

ERSI SCREAMER

JUNE 2019



The Who, What, and Why of ERSI

For those who are new to the Engineered Residual Stress Implementation (ERSI) working group, the ERSI Screamer is a recurring newsletter designed to facilitate communication across committees. A brief description of the who, what, and why of ERSI is included here.

Sponsoring Organization: This working group is sponsored by the United States Air Force (USAF) Aircraft Structural Integrity Program (ASIP) under the direction and guidance of Mr. Chuck Babish.

Purpose:

1. To identify and lay out a roadmap for the implementation of engineered deep residual stress which can be used in the calculation of initial and recurring inspection intervals for fatigue and fracture critical aerospace components.
2. To highlight gaps in the state-of-the-art and define how those gaps will be filled.
3. Then to define the most effective way to document requirements and guidelines for fleet-wide implementation.

Vision: Within 3-7 years have developed a framework for fleet-wide implementation of a more holistic, physics-based approach for taking analytical advantage of the deep residual stress field induced through the cold expansion process, into the calculations of initial and recurring inspection intervals for fatigue and fracture critical aerospace components. Then move from there to other deep residual stress inducing processes, like Laser Shock Peening and Low Plasticity Burnishing.

Organization: The Working Group is broken up into 8 committees with a chair for each, as shown below. If anyone is interested in being a committee chair, please contact one of the ERSI Organizers.

Committee	Chair(s)
INTEGRATOR	Dr. Dale Ball (Lockheed Martin) & Dr. TJ Spradlin (USAF AFRL)
VALIDATION TESTING	Mr. Jacob Warner (USAF A-10 ASIP)
RESIDUAL STRESS PROCESS SIMULATION	Mr. Keith Hitchman (FTI)
FCG ANALYSIS METHODS	Mr. Robert Pilarczyk (Hill Engineering)
DATA MANAGEMENT/QUALITY ASSURANCE	Mr. Kaylon Anderson (USAF A-10 ASIP)
NON-DESTRUCTIVE INSPECTION	Mr. John Brausch (USAF AFRL)
RISK ANALYSIS & UNCERTAINTY QUANTIFICATION	Ms. Laura Hunt (SwRI) & Mr. Lucky Smith (SwRI)
RESIDUAL STRESS MEASUREMENT	Dr. Mike Hill (Hill Engineering)

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Screamer Editors & ERSI Organizers:

Mr. Dallen L. Andrew
Hill Engineering | 916.635.5706
dlandrew@hill-engineering.com

Dr. Scott S. Carlson
Lockheed Martin | 817.763.3065
scott.carlson@lmco.com

Mr. Robert T. Pilarczyk
Hill Engineering | 916.635.5706
rtpilarczyk@hill-engineering.com

A Status Update of the ERSI Working Group

As we move through our third year as a Working Group and towards our fourth Workshop there is much to be excited about. We now have a total of 113 members and continue to grow.

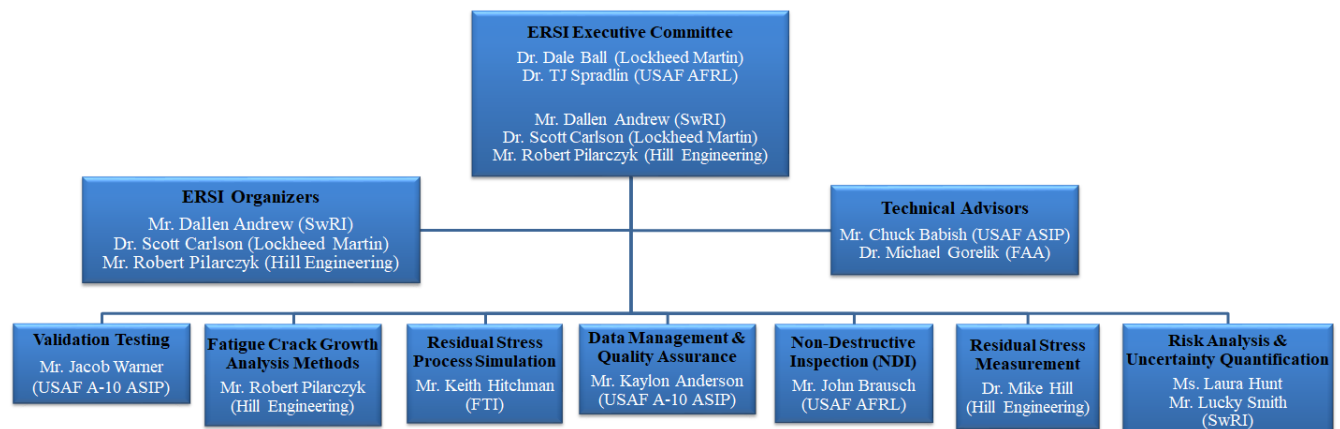
ERSI has representation from the USAF, US Navy, US Marine Corps, the Australia DST Group, and the National Research Council (NRC) in Canada. We have grown to have senior technical representation from all three major airframe Original Equipment Manufacturers (OEMs): Lockheed Martin, The Boeing Company, and Northrop Grumman. Over the last year we have also worked to include representation from the engine community, and now have representation from Rolls-Royce Engines.

