computational solid mechanics models for the international engineering community.

Overall, all the tasks were finished as planned and all deliverables and milestones have been achieved and submitted on time. As the results of these tasks will remain and continue after the end of the project, the international engineering community will be able to engage in knowledge exchange in the future and further accelerate international acceptance of the standardisation work. In particular, the on-line resources for CPD on the subject of validation of computational solid mechanics models for the international engineering community will help to disseminate the concept of the validation process to international engineering community and EU industrial base.

4.0 Project Management

In accordance with Articles II.2.3 and Article II.16.5 of the Grant Agreement consortium activities have taken place over the course of the project as planned and summarised in figure 9.

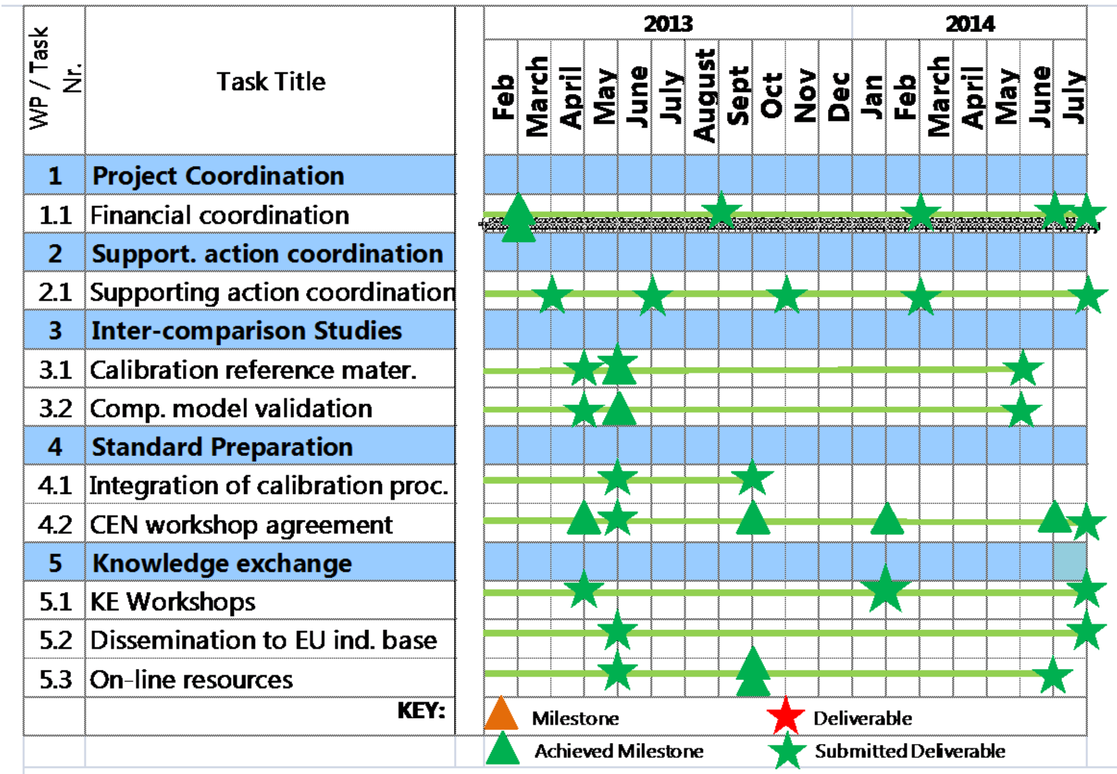

Figure 9 – Project Gantt chart showing completed status

4.1 Consortium management tasks and achievements

The following milestones have been achieved and deliverables have been submitted:-

MILESTONES			
Item	**Description**	**Due**	**Status**
MS1	Reference materials available	m4	Completed
MS2	Calibration round-robin initiated	m4	Completed
MS3	Validation round-robin initiated	m4	Completed
MS4	CWA kick-off	m3	Completed

