Third International Workshop on Jointed Structures

16 – 17 August, 2012
Hyatt Regency, McCormick Place
Chicago, Ill, USA

An Introduction

Outcomes of the First Workshop

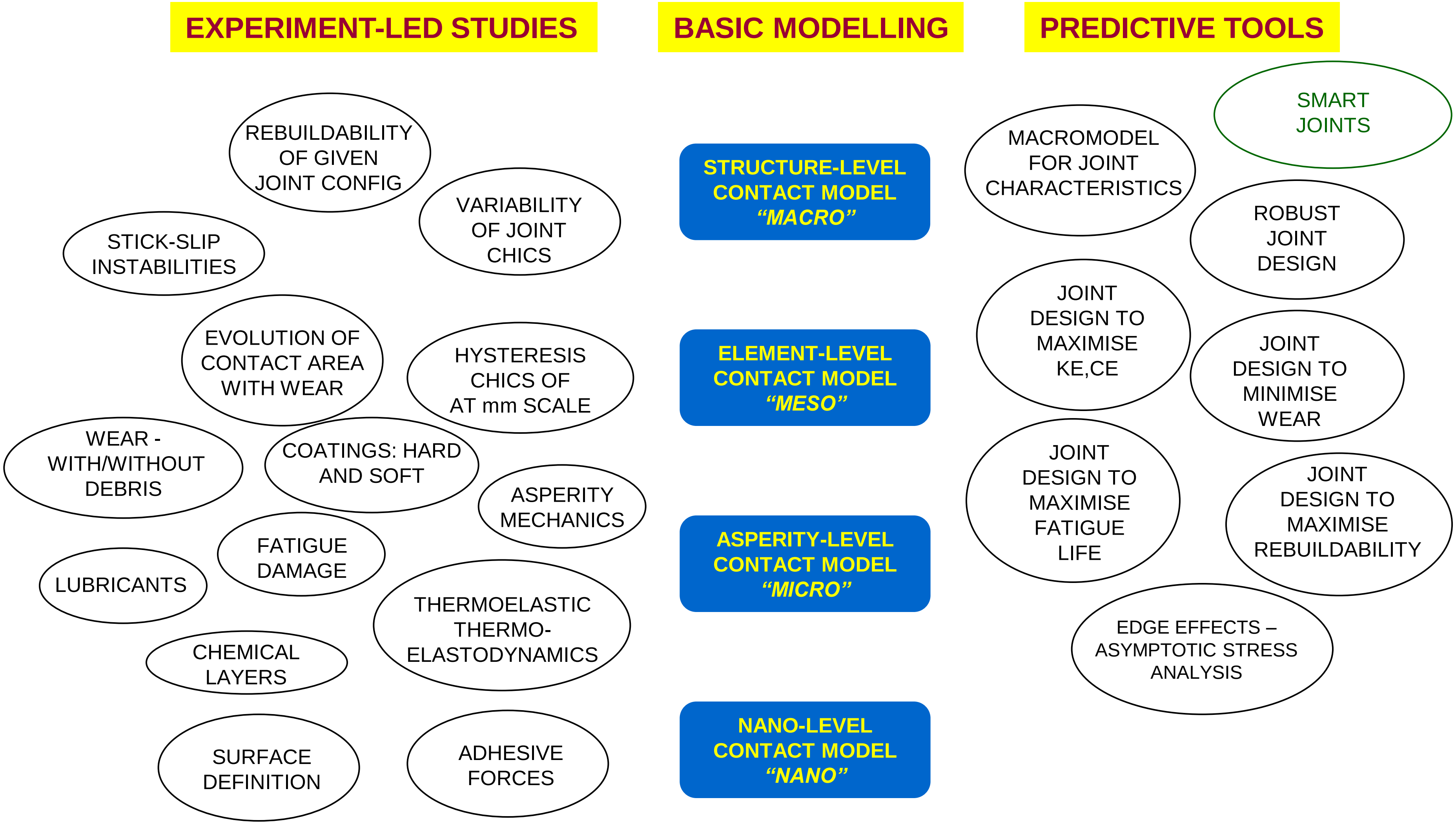
Arlington, Virginia, 16-18 October, 2006

This workshop attempted to identify each of the component technologies that touch on dynamics of jointed structures and then to draw the relevant connections among those technologies.