ERSI has also grown in the representation of USAF Aircraft Structural Integrity Program (ASIP) managers. Currently ERSI has participation from A-10, F-16, F-15, F-35, B-1, C-5, KC-135, and T-38 ASIP managers, analysis leads, or contractor representation. In addition to our ASIP Managers, we have welcomed Mr. Chuck Babish to the ERSI Working Group! This is a huge step forward as ERSI looks to accomplish its goals of the implementation of more holistic methods for the implementation of engineered residual stresses for the calculation of initial and recurring inspection intervals for fatigue and fracture critical components.

ERSI has also grown in industry and academic representation, to include a range of small to large businesses. Our growth is a testament to our continued focus on the needs of the warfighter, to ensure structural integrity while pushing the state-of-the-art.

This edition of the Screamer will provide an overview of some of the many programs and projects that ERSI is working on:

- The dates for the 2019 ERSI Workshop have been finalized and will be held September 12–13, 2019 in Layton Utah. There will be an ERSI Committee Leads meeting on the evening of the 11th to make final preparations for the Workshop and discuss additional items. We are very excited to have everyone come out to Utah again this year for our Workshop. The Workshop will be held at the Weber State Center for Continued Education, the same place we had it last year. Additional details regarding the Workshop, including assignments for presentations and the final agenda will be provided as they are finalized.
- The ERSI Integrators and Organizers have instituted an Executive Committee, as a decision-making body for ERSI. A diagram of the ERSI Working Group is included below.



ERSI Involvement as of June 2019

ERSI Working Group Total: 113

Countries Involved: **5**

DoD Organizations: **3 (+ FAA)**

USAF ASIP Managers: **6**

National Laboratory: **2**

Universities: **5**

OEMs: **3**

Industry Partners: **22**

A Status Update of the ERSI Working Group (cont'd)

- We have a new Committee Lead for the Quality Assurance and Data Management Committee. Thank you to Mr. Kaylon Anderson from the A-10 ASIP Analysis Group for taking that leadership responsibility. Currently seven out of our eight Committees are having regular telecons to coordinate programs and projects! This is a huge step forward and we want to thank all of our Committee Leads for their diligent efforts in organizing these. As the committee organizational structure continues to develop, the ERSI Working Group becomes more effective and efficient!
- The ERSI Integrator Committee and Committee Leads have reviewed and commented on a DRAFT Structures Bulletin, focused on the analytical process that is to be used when imposing an engineered residual stress into a crack growth analysis. As this Structures Bulletin continues to mature we will ask for additional focused input from those within the ERSI Working Group. Thank you to Dr. TJ Spradlin for his diligent efforts to keep this process moving forward and to all of those that have provided input to it.

We look forward to seeing all of you at this year's ERSI Workshop and hope that you and your loved ones will have a safe and wonderful 2019 summer.

