Out Brief for the Structural Reliability Partnership Workshop

August 29-30, 2017

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Background

Purpose

The Structural Reliability Partnership is envisioned to coordinate research, share best practices, and leverage investments from multiple institutions on areas of mutual interest in the domain of structural reliability. The prior work on ductile rupture under the Sandia fracture challenge can be viewed as a pilot effort for this partnership. Longer-term, the Partnership is intended to serve as an umbrella organization coordinating efforts to address additional areas that affect reliability, such as long-term creep, hydrogen-embrittlement effects, stress corrosion cracking, fatigue, etc. The Structural Reliability Partnership will demonstrate quantifiable and deployable improvements in structural reliability assessment.

There is frequent evidence in the community of multiple isolated institutions conducting similar research, which stalls progress due to redundancy. The lack of knowledge sharing also prevents the community from building upon progress as it is made. The Structural Reliability Partnership offers a framework for institutions to share knowledge, coordinate/synchronize efforts, and leverage funding on topics of mutual interest in structural reliability assessment.

The SRP is structured to include three activities: Model Material Exchange, Challenge Scenarios, and SRP Community Workshops. In keeping with this structure, a SRP Workshop took place on August 29-30, 2017 in Albuquerque, NM. As outlined in the charter for the SRP, agenda items for Workshop include:

- Reports/highlights from member institutions on independent work
- Reports on prior/ongoing Challenge Scenarios
- Assessment and prioritization of the most significant gaps in Reliability Assessment
- Coordination of resource needs, purchases, and distribution
- Coordination on research investments for addressing gaps
- Brainstorming sessions on next challenge scenarios
- Voting on next challenge scenarios
- Review of Action Items

This document provides an Out Brief of the August meeting.

U.S. DEPARTMENT OF ENERGY Sandia National Laboratories

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Agenda

Structural Reliability Partnership Workshop

August 29-30, 2017 | Marriott Uptown | Albuquerque, NM

Tuesday, August 29, 2017

Cimarron / Las Cruces Room

8:00 - 8:30 AM	Registration and Check In
8:30 - 8:55 AM	Welcome and Introductions—Jim Redmond, *Sandia National Laboratories*
8:55 - 9:00 AM	Ground Rules for Discussion—Alyssa Kolski, *Sandia National Laboratories*
9:00 - 9:30 AM	Background on the Sandia Fracture Challenge—Brad Boyce, *Sandia National Laboratories*
9:30 - 10:30 AM	Description of SRP—Brad Boyce and Jon Zimmerman, *Sandia National Laboratories* *Value Proposition: Labs, Industry, Academia* *Funding Model, Membership, & Voting Rights* *Material Exchange* *Challenge Lifecycle* *Database Management* *Overhead Coverage Mechanism*
10:30 - 10:45 AM	Break
10:45 - 11:15 AM	Technical Overview: Sandia National Laboratories—Eliot Fang
11:15 - 11:45 PM	Technical Overview: Exxon Mobil—Jevan Furmanski
11:45 - 12:15 PM	Technical Overview: University of Texas, Austin—K. Ravi-Chandar
12:15 - 2:00 PM	Lunch *(Off-site)*
2:00 - 2:45 PM	Group Discussion: Identify and rank potential Challenge topics of joint interest
2:45 - 3:00 PM	Break
3:00 - 4:00 PM	Breakout Discussions—Refine 3 highest priority Challenge topics (Cimarron, Santa Fe and Carlsbad Rooms) *See questions from Challenge Scenario form.*
4:00 - 5:00 PM	Group Discussion: Breakout groups report back and discuss
5:00 - 5:30 PM	Fodder for Evening: How might your institution benefit from and contribute to SRP?
5:30 - 7:00 PM	Reception & Networking Garduno's, of Mexico 2100 Louisiana Blvd NE, Albuquerque, NM 87110

Structural Reliability Partnership Workshop

August 29-30, 2017 | Marriott Uptown | Albuquerque, NM

Wednesday, August 30, 2017

Cimarron / Las Cruces Room

8:30 - 9:00 AM	Reconnect with Challenge Idea Teams *Are there more ideas to add from yesterday's discussion?*
9:00 - 10:30 AM	Technical Deep Dive Presentations (30 minutes each) Crystallographic Texture: Do We Need to Worry about Anisotropy in Structural Materials? —Martin Crimp, *Michigan State University* Micromechanical Failure Modes in Composite Laminates —Max Kismarton, *Boeing Corporation* Preliminary results from the 3rd Sandia Fracture Challenge —Sharlotte Kramer, *Sandia National Laboratories*
10:30 - 10:45 AM	Break
10:45 - 12:00 PM	Discussion on Challenge Topics *Review Quad charts and merge ideas.* *Goal to pick a 2018 Challenge Topic*
12:00 - 1:30 PM	Lunch *(Off-site)*
1:30 - 3:00 PM	Group Discussions: *How might your institution benefit from and contribute to SRP?* *Questions on SRP Concept and Technical Direction*
3:00 - 3:15 PM	Break
3:15 - 4:00 PM	Action Items for 2018 SRP Challenge *Determine host institution* *Material Procurement & Exchange logistics* *Experimental Support Labs* *Challenge Schedule*
4:00 - 4:30 PM	Timeline for Charter Finalization; Survey Participants: how can SRP be improved?
4:30 - 6:30 PM	Steering Committee Only: Synthesize feedback, discuss Charter revisions