- Relevant phenomena span scales from nanometers to the lengths of structures. A significant conclusion at the end of that workshop was that the range of length scales and the physics and chemistry that dominate at each scale made it unlikely that those scales could be coupled in a rigorous manner in the near future.

- This conclusion was first prompted by the observation that participants could address modeling issues either at the extremely small scales (atomistic-nano) or scales moderately large (asperity and up), but there were no clear strategies to bridge those scales. The difficulty seems to be that analysis at each scale requires consideration of physics and chemistry that dominate at that scale and that there are many discretely defined scales between the small and large scales that that remain to be addressed.

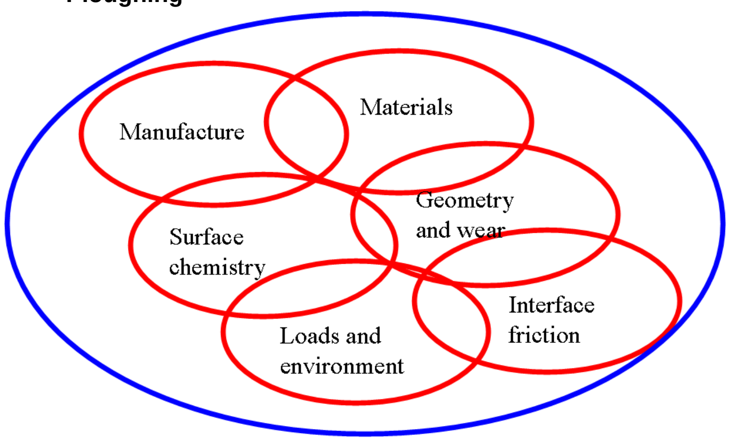
RESEARCH ROADMAP FOR FRICTION CONTACT AND WEAR IN STRUCTURES



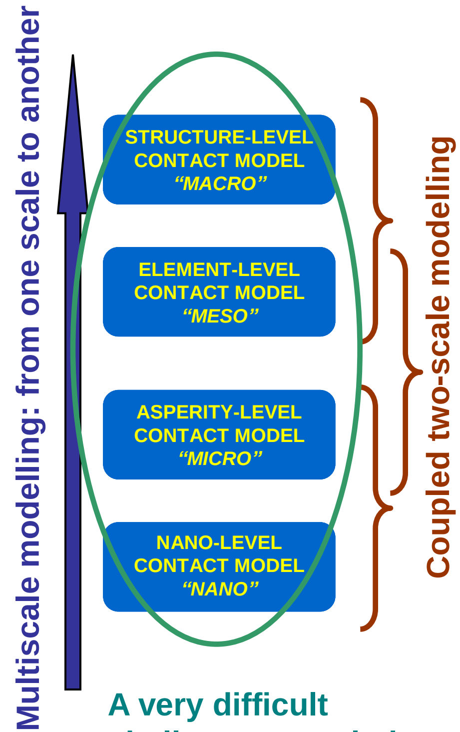
RESEARCH ROADMAP FOR FRICTION CONTACT AND WEAR IN STRUCTURES

PHYSICAL PHENOMENA

- Friction
- Materials properties
  - Elastic, plastic, visco, creep, microstructure, thermal exp
- Lubrication
- Fatigue, Fracture
- Wear
- Debris
- Thermal (heat gen?)
- Environment
- Contamination
- Surface Chemistry
- Ploughing
- Loads
- Load history
- Manufacturing
- Tolerance
- Residual stress
- Oxidation
- Corrosion
- Roughness
- Surface registration
- Adhesion (stick/slip?)
- Adhesives
- Dynamics



MODELS



A very difficult challenge: coupled multiscale modelling

PREDICTIVE TOOLS

- Vibration damping 3B
- Self-excitation
- Accuracy of positioning (in robots and manipulators)
- Stiffness 4B
- Hysteresis loop
- Fatigue life 2B
- Wear life 2C
- Impact strength 3C
- Temperature
  - Macro 4B
  - Micro 2C
- Heat transfer
  - Macro 4B
  - Micro 2C
- Electrical resistance ?
- Shock load transmission 3B
- Acoustic transmission ?
- Frictional limit (onset of slip) 3B
- Deformed shape (when slipped) 3B
- Surface roughness evolution
- Concept evaluation tool 1C