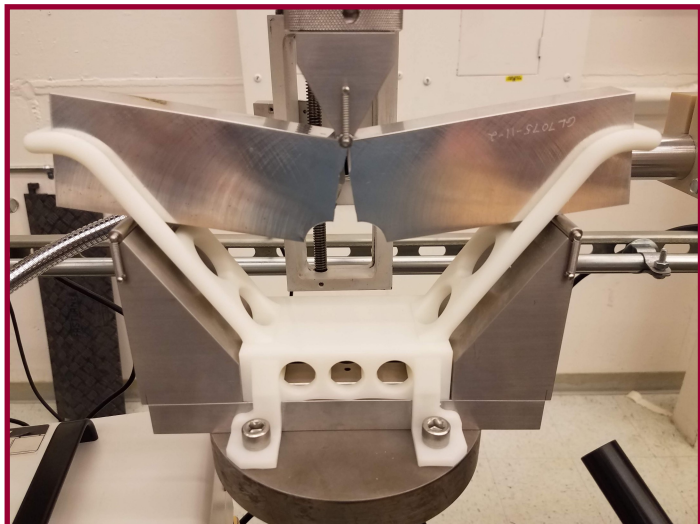
Dr. Scott Carlson
ERSI Organizer and Executive Committee Member

Committee Spot

Validation Testing

Continued progress on Geometrically Large (GL) 3 point bend test program:

See pictures of failed specimen at right and below. Current test scope is 2024 and 7075. These specimens are made from 4 inch wide, 1 inch thick plate with a centered 1 inch diameter hole. The specimen is cut lengthwise for fatigue testing. The unique geometry was selected to minimize the stress concentration from 3 to 1.6, and induce a more shallow stress gradient from cold expansion, since the hole and thickness are "large" the residual stress field gradient is shallower. With those benefits this testing provides a basis to potentially better understand analysis successes/shortfalls by minimizing the effects of stress concentration and steep residual stress gradients in a crack growth simulation.



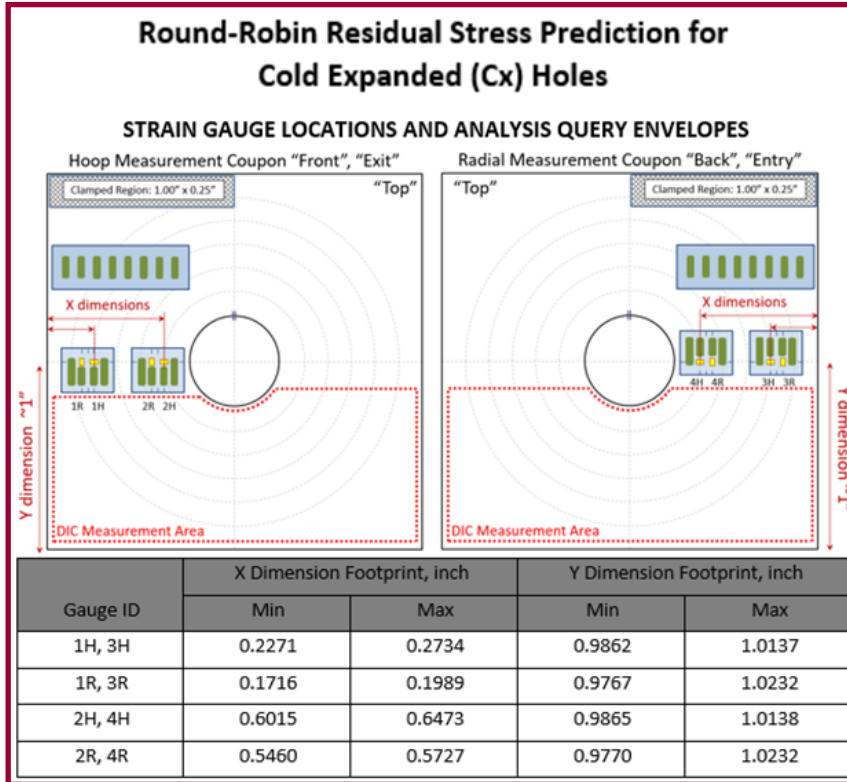
POC: Mr. Jacob Warner (USAF A-10 ASIP); jacob.warner@us.af.mil



Residual Stress Process Simulation

Committee Spot

Primary topics of recent discussion focus on two main group projects that are both closely tied to the 2" x 2" coupon multiple measurement correlation work that has been going on in collaboration with many within ERSI and without. The PSC has been working on cyclic material testing of the same 7075-T651 aluminum provided by Dr. Spradlin at AFRL that was used in 2" x 2" coupon manufacture; the cyclic test coupons have been delivered to NRC, who have graciously offered to perform the testing. Testing will be conducted in both L and LT directions. This data can be made available to any ERSI member; contact a PSC member for details about this or the previously obtained 2024-T351 cyclic data.