WiFi Password: SRP2017

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Summary

The Structural Reliability Partnership Workshop was held in Albuquerque, NM on August 29-30, 2017 and was hosted by Sandia National Laboratories. Attendees were present from academia, industry and several other national laboratories. The workshop kicked off with an introduction to the SRP to familiarize potential members with what the purpose, structure and benefits would be to their organization. Technical overviews were given on several topics by attendees from each sector – national labs, universities and industry – to provide a snapshot of the type of work that is currently being conducted on structural reliability.

Attendees were then given the opportunity to suggest and discuss potential Challenge Scenario topics. Three were ultimately decided upon as being the most important: Additive Manufacturing, Hydrogen Pipeline Steels, and Bolted Joined Structures. These were then analyzed using Quad Charts to determine What, How, Who, and Why these areas would be further investigated. Rather than restricting future research to only one area, the option was left open to investigate ***both*** the top two, depending on interest and cost associated with hosting such an event. More informal collaboration may be undertaken for the third topic if members have time and interest.

Other items discussed pertained to the organization, structure and policies of the Partnership. Topics including Data Management, IP, and mechanisms of partnering/information sharing were touched upon but final decisions were not made. Further action is needed before this can be done. Action items were outlined and assigned, where possible. The next workshop is to be held in early August 2018 in Boulder, CO and is to be hosted by NIST. In the interim, quarterly updates are to take place via WebEx to maintain a line of communication and to ensure progress on both the administrative and technical tasks.

Attendees

1. Yared Amanuel, *Naval Surface Warfare Center* | yared.amanuel1@navy.mil
2. Dave Bahr, *Purdue University* | dfbarh@purdue.edu
3. Erin Barker, *Pacific Northwest National Laboratory* | erin.baker@pnnl.gov
4. Brad Boyce, *Sandia National Laboratories* | blboyce@sandia.gov
5. Arthur Brown, *Sandia National Laboratories* | aabrown@sandia.gov
6. Martin Crimp, *Michigan State University* | crimp@egr.nsu.edu
7. Frank DelRio, *National Institute of Science and Technology* | frank.delrio@nist.gov
8. Eliot Fang, *Sandia National Laboratories* | hefang@sandia.gov
9. John Foster, *University of Texas, Austin* | jfoster@austin.utexas.edu
10. James Foulk, *Sandia National Laboratories* | jwfoulk@sandia.gov
11. Jevan Furmanski, *Exxon Mobil* | jevan.furmanski@exxonmobil.com
12. Youssef Hammi, *Mississippi State University* | yhammi@cavs.msstate.edu
13. Mark Horstemeyer, *Mississippi State University* | mfhorst@me.msstate.edu
14. Max Kismarton, *Boeing Corporation* | Max.U.Kismarton@boeing.com
15. Alyssa Kolski, *Sandia National Laboratories* | ajchris@sandia.gov
16. Sharlotte Kramer, *Sandia National Laboratories* | slkrame@sandia.gov
17. Jessica Krogstad, *University of Illinois, Urbana-Champaign* | jakrogst@illinois.edu
18. Stelios Kyriakides, *University of Texas* | skk@mail.utexas.edu
19. Drew Lancaster, *Pratt & Whitney* | drew.lancaster@pw.utc.com
20. Alexis Lewis, *National Science Foundation* | alewis@nsf.gov
21. Matthew McDowell, *Sandia National Laboratories* | mdmcdow@sandia.gov
22. John Moore, *Lawrence Livermore National Laboratories* | moore236@llnl.gov
23. Richard Neu, *Georgia Tech University* | rick.neu@gatech.edu
24. Mike Parks, *Sandia National Laboratories* | mlparks@sandia.gov
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27. Siddiq Qidwai, *National Science Foundation* | sqidwai@nsf.gov
28. Krishnaswamy Ravi-Chandar, *University of Texas, Austin* | ravi@utexas.edu
29. Jim Redmond, *Sandia National Laboratories* | jmredmo@sandia.gov
30. Joseph Ronevich, *Sandia National Laboratories* | jaronev@sandia.gov
31. Chris San Marchi, *Sandia National Laboratories* | cwsanma@sandia.gov
32. Ashley Spear, *University of Utah* | ashley.spear@utah.edu
33. Xin Sun, *Oak Ridge National Laboratory* | sunx1@ornl.gov
34. Jon Zimmerman, *Sandia National Laboratories* | *jzimmer@sandia.gov*

Sandia Fracture Challenge - Background

The workshop began with an overview presentation given by Brad Boyce of completed Sandia Fracture Challenges. The objective of these challenges was to assess how well one could blindly predict metallic fracture of an unfamiliar geometry. The philosophy was to solve a 'toy problem' while replicating real-world engineering constraints (time, budget, information). Competitors were to assess the whole prediction stream: (physics, numerical methods, code, calibration & people). Models/tools/methods were not specified but were chosen based on engineers' judgement and strengths. Experimental outcome was verified by multiple labs, and results were only disseminated after blind predictions had been reported.