1. Clear problem, no known solution
2. Predict within 1-2 orders of magnitude
3. Predict within order of magnitude; trend correct not value
4. Predict to withing 10-20%
5. Predictable to within uncertainty from other factors

Increasing cabability

Increasing understanding

A. Generic model based on few parameters
B. Component specific, needs calibration exps
C. Non-physical, empirical model, lots of testing

Increasing cost

Outcomes of the Second Workshop

Dartington Hall, Totnes, Devon, UK, 26 -29 April, 2009

This workshop emphasized topics more on the macro- and meso-scales, where coupling through the relevant length scales becomes more tractable. Focus on these larger length scales resulted in identification of several core issues and the development of strategies to address them.

Consistent with the above, invited talks and breakout sessions focused on the following themes:

- **Theme A** concerns the engineering end-user needs for better predictive models of joints. It concerns the need for better understanding and theoretical modelling of the various friction phenomena which ultimately determine the mechanical characteristics of so many joints in engineering structures of all types. It also concerns the potential future benefits that might result from an improved prediction cap ability, such as the design of much more effective joints, and much more repeatable ones.

Outcomes of the Second Workshop

Dartington Hall, Totnes, Devon, UK, 26 -29 April, 2009

- **Theme B** represents a critical and comprehensive assessment of our current capabilities in this general area. Theoretical, numerical and experimental techniques allow us a degree of control over the joints that we design and use today, but they are still far from ideal, or from the levels of predictability that apply to the components which are assembled by using the joints of current interest.

- **Theme C** includes the various recent developments and ideas for future methods which will eventually allow us to deliver the predictive modelling and design capabilities to make the joints of the future exactly what we want them to be: repeatable, efficient, with stiffness and damping performance characteristics as desired to optimize the dynamics of the stricture of which they form part.

JOINTS MODELLING WORKSHOP #2

SUMMARY OF FINAL SESSION DISCUSSIONS ON 29/4/09

AGREED ACTIONS/CHALLENGES, INTERESTED PARTIES AND SUGGESTED LEADERS (in bold)

ACTIONS

1. Terminology & Vocabulary (***Segalman***; *Bergman)*
2. Develop Hills Chart *(**Dini**; Berger)*
3. Classification of Standard Joint Types *(Hills; Vakakis; **Starr**)*
4. Classification/Cataloguing of

   4.1 Non Linearity ID Methods (***Vakakis***)

   4.2 Modelling approaches (***Polycarpou***; *Quinn)*

   4.3 Measurement methods *(**Nowell**; Bergman; Akay)*

5. Benchmark current computation multiscale methods against analytic solutions *(**Masud**; Laurson; Quinn)*
6. Create a formal Joints Modelling Network (or Community) with more frequent and regular contacts (!); meetings at relevant conferences; workshop series;... Wiki..Joints Chat room

   *(**Ewins**; **Segalman**; Nowell; **Bergman** Gaul; Green;Surampudi; Dini;Quinn)*