Additionally, the group will be shortly beginning work on a round robin effort related to process simulation of the 2" x 2" specimen geometry, focused on evaluating differences in modeling practices, and other simulation drivers such as material models (left). Some preliminary results have begun to trickle in (below)

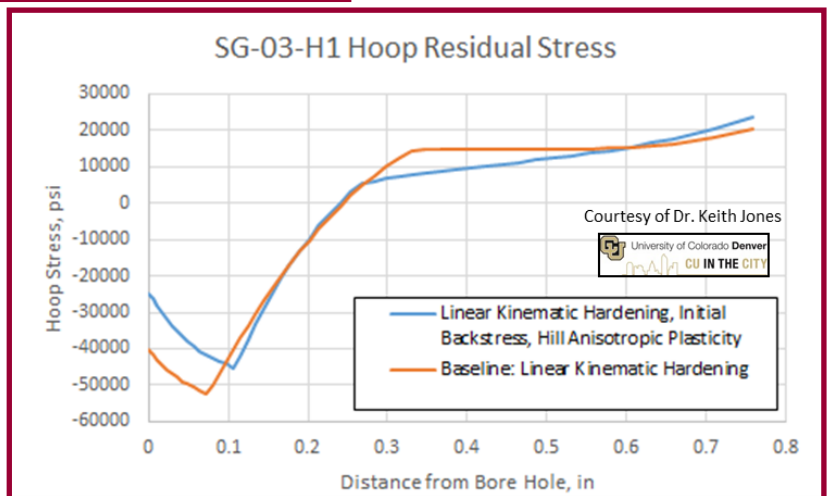
Contact Keith Hitchman, 206-701-7232 (Keith.Hitchman@pccairframe.com) if you or your organization are interested in participating.

We look forward to providing ERSI updates on these topics, and other items of interest (general process simulation data set comparison, correlation metrics, validation) at the workshop in September!

As a final note: The Process Simulation Committee has been fairly successful at holding regular monthly meetings. The chair would like to

thank the PSC members for their participation. Meetings are held the 3rd Friday of each month, at 11am EDT (8am PDT); contact a PSC member for details, we'd love to have you on a call!

POC: Mr. Keith Hitchman (FTI);
Keith.Hitchman@pccairframe.com



Committee Spot

Residual Stress Measurement

Update on the Residual Stress Determination Method Round Robin on a Cold Expanded Coupon Configuration

The four 2inch x 2inch Cold Expanded (Cxed) coupon sets continue to make their rounds across North America. As previously presented in the last Screamer issue, these coupons were instrumented with three surface strain measurement equipment to measure elastic and total strains during the Cx process. The coupon set was then sent up to NRC-Canada to have surface residual stresses determined via X-Ray Diffraction (XRD). They were then sent to Argonne National Labs and were processed via Energy Dispersive XRD (ED-XRD) at the Advanced Photon Source (APS) - see the results from APS in the images at right. Data has been processed for all of these techniques, and from that work it was determined that due to "texturing" effects the APS data had a high amount of spatial measurement uncertainty. AFRL requested to have the 7075 coupons sent to Cornell University and a set of experiments were performed using their ED-XRD instrument (CHESS). The data from that work continues to be processed at AFRL, under the oversight of Dr. Mark Obstalecki. In addition to having the 7075 coupons processed at CHESS all four coupons were sent back to APS and a series of additional experiments were performed on them, in an effort to develop a more robust process protocol for these types of textured engineering materials when being shot with ED-XRD. The goal of this work at APS is to produce residual stress via ED-XRD with greater spatial measurement confidence.