Specified details of the experiments and results are not reported here but the impact of the challenges are as follows. The findings of the challenge provide documentation of the current "state of the art" and offer evidence to support use of codes to solve engineering problems. In addition, the weaknesses and gaps identified help to not only educate the analysts who use, but do not develop, the methods employed, but also motivate mechanicians and code developers to fix these deficiencies.

Finally, the challenges help to raise international awareness of the need for improved simulation capabilities for improving structural reliability, and can help revitalize and guide funding in what has been considered a 'mature' area.

Technical Overviews

A brief description of the Structural Reliability Partnership Charter was given by Brad Boyce and Jon Zimmerman of Sandia National Laboratories (See Charter Document). Following this summary, three technical overviews were presented. The speakers included Eliot Fang from Sandia, Jevan Furmanski from Exxon Mobile and K. Ravi-Chandar from the UT-Austin. Eliot Fang gave an Overview of Sandia's Research & Predictive Capabilities Development for Fracture and Jevan Furmanski spoke about Fracture mechanics of vintage pipeline ERW seam welds.

Challenge Scenarios

The next activity involved a group discussion to identify and rank potential Challenge topics of joint interest to the participating organizations.

Criteria for Scenarios

- Should seek to address the bigger problems that can be covered in a 5-year time frame
- Material advancements are outgrowing tests, need to invent replacements that capture necessities that models need to capture, customer's understanding of multiple iterations of a product.
- Model materials should be de-coupled from Challenge Scenarios to have long term impact
- Challenge Leads will need to embargo certain information from people who aren't part of the planning team
    - The SRP can't run a blind challenge if participating team members know too much about the proposed Challenge

  - Certain teams shouldn't be given extra information till the other teams/community has the information
- Everyone in the partnership can contribute and participate in challenges, but the top people get to decide on what challenges will be done

Brainstorm Topics

Initial activities surrounding the Challenge Scenarios included a brainstorming session that was designed to generate ideas from the group as to what areas were of greatest importance to their research. The brainstorming resulted in a list of 22 topics, shown in Table 1. The topics were divided into two groups, based on their underlying premise.

  - "What" topics discussed potential applications or materials for study
  - "How" topics discussed potential processes, or phenomena to study

Attendees were then asked to examine the topics that received the most votes and refine them to the six that were of highest importance – three from each "What" and "How." The results of this refinement are shown in Table 2. At this point, attendees were asked whether the "What" or the "How" would be of greater benefit for further examination. The group decided on the "What" topics and broke into focus groups for detailed discussions, using the Quad chart presented earlier in the workshop (See below).

Table 1. Round 1 Topics with top 6 selected by vote.

What (Number of Votes)	How (Number of Votes)
Additive Manufacturing / Residual Stress (16)	Uncertainty Propagation and Measurement Error (16)
Hydrogen Pipeline Steels (11)	Toughness Measurement (11)
Bolted Joined Structures (7)	Multiscale Modeling (11)
Failure Transition (Flat → Shear Lips) (6)	Gradient Microstructure (6)
High Rate Adiabatic Shear Bands (5)	Worst Case Analysis (6)
Stochastic Microstructure DPHS Steels (3) • Microstructures differ, pick out the tails of the strongest and the weakest rather than the average values	Distributed Composite Damage (5) • Tool makeup to handle large number of fractures
Cast Nuclear Waste Container (0)	Standardizable Shear Test (5)
Shot Peened Weld (3)	Failure Loci Best Practices—Converge / Generality / Transferability (4)
Car Crash Scenario (Int. Rate Regime) (1)	Meta Model (3)
	Multi-Material Additive Manufacturing (Combine with Additive Manufacturing) Predicting optimal outcomes from various combinations of materials and stacks

High Temperature Extrapolation (Time-Temperature Super Position) (1) • Problem with accelerated aging, long-life extrapolation • Time-temperature super position
Creep & Non-Creep Damage (1)
Health Monitor—Model Learning (1)

Table 2. Round 2 Topics, with votes. "What" topics chosen to be explored as scenario ideas.

What (Number of Votes)	How (Number of Votes)
Bolted Joined Structures (3)	Multiscale Modeling (7)
Additive Manufacturing (2)	Toughness Measurement/Failure Transition (4)
Hydrogen Pipeline Steels (1)	Uncertainty Propagation (3)

Challenge Scenario Quad Chart	*TOPIC:*
WHAT? Describe the topic of interest: What are the gaps to be explored? Describe and example of a challenge scenario to explore the topic area. Describe materials of relevance to this topic, and a specific proposed case study material: Likely computational methods to be evaluated:	HOW? Experimental data given to participants for model calibration: Describe test capabilities required: Example materials of interest:
WHO? Expected host institution Suggest possible institutions to provide material calibration data/experiments and/or challenge experiments. Which likely institutions would participate in the blind computational challenge? Who might provide testing services?	WHY? Experimental outcomes to be predicted: What metrics can be used to measure success? What could the impact of success be for the community?