7. Form Specialist sub-groups of Community to collaborate on specific Actions/Challenges, e.g.

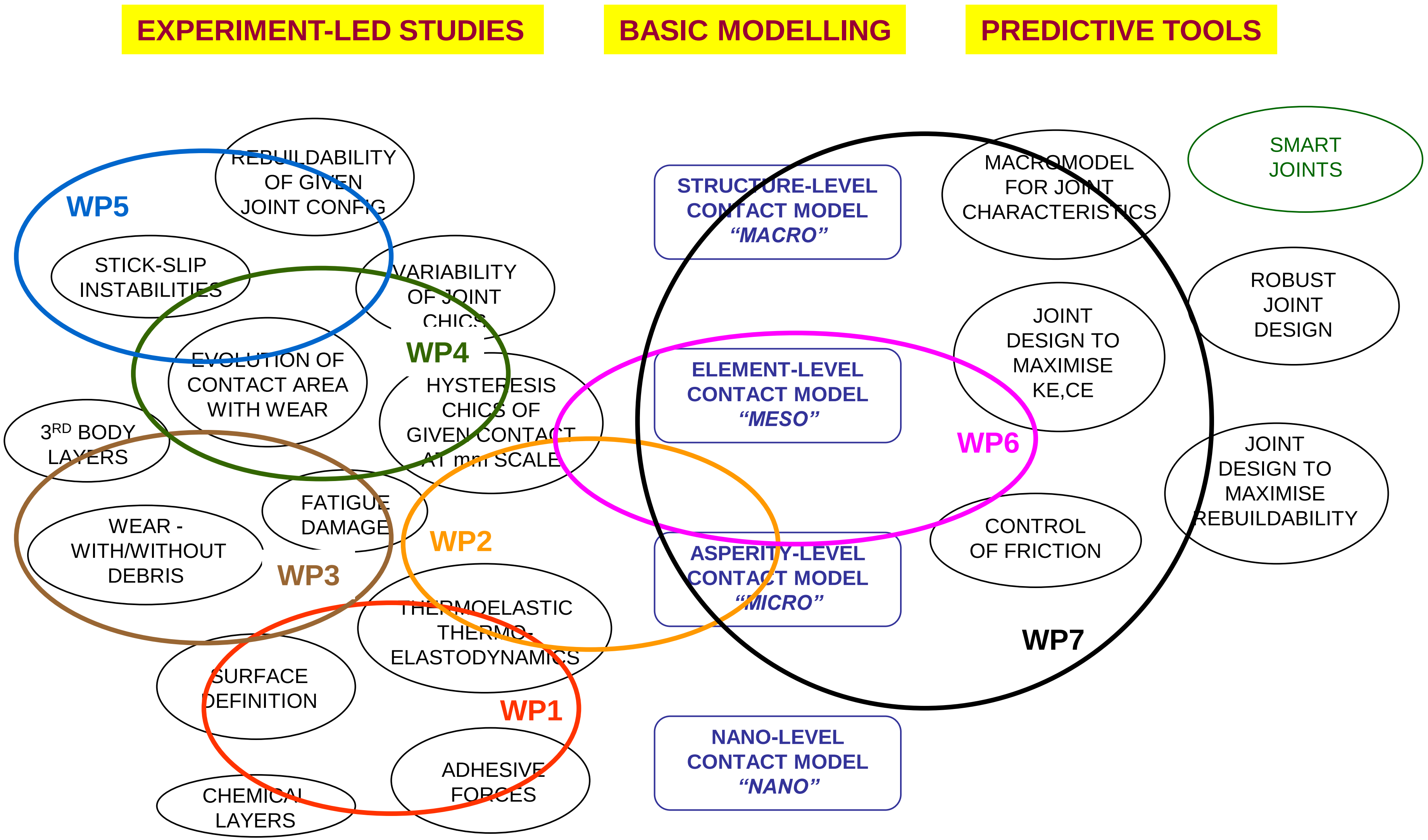
   University group on basic joints contact
   i. mechanics science
   University/industry group on measurements of
   ii. friction properties required for industrial
   iii. applications
   Industry-led group(s) to ensure liaison between end-user requirements and academic research activities (e.g. balancing accuracy requirements for application against accuracy of predictions)

CHALLENGES

1. Round Robin/Benchmark Exercise for Hysteresis Measurements *(**Ewins**: Nowell: Gola; Polycarpou; + possibly Epsion(Technion))*
2. Round Robin/Benchmark for Measurement/Prediction of Dissipation in Standard Joints *(**Leming**; Goyder; Gaul; Ind; Vakakis)*
3. Repeatability (meast-meast) and Variability (unit – unit) Issue: need to be able to distinguish between, and to greatly improve performance in both aspects (i.e. design of better, more repeatable joints) *(Leming; **Goyder**; Gaul; Ind; Polycarpou; Farris; Mignolet)*
4. Framework for MultiScale Modelling *(Masud; Dini; **Nowell**)*
5. Strategy for Uncertainty and Nonlinearity
6. Methodology to quantify cost benefits of improved joints designs
7. Universally-accepted Physical Theory of Friction (which explains, inter alia, where the energy goes)
8. Complex Loading Strategies
9. Measurement of Spatial Distribution of Key Physical Parameters
10. How to include surface chemistry?
11. Eventual implementation of prediction methods in commercial numerical codes

DJE 6/5/09

RESEARCH ROADMAP FOR FRICTION CONTACT AND WEAR IN STRUCTURES



CONTACT ROADMAP v 4.1

Introduction to the 2nd Workshop on Joints Modelling, 2009

Background

Joints have long been a problem for the structural dynamicist and, increasingly, the joints are becoming the weakest link in many design analyses.