During the committee telecons it was determined that additional surface XRD measurements should also be taken, to see if improved protocols could be developed. This effort would be similar to that under development for ED-XRD, and would strive to overcome some of the texturing obstacles experienced during the previous round of measurements. The four coupons are currently at Proto where Mr. James Pineault is working with Dr. Dave Backman from NRC-Canada to perform a reproducibility round robin between their two labs, with the improved techniques. It is hoped that this improvement will be published to enable future users of this technique to have a more robust protocol when looking at Cx holes in aluminum sheet and plate.

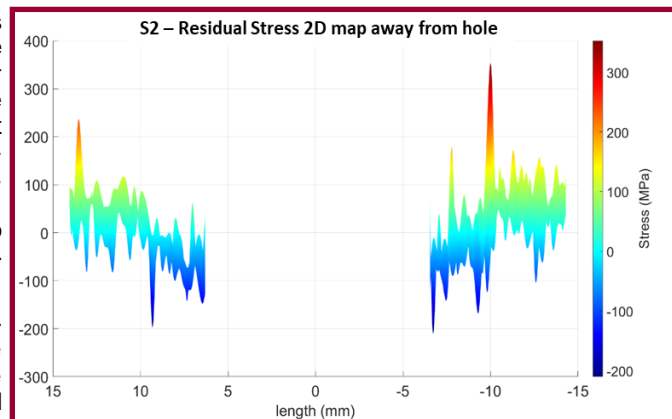
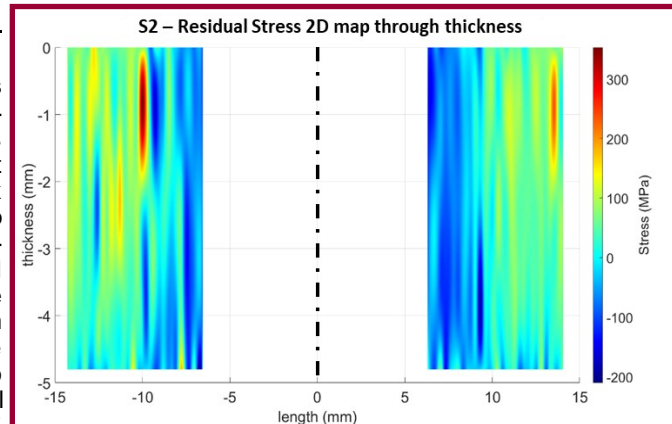
This project has also been in contact with Prof. Fitzpatrick at Coventry University in the UK to see if it would be possible use their Neutron Diffraction instrument at the ENGIN-X facility. The purpose of this work would be to try and utilize a similar through-thickness technique to confirm the data that was developed at CHESS and APS. Because of the texturing effect of the material these techniques struggled to capture enough grains to provide high-confidence data. Thus with the larger gauge volume size of the neutron technique it may be possible to get higher confidence data that can be used to fill-in data from the CHESS and APS work. This work is in the proposal writing process and we hope to be able to demonstrate the need for this work, even though neutron has been used previously at Cxed holes.

The final stage of this multi-year program will be to have the coupons processed via the Contour Method at Hill Engineering. If the Neutron Diffraction work cannot be performed, then towards the end of the summer, these four coupons will make their final trip across the country to California where they will have their final measurements performed on them. With that final dataset in hand it is hoped that new techniques will be developed to compare the surface residual stresses and the through-thickness residual stress to look at differences and similarities between them. From this work the Residual Stress Process Simulation Committee will also have a robust dataset to use for simulation validation work. Again, methods for comparing full-field residual stress data will need to be validated. Recently at the 2019 HOLSIP Workshop, FTI presented a method developed for doing this at holes in plates, which may be perfect for this work.

Through this project it is hoped that three technical papers will be published. Currently the first is in development to discuss the surface strain measurements that were performed during the cold expansion process, and those will be compared to each other, and to the surface XRD data that is being developed by Proto and NRC. Next will be the through-thickness data, and finally the use of this data for process simulation validation.