Shortlist Topics

Groups had time Tuesday afternoon and Wednesday morning to discuss the selected topics, share, and re-group. After the Wednesday afternoon discussion, attendees voted for the topic of most interest to their organization. An overview of each shortlist topic is captured below, with details on What/How/Who/Why captured in Appendix 1.

Two topics were very close in popularity among the attendees (Additive Manufacturing and Hydrogen Pipeline Steels) with a third also of significant interest. Rather than limiting further exploration to only one topic, the group decided that both the top two areas warranted more detailed discussion after the

workshop. In addition, the potential for holding a third gathering to pursue the third topic (Bolted Joined Structures) at a later date was also left open.

The SRP may down select to one challenge as the ideas solidify, or choose to run them both, depending on both interest and cost associated with hosting two such events.

Additive Manufacturing (14 Votes)

Leader:	Oak Ridge National Laboratory: Xin Sun
Other Leaders:	Georgia Tech University: Rick Neu Sandia National Laboratories: Eliot Fang
Participants:	Boeing: Max Kismarton Lawrence Livermore National Laboratory: John Moore Mississippi State University: Youssef Hammi NIST: Frank DelRio NSWCLD: Yared Amanuel Sandia National Laboratories: Arthur Brown, Brad Boyce, Sharlotte Kramer Pacific Northwest National Laboratory: Erin Barker Purdue University: Dave Bahr University of Illinois: Urbana-Champaign, Jessica Krogstad University of Utah: Ashley Spear
Additional Nominees:	Colorado School of Mines: Aaron Stebner University of California-Davis: Mike Hill University of Illinois, Urbana-Champaign: Huseyin Sehitoglu Penn State University: Allison Beese

Hydrogen Pipeline Steels (13 Votes)

Leader:	Exxon Mobil: Jevan Furmanski
Other Leaders:	NIST: Frank Del Rio Sandia National Laboratories: Jay Foulk, Joe Ronevich, Chris San Marchi,
Participants:	Mississippi State University: Mark Horstemeyer Purdue University: Dave Bahr Sandia National Laboratories: Sharlotte Kramer University of Illinois, Urbana-Champaign: Jessica Krogstad University of Texas, Austin: John Foster, Krishnaswamy Ravi-Chandar University of Utah: Ashley Spear
Additional Nominees:	University of Illinois: Urbana-Champaign, Petros Sofronis

Third Option: Bolted Joined Structures (10 Votes)

This topic will be tabled until next year. Members are encouraged to explore options for this topic, as their time and interest allow.

Leader:	Rice University: Matthew Brake (Not in attendance)

Other Leaders:	Sandia National Laboratories: Jim Redmond, Mike Pasik
Participants:	
Additional Nominees:	Rice University: Matthew Brake

Challenge Scenario Next Steps

For each of the top Challenge Scenario topics, a lead was chosen (see tables above) to champion the effort and lead future discussions. It was decided that a WebEx meeting would be held approximately six weeks following the workshop to discuss any progress that had been made. In addition, the teams decided to hold quarterly meetings to update progress and obtain relevant feedback.

The goal is to have one of the two challenges launched and producing results by the next annual workshop. However, it is not in the interest of the effort to rush to produce results for the sake of results. Results will only be presented if the project is proceeding smoothly and quality results are produced. Future work needs to be carefully planned to include a list of resources and a detailed plan for the research challenge so that any pitfalls that have previously been encountered can be avoided.

Technical Deep Dive Presentations (30 minutes each)

On the second morning of the workshop, after a brief discussion and update on the Challenge Scenarios, three technical Deep Dive Presentations were given to provide results from different areas of research conducted at participating institutions.

Martin Crimp of Michigan State University spoke about Crystallographic Texture and if researchers need to consider anisotropy in structural materials. Micromechanical failure modes in composite laminates were examined by Max Kismartin of Boeing Corporation and the preliminary results from Sandia's third Fracture Challenge were presented by Sharlotte Kramer of Sandia.

Benefits of SRP Membership – Focus Areas/Technical Direction

After deciding which technical areas would be best for 2018 Challenge Topics, the group discussed how each organization might benefit from and contribute to the Partnership. Participants were encouraged to ask questions about the SRP concept and help to guide its future Technical Direction. Arising from this roundtable were several focus areas.

Focus Areas

- It was suggested that, while Challenge Scenarios are good to validate the level of understanding about a topic and gather lessons learned, they do not necessarily allow for leveraged contribution among the group to gain new capabilities.
- It's important to make a creative partnership. It is difficult to enlist financial support if the investor does not see any value added from the investment.
    - Based on this idea, a second mechanism of the SRP was suggested in which members can form focus groups around topics of interest. This would enable groups to work together on these topics and leverage data, testing capabilities, and other resources to accelerate advancement of the field. For example:

- SRP members could perform their own experiments using the same model material from the SRP; and data can be shared to accelerate progress.
- SRP model materials would be available to all members, adding value to their work.
- Members would have opportunities to present data on new materials at the annual conference.

Future Technical Areas

One potential area for future exploration is crash design for automobiles. Automobile companies do not trust the current models and therefore rely on experimental testing. This could be an opportunity for the SRP.