This has been recognised often and there have been many previous attempts to improve the situation. This workshop is the latest in one series of such efforts that can be traced back at least 10 years…

Previous Activities

SD2000: Forum for Future Directions in Structural Dynamics
1999, Sponsored by LANL

Workshop on Predictive Models for Joints and Interfaces
2000, Sponsored by SNL

Workshop on Modelling, Analysis and Measurement for Friction Constraints in Gas Turbine Components
2001, Sponsored USAF, AFRL, AFOSR

Workshop on Benchmarks in Contact Mechanics and Friction Damping ***2002, Sponsored by USAF, AFRL, AFOSR***

Workshop on Joint Mechanics
2006, Sponsored by NSF, SNL

Previous Workshop

Brought together wide range of engineers from different groups, and covered a much broader range of disciplines than had been present in the earlier workshops. That meeting a Road Map as a central feature around which to structure discussions from the macro scale down to the nano scale. There, the objective was to construct a comprehensive map of all the features that might be important in the construction of a truly predictive model for friction contact phenomena.

Previous Workshop

We started with…..

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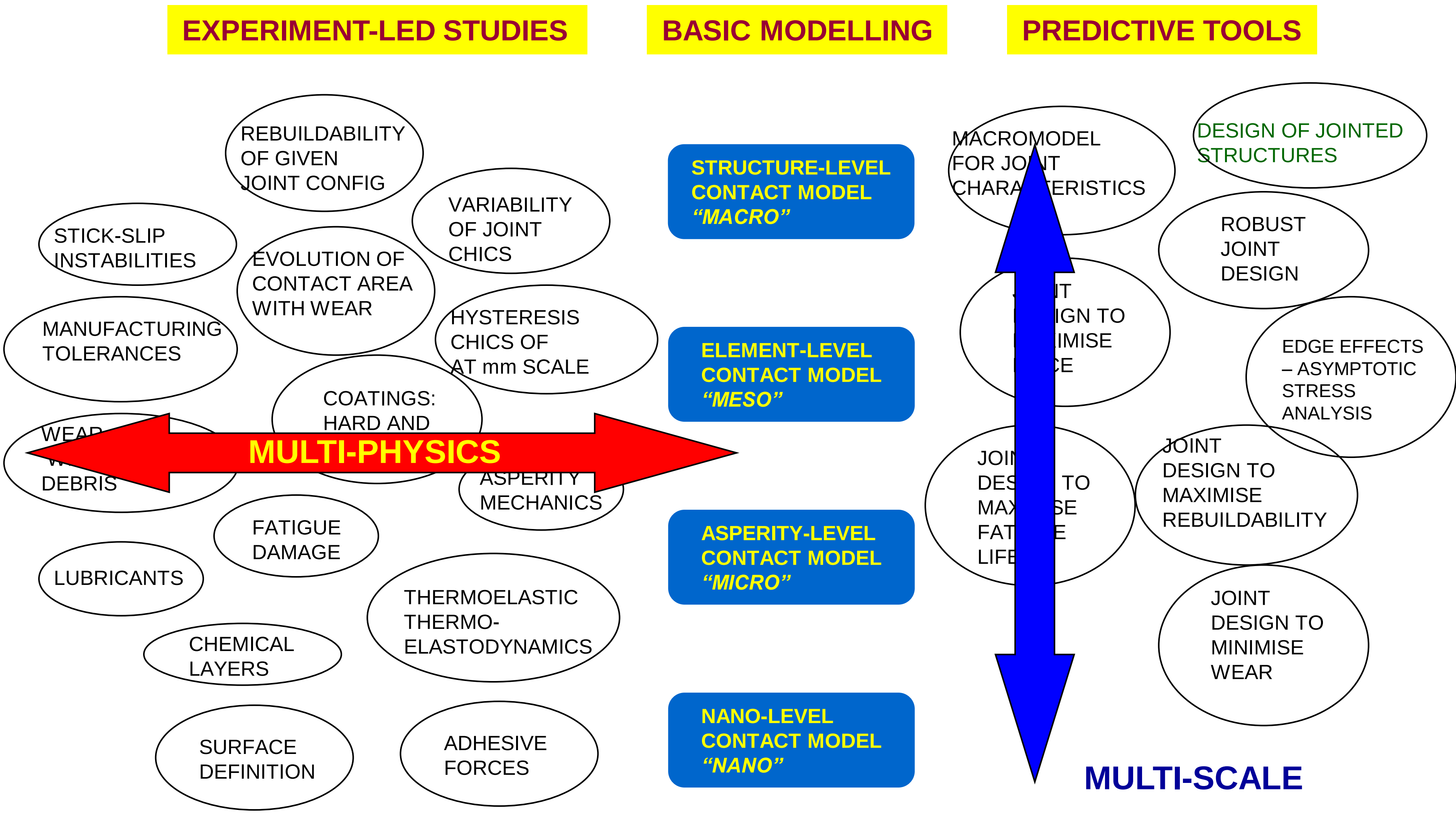