For additional ideas of what can be done with these coupons or the additional four coupons that have been final reamed, please reach out to Dr. Scott Carlson.

POC: Dr. Scott Carlson (Lockheed Martin); scott.carlson@lmco.com

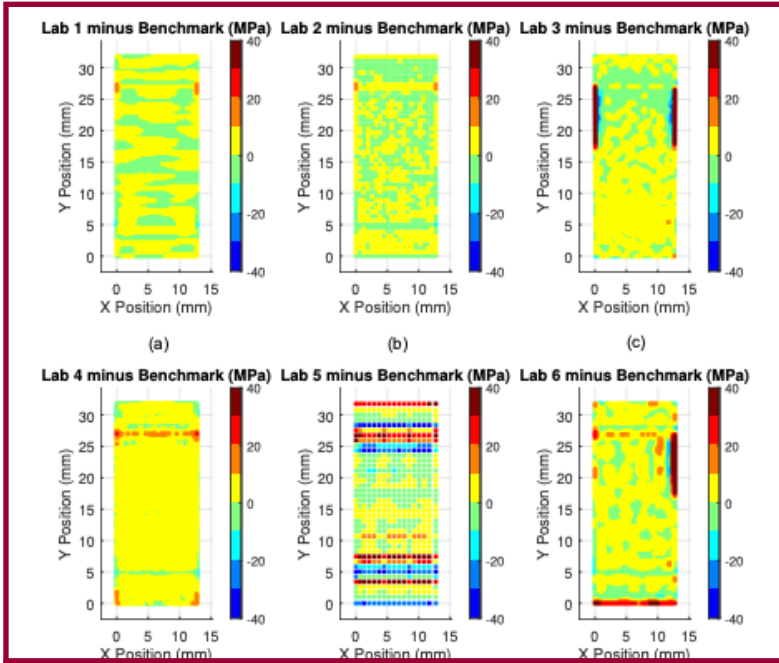


Residual Stress Measurement (cont'd)

Committee Spot

Update on the Contour Method Interlaboratory Round Robin

The interlaboratory contour method round robin exercise continues to move forward. Currently Phase I, spatial residual stress data developed via a FEA simulation of the four-point bend experimental condition, is in the final draft format with the core authors. The purpose of the Phase I of this work was to provide an idealized dataset to the group to process from displacements to residual stress. This work would isolate out the spatial uncertainty associated with the data processing of the simulated surface topography. Results from the group are shown below.



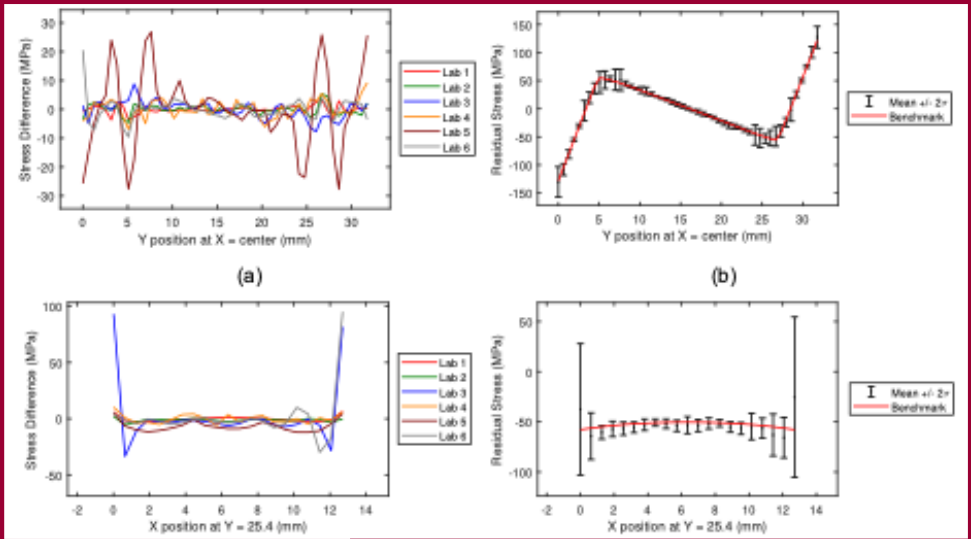
From these results it was demonstrated that the maximum spatial uncertainty is along the edges of the coupon, and also at the locations of slope change, from tensile to compression, and from compression to tensile. Tabulated results for each individual are provided in the below table. From this it can be seen that the maximum spatial uncertainty is 119MPa (17.3ksi) for the group, and the maximum RMS Average Difference between the result and the FEA simulation is 15.4MPa (2.2ksi).