- **ACTIONS** - Attendees will provide:
  1) Their top 5 topic areas of interest, so members can gauge level of synergy and form groups of common interest
  2) A list of the capabilities they have available to offer other members as part of their collaboration

Benefits of Membership – SRP Concept Feedback

Participants were asked to give feedback on what they felt were the benefits to belonging to the Structural Reliability Partnership.

The main points, offered in various degrees include:

1) The ability to network with others in the community
    a. Students, in particular
        i. Can make connections to labs and industry
            1. Learn from challenges, experience of mentors
            2. Form a talent pipeline that benefits both member organizations and students
    b. Industry/Lab participants
        i. Allows collaboration on topics of interest that were not chosen as Challenges
            1. Benchmark results
        ii. Builds a technical base among the community – research collaboration
            1. Leverage other researchers' work for maximum utilization
            2. Share data and results during conferences and recurring meetings
2) Gather community feedback on state of technologies as well as standards and best practices—i.e., FAA.
    a. Help NSF identify gaps that need to be addressed

Opportunities for Funding

Discussion around the preferred funding model brought up several points that need further consideration. The "leveraged" contribution model is not attractive to all partnerships members. Not all the members have the proper resources to contribute to the same level. Some only possess research funds that cannot

be used in this manner. In place of some financial contribution, these partners could contribute material or labor. However, if this is to be considered, the cost of the resource must be appropriately assigned to ensure an equal "trade."

In addition, a scale must be developed to account for an institution's ability to devote resources to fit SRP's priorities. If a member is not able to prioritize SRP goals, due to other restrictions, the tiered structure of the SRP could force them to a lower tier, despite that member's desire to contribute. A mechanism must be in place to ensure that all members have access to the data and benefits, regardless of their tier.

UT Austin proposed a hybrid model involving a Clearinghouse that would collect and distribute membership fees. The charter includes a similar plan, it does not involve a Clearinghouse per se, but does allow institutions to fund each other.

ACTION

- Executive Committee will reexamine this option to determine its viability

One of the benefits of the Partnership is that members can cooperate to request funding from large organizations – partnership members can provide letters of support for one another.

Potential funding sources:

- Research Coordination Network is an opportunity for funding SRP
- NSF – Grant Opportunities for Academic Liaison with Industry (GOALI)
- DOE GEMM program for student funding

ACTION

- Follow up with NSF—administrative funding, not research as s specific sponsor. They could potentially fund relevant ideas under their existing streams.
    - Create checklist and duties for admin role
    - What could NSF fund?

Data Management

The partnership will need to determine an efficient and effective data management system. Research on model materials, etc. is only valuable if we have a way to store and share the resulting data.

Several options were suggested, see below; however, it was recommended that a subcommittee investigate all the options available and determine what would work best for this situation.

Volunteer Committee

- Mark Horstemeyer, Mississippi State University
- Drew Lancaster, Pratt & Whitney
- Erin Barker, Pacific Northwest National Laboratory
- Krishnamurthy Ravi-Chandar, University of Texas, Austin
- Max Kismarton, Boeing

- Kim Mish, Sandia National Laboratories (Nominated—Not in attendance)

Potential Options Presented: (Not Comprehensive)

- NIST DSpace may be a viable option for data storage
- Data science options (i.e., GitHUB); Use metadata to manage.
    - This could get expensive. Some data could be published in archival journals, where they make the information openly accessible.
- Icme.hpc.msstate.edu—Mark Horstemeyer, Mississippi State University
    - Form a wiki like page for data management and publication for the partnership
        - Can keep data private and require password access to change/input material
        - Private things could go "public" when this is deemed appropriate
        - Database can be made searchable
        - Need to ensure continuity of style and flow
        - Include links to partner orgs for easy access
- Materials Data Facility—Sharlotte Kramer, Sandia National Laboratories
    - DOI for all published (public) data/research
    - Provide metadata and data for the people to put into a report
    - Currently a free service
    - Can be indexed and searched

Lessons Learned and Best Practices

There were several take-aways from the workshop. In performing research that will be shared with other members of the partnership, it is important to keep in mind that simply obtaining an answer is not sufficient. It is crucial to explain how and why the answer was achieved. In addition, these explanations should be compiled and shared so that others can learn from previous research and avoid mistakes already made and corrected. For example, a check list for the fracture challenge would be beneficial to expedite successful new research. While every problem is not exactly the same, it would raise awareness of certain issues and could help define best practices for future work.

Testing is typically performed locally at individual facilities. What is the best method for distributing the results and lessons learned to multiple facilities? WebEx capabilities could be used to host regular seminar talks by members to help SRP members gain a greater understanding of the capabilities represented by members and the results obtained by the member institutions.

Intellectual Property

The SRP would like to use non-disclosure agreements (NDAs) and other IP as metrics for success. As such, workshop attendees discussed the best mechanism for sharing information and handling the development of intellectual property. The consensus was that the SRP should be open to sharing information. NDAs were viewed as limiting; an overarching NDA would not be instituted, but members could make agreements among themselves if that were deemed necessary. Information that is shared should be pre- competitive, or in the process of being patented.