Friction CONTACT ROADMAP v 6.3

Previous Workshop

and ended up with…..

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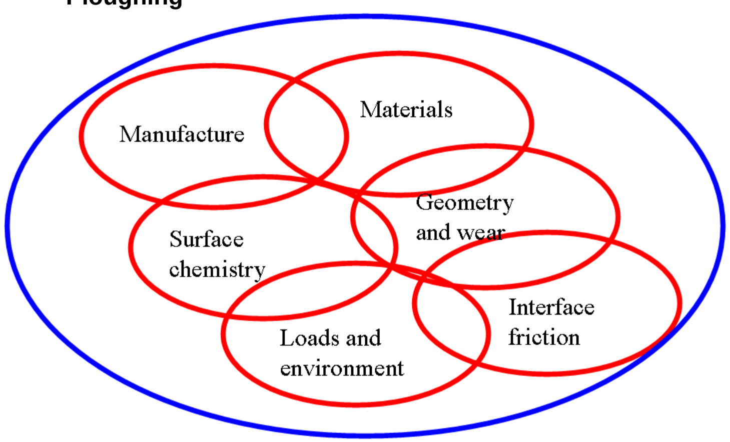

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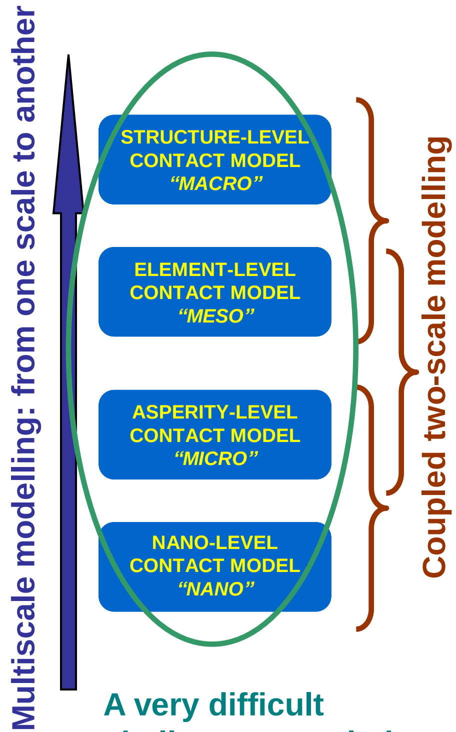

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Previous Workshop

One of the specific outcomes from the previous workshop was the formulation of three ‘mini challenges’:

Challenge 1: Experimental Measurements of Joint Properties

Challenge 2: Interface Physics

Challenge 3: Multi-scale Modelling

These were intended to focus attention for future research, and we shall hear shortly what has happened in the 2+ years since Washington

This Workshop

We need to re-group and move ahead…..

GOAL, OBJECTIVE, TASKS

GOAL

To be able to optimise design of structures with joints and interfaces from structural dynamics and integrity considerations

OBJECTIVE

To be able to construct mathematical models of joints and interfaces from conventional input data

TASKS

(a) To review the specific requirements for modelling joints in critical engineering structures and to identify future trends in joint design which will become possible with better models

(b) To review recent developments and the current state of the art of joint modelling

(c) To explore ideas for future developments in modelling methods to provide the predictive capabilities required by (a)

Structure for this Workshop

Focus on 3 aspects of the subject:

A End User Needs, Requirements and Opportunities

B Current State of the Art in Joint Modelling

C New Ideas for Future Development of Joint Models

These correspond to -

A, Where do we want to be?

B, Where are we now?

C How might we get from B to A?

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