Currently the round robin group is processing the Phase II data in which a total of three four-point bend experiments were conducted on samples made from 7075-O material. Two of these coupons were bent at SwRI, cut at Hill Engineering, and the surface topography was measured at Hill Engineering. The other was sample was processed completely at AFRL. Both sets of bars were processed with the same fixture, under the identical loading and load rate. Data for all three bars have been provided to the same round robin group for processing. The results of that Phase of this work will also be published and provided at the ERSI Workshop.

Surface contour plots of results as difference from benchmark

For additional information on this effort or ideas on what you would like to see investigated, please reach out to Dr. Scott Carlson.

POC: Dr. Scott Carlson
(Lockheed Martin);
scott.carlson@lmco.com



ID	Number of Points	RMS Avg Difference (MPa)	Skewness	Max Difference (MPa)
1	3141	2.1	0.43	18.9
2	1071	2.1	0.73	15.7
3	4141	11.5	5.99	116.5
4	12281	3.1	0.16	24.5
5	680	15.4	0.03	44.0
6	4515	9.8	5.73	119.2

Line plots on center lines for X and Y axes with ± 2 standard deviations

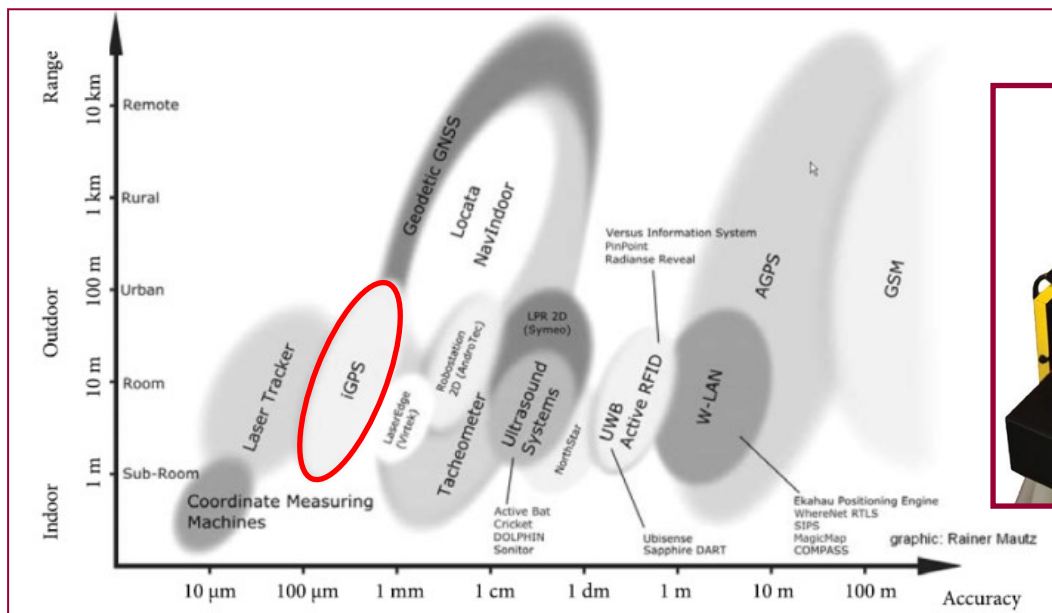
Committee Spot

Data Management and Quality Assurance

In preparation for the ERSI 2019 Workshop the committee will focus on determining the appropriate steps required to develop validated Quality Assurance (QA)/ Non-Destructive Evaluation (NDE) methods. A valid QA/NDE method will be necessary to verify the engineered residual stresses are attained as intended, both when the residual stress is first imparted into the structure and during sustainment of that structure. There are several programs under way which will help to establish a valid NDE method. Some of these programs have not been awarded yet, so will be presented in the next edition of the ERSI Screamer. One program that is under way is described below.