IP would be developed by each institution, independent of the Partnership. Thus, SRP would have no legal authority in IP, but could make decisions on membership status based on displayed IP behavior.

Metrics

- Internships
- Required posting to data repository
- Teaming between partners

Next Steps

Action items were identified and assigned to a specific attendee.

1) Next workshop to be held in early August in Boulder, CO by NIST
    - Goal to have outcomes from Challenges to present?
2) Alyssa Kolski, Sandia National Laboratories
    - Email actions to attendees
        - Membership Form (if interested)
        - Contribution
        - Areas of interest (Top 5)
        - Capabilities for collaboration
        - Other member suggestions
            - Send a Membership Packet including the updated SRP Charter, executive summary from the workshop, and membership form.
    - Schedule WebEx for week of Oct. 16-20
        - Update on Challenge Scenarios
        - Update on Data Management
    - Schedule Quarterly Update meetings through WebEx (November, February, May, August) —
        - Check progress and deadlines for current activities
        - Discuss further SRP governance, resource model, etc.
        - Discuss future logistics and new ideas
            - The SRP seeks to share resources and focus on solving problems relevant to the SRP members, not just hosting challenges.
    - Sandia will provide admin and business development support for the SRP for now
        - Details to resolve:
            - Flesh out focus area process guidelines
            - Strike NDA from Charter and make other updates
3) Challenge POCs to work on fleshing out details for Scenarios
    - Xin Sun, Oak Ridge National Laboratory — Additive Manufacturing
    - Jevan Furmanski, Exxon Mobil — Hydrogen Pipeline
4) Mark Horstemeyer, Mississippi State University
    - Data Management team to work on options
    - Need more discussion on how we will coordinate experiments, data collection, etc.

Appendix 1: Challenge Scenario Details

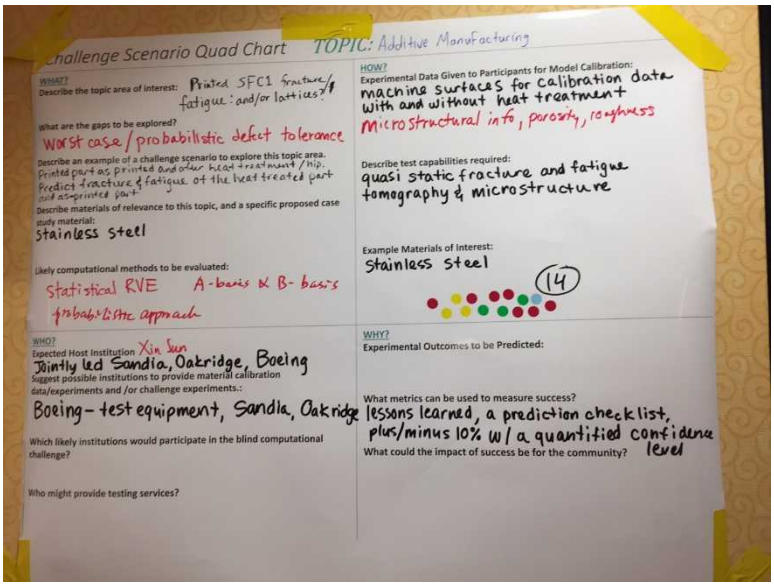
Specifics of voting procedure

- Attendees were given 4 voting stickers, and asked to choose their highest interest topics. 2 votes for "What" topics and 2 votes for "How" topics.
    - From this vote, the top 6 topics were selected, 3 for "What" topics and 3 for "How" topics. (See Table 2)
- At this point, it was recognized that 1/3 of the attendees were representatives of Sandia.
    - Moving forward only 2 Sandia representatives were allowed future vote. (Eliot Fang—NM and John Zimmerman—CA.)
    - The group did not think it was necessary to re-vote on the original list.
- Attendees were given 2 voting stickers, and asked to choose their highest interest topics. 1 vote for "What" topics and 1 vote for "How" topics. Topics were ranked based on their vote count. (See Table 2)
    - After the vote, attendees discussed the merit of choosing "What" topics or "How" topics as the basis for fleshing out more detailed Challenge Scenarios.
        - By a show of hands, the group decided to focus on "What" topics, and the attendees broke into 3 groups to discuss the 3 topics in detail, using the quad chart presented earlier in the day.

Next Steps – Potential schedule for results

- Calibration experiments done by December?
    - Couldn't have a model system before December/January?
    - What data do we want to have done and what can we do that's realistically possible?
    - Someone can calibrate it and someone else can perform the experiment.
    - Good to run challenge geometry before trying the challenge. Make sure it's possible and try to avoid some of those "gotcha" problems.
    - 6m-1yr for a small team to make the geometry challenge
    - Material will need to be provided as well
- Experiments done by March?

Additive Manufacturing



What?

Describe the topic area of interest:

- Printed SFC1 Fracture/Fatigue: and/or lattices?

What are the gaps to be explored?

- Worst case/probabilistic defect tolerance

Describe an example of a challenge scenario to explore this topic area.