MS5	1st CWA meeting	m8	Completed
MS6	2nd CWA meeting	m12	Completed
MS7	3rd CWA meeting	m17	Completed
MS8	Website Integration	m8	Completed
MS9	On-line resources	m8	Completed

DELIVERABLES			
Item	**Description**	**Due**	**Status**
D1.1	Six-month report	m7	Completed
D1.2	12-month report	m13	Completed
D1.3	IP Plan	m17	Completed
D1.4	Final report	m18	Completed
D2.1	PSC minutes: kick-off meeting	m2	Completed
D2.2	PSC minutes: month 4	m5	Completed
D2.3	PSC minutes: month 8	m9	Completed
D2.4	PSC minutes: month 12	m13	Completed
D2.5	PSC minutes: month 18	m18	Completed
D3.1	Calibration Inter-laboratory Study (round-robin) protocol	m3	Completed
D3.2	Validation Inter-laboratory Study (round-robin) protocol	m3	Completed
D3.3	Calibration Inter-laboratory Study (round-robin) report	m16	Completed
D3.4	Validation Inter-laboratory Study (round-robin) report	m16	Completed
D4.1	Draft unified calibration procedure	m4	Completed
D4.2	CWA Business Plan	m4	Completed
D4.3	Unified calibration procedure	m8	Completed
D4.4	CEN Workshop Agreement	m18	Completed
D5.1	Workshop proposal	m3	Completed
D5.2	Dissemination programme	m4	Completed
D5.3	Website constructed	m4	Completed
D5.4	1st KE Workshop	m12	Completed
D5.5	CPD resources	m17	Completed
D5.6	2nd KE Workshop	m18	Completed
D5.7	Publication report	m18	Completed

4.2 Project Finance

As this is an 18-month project only one official financial report has been requested which is due for submission to the EC in September 2014. No financial problems have been reported or are anticipated.

Only one change was made to the allocation of budget as outlined in the DOW. The decision was made to reallocate responsibility of the manufacture of reference materials to UNIL as resources for the manufacture were available in-house which presented both a more cost effective solution and also allowed the consortium to monitor production closely and ensure all materials produced remained within the specified tolerances.

In order to balance this change to the budget, organisation of the 2nd Knowledge Exchange workshop was handed over to EMPA.

This was formally agreed by all members of the PSC and recorded in the minutes of the meeting in Munich, June 2014.

4.3 Problems which have occurred and how they were solved

The project has run smoothly with only minor amendments to the original plans. The following deliverables and milestones have encountered minor changes:

<u>MS1 - Reference materials available</u>

During the production of reference materials required for the Calibration round-robin there were initial difficulties maintaining the tolerances required for the width along the length of the cantilever. A number of different manufacturing techniques were tested, and a staged approach to the manufacture was found to achieve results within the tolerances required. In order to ensure quality in the manufacturing process each cantilever has been independently measured, and is issued with signed certificate of the measurements.

<u>D5.4 - 1st Knowledge Exchange Workshop</u>

The British Museum in London was chosen to be the venue for the 1st Knowledge Exchange Workshop to be held on November 6th, 2013. A reservation was made in April 2013 and plans to publicise the event were put in place. Unfortunately in August the consortium was advised by the Museum that due to an unexpected visit by a Head of State, our reservation could no longer be honoured. A number of alternative venues were explored, along with alternative dates. Following this investigation and discussion with consortium member and key-note speakers who had been booked for the event it was decided to move the workshop to the 5th November 2013 at the Museum. Industry organisations which had been publicising the event were contacted and the revised information issued.

<u>D1.1 - Six month report</u>

This was delayed by a month as a consequence of a number of partners being on summer vacation during August 2013. The deadline was moved by unanimous approval of the PSC and the report submitted by the new deadline. The deliverable has been accepted.

4.4 Changes in the consortium

There have been no changes to the consortium.