Data Spatial Positioning System RIF (Hill Engineering, FTI, NLIgn, USAF)

This effort is in response to USAF Rapid Innovation Fund topic “Maintenance Data Spatial Positioning System” The effort will develop next-generation maintenance technology capable of supporting advanced fleet management strategies. The advanced maintenance technology will utilize smart tools integrated with Data Spatial Positioning (DSP) to track location. These tools will be combined with software to guide the process and generate a Digital Thread. This technology will be developed and demonstrated for select maintenance tasks including cold expansion and crack detection.



<https://www.nikonmetrology.com/en-gb/product/igps>

Mautz, R., 2008, “Overview of Current Indoor Positioning Systems,” Swiss Federal Institute of Technology.

The primary tasks associated with this effort are to:

- Provide real time location compliance feedback of maintenance actions using an Indoor Global Positioning System (iGPS)
- Develop process and hardware/software to connect to the FTI instrumented Cx puller
- Associate Cx puller outputs to determined residual stress
- Develop method to send data directly from Cx puller to NLIgn

POC: Mr. Kaylon Anderson (USAF A-10 ASIP); kaylon.anderson@us.af.mil

Announcements

• **Recent and Upcoming ERSI-related events:**

- ASTM E08 Committee Week, May 13-15, 2019
- 19th International ASTM/ESIS Symposium on Fatigue and Fracture Mechanics (42nd National Symposium on Fatigue and Fracture Mechanics), May 17, 2019
- ERSI Workshop, Sept. 11-12, 2019 in Layton, Utah
- ASIP Conference, Dec. 2-5, 2019 in San Antonio, Texas

• **Change in ERSI Executive Committee**

- We wanted to recognize Dr. Mark Thomsen for his tremendous service within the ERSI Working Group, as he leaves the ERSI Executive Committee and will be focusing his time on the A-10 Structures and Aero organization and their related sustainment and analysis activities.
- As many of you are aware of, Mark was one of the main driving forces behind the formation and current state of the ERSI Working Group. In 2015 when we had the idea of developing this Working Group, Mark was fully supportive and provided the financial support to initially put this together. Since then he has not only been one of the principle sources of funding behind many of the projects within ERSI, he has also been a strong voice for the development of methods and tools to advance the state-of-the-art.
- From the entire ERSI Working Group, we say thank you to Mark for his vision and leadership, and look forward to his continued contribution from within the Validation Testing and the Quality Assurance/Data Management committees.

• **ERSI Committee participation and ERSI Workshop attendance**

- We encourage you to continue to discuss ERSI-related topics with colleagues, at conferences, and in other technical interchanges. If you find there are others who would like to participate in one of the committees, please refer them to contact the ERSI Organizers or applicable committee chair.
- REMINDER: While we do encourage people to join in the different committees freely, attendance at the ERSI Workshop is by invitation only from the ERSI Organizers. If you would like to attend the 2019 ERSI Workshop, please contact the ERSI Organizers and we will review your request. Active participation and involvement in at least one of the committees is one of the metrics used to assess Workshop attendance.

Announcements

- **ERSI contact info:**

- If you ever have questions, suggestions, complaints, etc., please let us know by sending an email to ERSI@swri.org. Any feedback on the ERSI workshop, committee lead roles, ERSI purpose, or any other topic is always appreciated.

- **ERSI website is up and running!**

- If you have an account, go to <https://member-ersi.swri.org> and login. If you need an account, please send an email to ERSI@swri.org and an account will be created for you. Please include your name, organization, and contact information.



We Need You!

We would like to have input from YOU for the next publication of the ERSI Screamer!

Please send us an email to ERSI@swri.org and tell us what residual stress related problems you are facing, which ones you have solved, or which ones you wish you could solve. And of course you can also directly contact the appropriate committee chair.

Remember, the only way the vision and purpose of ERSI will be realized is by consistent contributions from the ERSI community.

Who is ERSI?

ERSI