- Printed part as printed and after heat treatment/hip
- Predict fracture and fatigue of the heat-treated part and as-printed part
- Describe materials of relevance to this topic, and a specific proposed case study material:
- Stainless Steel

Likely computational methods to be evaluated:

- Statistical RVE A-Basis and B-Basis
- Probabilistic Approach

How?

Experimental Data Given to Participants for Model Calibration:

- Machine surfaces for calibration data with and without heat treatment
- Microstructural info, porosity, roughness

Describe test capabilities required:

- Quasi static fracture and fatigue tomography and microstructure

Example Materials of Interest:

- Stainless Steel

Why?

Experimental Outcomes to be Predicted:

- N/A

What metrics can be used to measure success?

- Lessons learned, prediction checklist, plus/minus 10% w/ a quantified confidence level

What could the impact of success be for the community?

- N/A

Who?

Expected Host Institution

- Xin Sun, Jointly led Sandia, Oak Ridge, Boeing

Suggest possible institutions to provide material calibration data/experiments and /or challenge experiments.:

- Boeing-test equipment, Sandia, Oak Ridge

Which likely institutions would participate in the blind computational challenge?

- N/A

Who might provide testing services?

- N/A

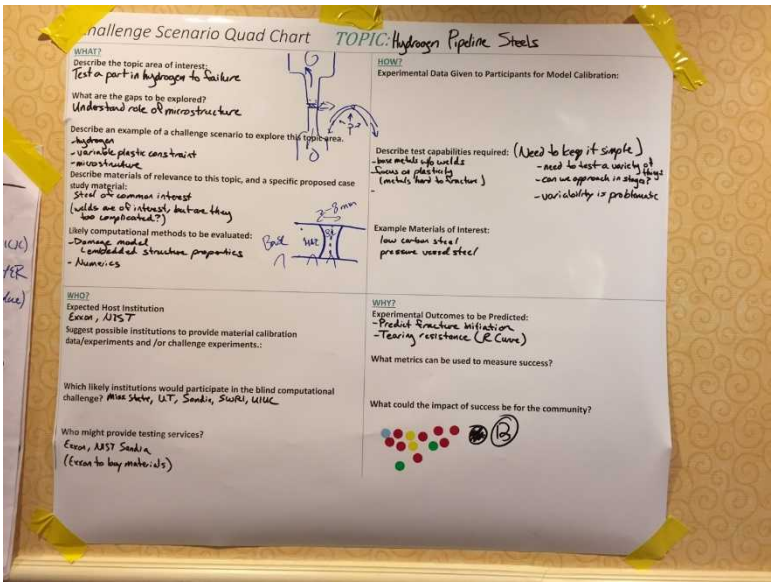
Brainstorm Topics

- Defects and anisotropy
- Residual stresses & distortion
- Predicting fatigue properties in a layered rough surface
    - Modeling peculiarities of 3D printed structure
- Thermal history
- Microstructural variation
- Process/location variability
- Material selection/alloy design
- Microstructure effects (first order)
- Effects of feedstock/recycling uncertainties
- High thru-put materials characterization
    - Machined parts
    - As-printed parts
- Stochasticity/uncertainty

Other notes from discussion:

- Want to start with stainless steel. Printed flaws, heat treated,
- Microstructure scale level, then consider the other flaws as they go up.
- What process have you decided on how to print this?
    - Not known yet, still to be considered.
- Where do you see differences between 3rd fracture challenge and yours?
    - Want to look at more print inherited defects, not later on from fatigue.
- If 1x1 inch bar out of 3d material vs thin plate on statistical knockdown?
    - Surface roughness (this stuff needs to be done for manufacturing)
    - what will the knockdown be?
- Heat treat it might cause more damage?
- Confident with defect distributions or vary the size of the bars? Lattice systems understanding, trying to not have any pores to cause issues. Length scales change though and so does roughness. Lattice is beyond the scale?
- How is this different form other companies? Side by side computational vs. Want to accelerate the process and reduce the amount of time to get the results.
- How do you envision this to be transferred? Will find out through the 3rd approach. Generic framework for predicting different frameworks.

Hydrogen Pipeline Steels



What?

Describe the topic area of interest:

- Test a part in hydrogen to failure
- Hydrogen physics/crack path prediction (gradient microstructure)
    - Combination of both

What are the gaps to be explored?

- Understand role of microstructure
- How well do our models do right now to predict this? – We don't have models for this.
    - Damage nucleation model
    - has not been used in fatigue and creep
- There is a hydrogen effect on plasticity and failure loci
- Bauschinger Affect
- (Can utilize existing pressure vessel test results (San Marchi) but no welds)

Describe an example of a challenge scenario to explore this topic area.

- *Look at effects of hydrogen*
- Hydrogen, variable plastic constraint, microstructure

Same as original fracture challenge, just adding hydrogen

- *One weld with additive, one with electric resistance*
- *One steel alloy*
- *Macroscale and mesoscale modeling*
- *(Same physical problem at different scales)*

- *2 challenges that merge 3 years from now*
  - *Hydrogen*
  - *variable plastic constraint*
  - *microstructures*
  - *then merge*
- *((neither one needs a weld))*
- *Test under a variety of conditions*
- *Gradient microstructures—too far??*
- *Different thickness pipelines*

Describe materials of relevance to this topic, and a specific proposed case study material:

- Steel of common interest (welds are of interest but are they too complicated?)
- Are we talking about steel or welds? (The base material does not fail, it fails at the welds)
  - Welds are of interest, but may be too complicated? Can it be simplified?