4.5 List of project meetings, dates and venues

Table 7 - VANESSA project meetings held and scheduled

Year	Month Nr		Event	Output & due date	Location	Dates	Comments
2013	1	Feb	Kick-off meeting	D2.1, month 1	Liverpool, UK	6-7 Feb	
			WP3 Brainstorming meeting	D3.1, month 3	Liverpool, UK	8th Feb	
	2	March	WP3 Brainstorming meeting	D3.1, month 3	Ulm, Germany	20-21 March	Overlapping with ICAIM conference.
	5	June	CWA kick-off meeting with CEN	MS4, month 6	Brussels	12th June	
			PSC meeting	D2.2, month 5	Brussels	13th June	
	7	Aug	WP5 meeting	D5.6, month 18	Munich, Germany	20-21 August	Preparation of D5.6
	8	Sept	1st CWA meeting	MS5, month 8	Cardiff, UK	4th Sept	Coinciding with BSSM conference and exhibition
			PSC meeting	D2.3, month 9	Cardiff, UK	5th Sept	
	10	Nov	Knowledge Exchange Workshop	D5.4, month 12	London UK	5th Nov	1 day workshop at the British Museum
2014	12	Jan	2nd CWA meeting	MS6, month 12	Dubendorf, Switzerland	13th Jan	Webinar hosted for those who cannot attend meeting at EMPA premises
			PSC meeting	D2.4, month 13	Dubendorf, Switzerland	13-14 Jan	
	16	May	WP3 Meeting	D3.3 & D3.4, month 16	Patras, Greece	13-14 May	ILS conclusions needed for 3rd CWA meeting
	17	June	3rd CWA meeting	MS7, month 17	Munich, Germany	11th June	Air museum
			Knowledge Exchange Workshop	D5.6, month 18	Munich, Germany	12th June	New Town Hall
	18	July	Final Project meeting	D2.5, month 18	Liverpool, UK	1-2nd July	University of Liverpool
			Knowledge Exchange Session	D5.6, month 18	Barcelona, Spain	25th July	Special session in WCCM, 2014

Table 8 – List of VANESSA Dissemination Activities

No	Type of Activities	Main Leader	Location	Dates	Comments
1	CWA kick-off meeting with CEN	SNV	Brussels	12th June	
2	1st CWA meeting	SNV	Cardiff, UK	4th Sept	Workshop held within International BSSM conference and exhibition
3	Knowledge Exchange Workshop	UNIL	London UK	5th Nov	1-day workshop at the British Museum with international participation
4	2nd CWA meeting	SNV & EMPA	Dubendorf, Switzerland	13th Jan	Webinar hosted at EMPA premises
5	3rd CWA meeting	SNV & HPS	Munich, Germany	11th June	Workshop held at Munich Air Museum
6	Knowledge Exchange Workshop	HPS & EMPA	Munich, Germany	12th June	1-day workshop at the New Town Hall, Munich with international participation
7	Knowledge Exchange Session	UNIL	Barcelona, Spain	25th July	Special session organised at WCCM, 2014

5.0 Plan for use and dissemination of foreground

The principal output from the project is the CEN Workshop Agreement which will be published as CEN 16799 'Validation of Computational Solid Mechanics Models'. Thus it will be available for use by the entire scientific and engineering community.

In addition a special issue of the Journal of Strain Analysis for Engineering Design (JSA) has been commissioned based on selected presentations from the two Knowledge Exchange Workshops which will be written up has manuscripts and subject to peer-review prior to publication. In addition, the Task Leaders for the Inter-Laboratory Studies on Calibration and Validation are preparing a pair of manuscripts based on the ILS reports (D3.3 & D3.4) which will also be included in the JSA Special Issue. It is planned that the Special Issue will be published in late 2015. This publication will increase awareness of the project and CEN 16799 as well as extending the visibility of the VANESSA project by 12 months.

Work is underway to embed the procedures described in CEN 16799 in the in-house protocols used by companies in the aerospace and nuclear industry in Europe and discussions have taken place with the US defence sector.

There are currently no published peer-reviewed publications. A complete list of dissemination activities has been submitted in SESAM and a summary of dissemination meetings organised as part of the VANESSA project is shown in Table 8.