Likely computational methods to be evaluated:

- Damage model (embedded structure properties), numerics

How?

Experimental Data Given to Participants for Model Calibration:

- (previous challenges did not give enough information)
- N /A

Describe test capabilities required:

- Base metals w/o welds, focus on plasticity (metals are hard to fracture), need to test a variety of things, can we approach in stages?
- Variability is problematic, (need to keep it simple)
- Use damage modeling, is it giving me the right information to reproduce…

Example Materials of Interest:

- Low carbon steel, pressure vessel steel
- Need to test a variety of things, to get to weld assessment
- Could we approach this problem in stages?

Why?

Experimental Outcomes to be Predicted:

- Predict fracture mitigation, tearing resistance (R Curve)

What metrics can be used to measure success?

- N/A

What could the impact of success be for the community?

- N/A

Who?

Expected Host Institution

- Exxon, NIST

Suggest possible institutions to provide material calibration data/experiments and /or challenge experiments.:

- N/A

Which likely institutions would participate in the blind computational challenge?

- Mississippi State, UT, Sandia, SWRI, UIUC

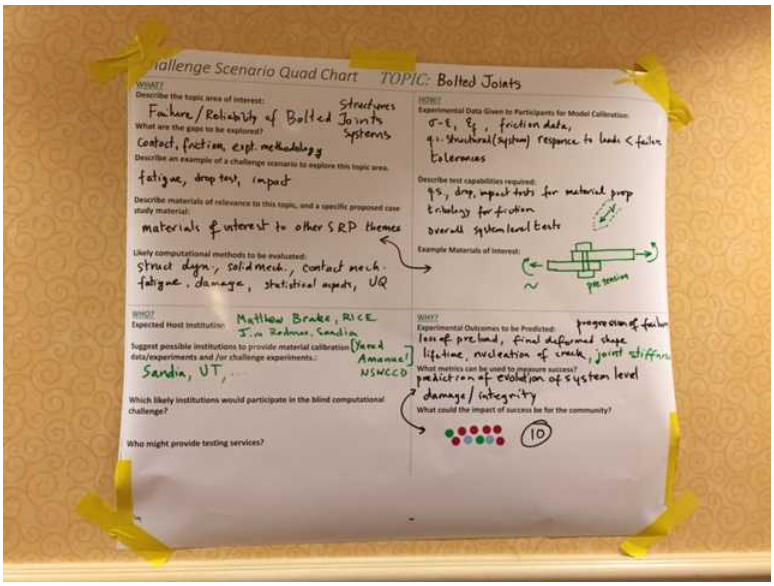
Who might provide testing services?

- Exxon, NIST, Sandia (Exxon to buy materials)

Other notes from discussion:

- 5-year plan is to get to this, may not be a first challenge task,
    - Multiple step approach, likely year 4 or 5 to deliver the approach.
    - It will be very challenging to keep people around for the entire time with this one.
- Predict the sharpness in each of the three regions.
- Phased in hydrogen
    - Will have to have calibration info then what will you give the modeling community?
    - Be able to capture the hydrogen sinking to the crack.
    - Hydro diffusion response experiment, challenging to measure concentration.
        - Make a homogenous process for it.
        - Will be breaking up the process so not everyone will be doing too much at once.
- Multiscale modeling aspect, it would be good and is encouraged.

Bolted Joined Structures



What?

Describe the topic area of interest:

- Failure/Reliability of Bolted Structures Joints Systems

What are the gaps to be explored?

- Contact, function, expt. methodology

Describe an example of a challenge scenario to explore this topic area.

- Fatigue, Drop Test, Impact

Describe materials of relevance to this topic, and a specific proposed case study material:

- Materials of interest to other SRP themes

Likely computational methods to be evaluated:

- Structural Dynamics, Solid Mechanics, Contact Mechanics Fatigue, Damage, Statistical Aspects, UQ

How?

Experimental Data Given to Participants for Model Calibration:

- **σ - ϵ, ϵf,** Friction data, q.s. structural (system) response to leads < failure tolerances

Describe test capabilities required:

- W.s., drop, impact tests for material prop, tribology for friction overall system level tests

Example Materials of Interest:

- Materials of interest to other SRP themes

Why?

Experimental Outcomes to be Predicted:

- Loss of preload, final deformed shape lifetime, nucleation of crack, joint stiffness

What metrics can be used to measure success?

- Prediction of evolution of system level, damage/integrity

What could the impact of success be for the community?

- Prediction of evolution of system level, damage/integrity

Who?

Expected Host Institution

- Matthew Brake, Rice University, Jim Redman, Sandia, Yared Amanuel, NSWCCD

Suggest possible institutions to provide material calibration data/experiments and /or challenge experiments.:

- Sandia National Laboratories, University of Texas

Which likely institutions would participate in the blind computational challenge?

- N/A

Who might provide testing services?

- N/A