# A Micro-electrochemical Study of Friction Stir Welded Aluminum 6061-T6

Paul E. Hintze, Andrew P. Bonifas and Luz M. Calle

Corrosion Technology Testbed

NASA Kennedy Space Center

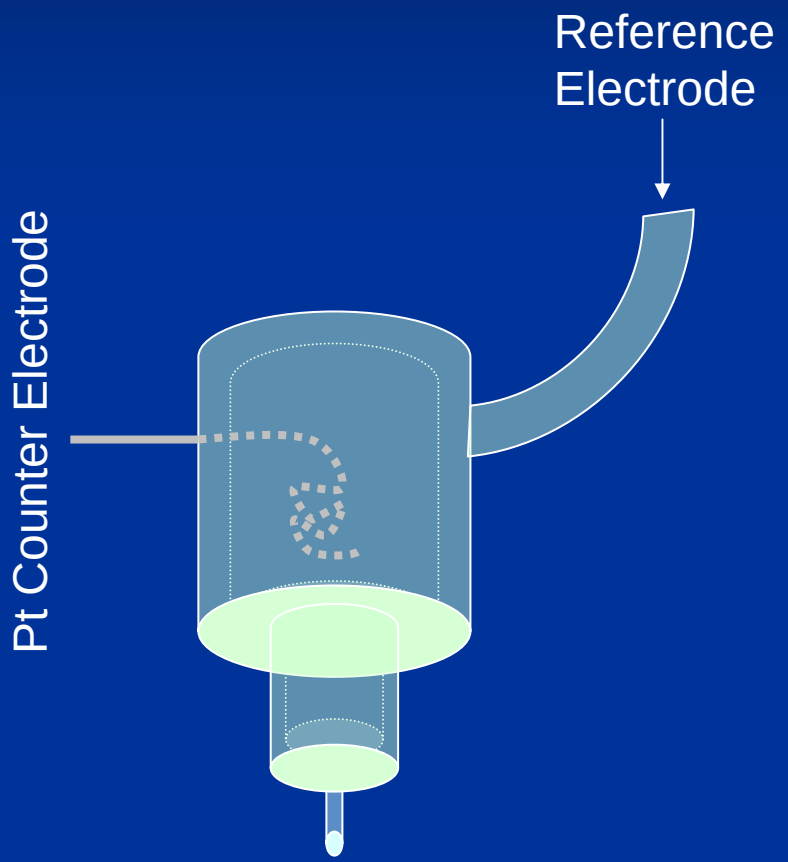
# Overview

- Introduction
  - Micro-electrochemical cell
  - Friction Stir Weld
- Methods
- Results
- Summary and future work

# Micro-Electrochemical Cell

- Technique first described by Suter and Böhni
- Measures electrochemical properties of small areas
- Does not expose entire surface to electrolyte
- One sample can be used for many measurements

# Micro-Electrochemical Cell




- Capillary tip is mounted to the bottom of a small Teflon electrolyte reservoir
- Ports for reference and counter electrodes
- Mounted on a microscope in place of an objective

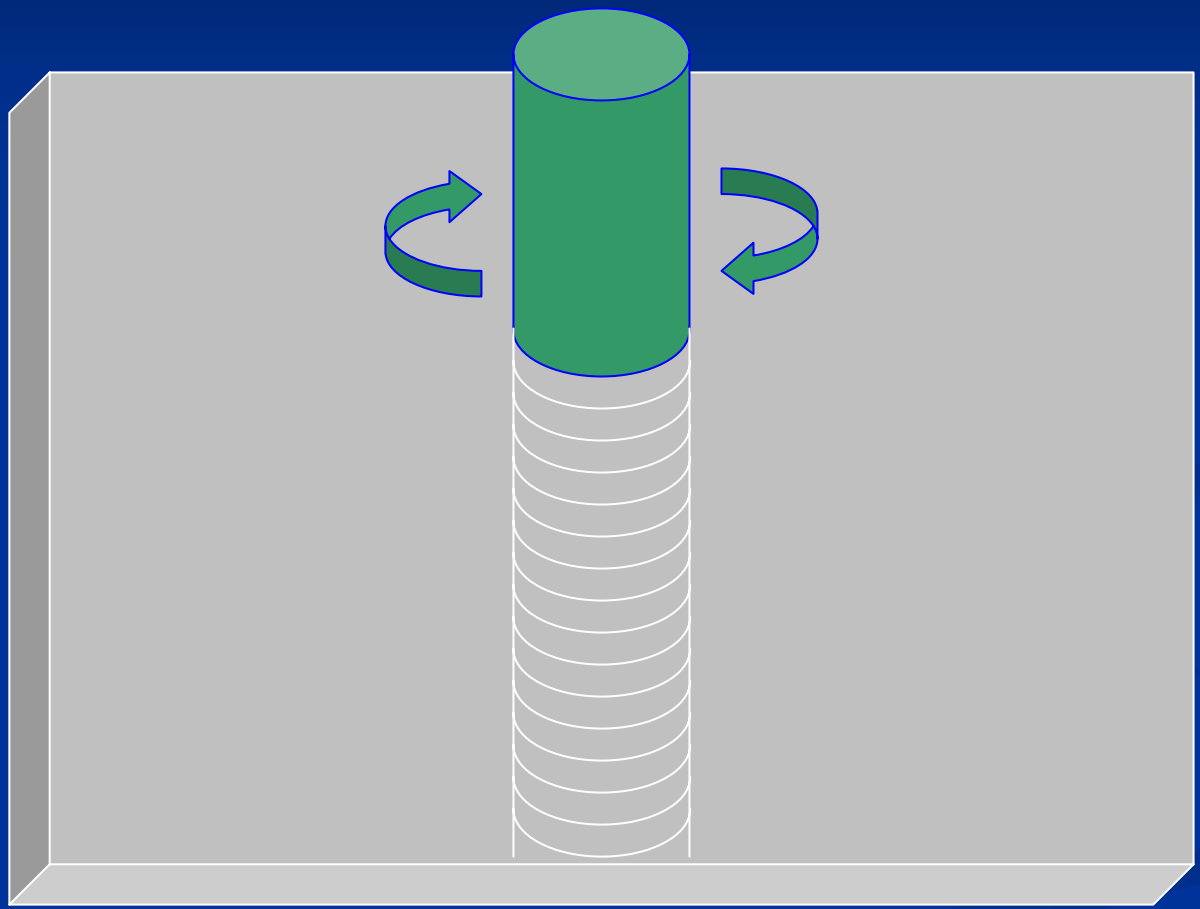
# Micro-Electrochemical Cell


- Tip is approximately 500 μm in diameter (Area ~ 0.2 $mm^2$)
- Ideal for measuring properties of welded samples or studies of localized corrosion

# Friction Stir Weld

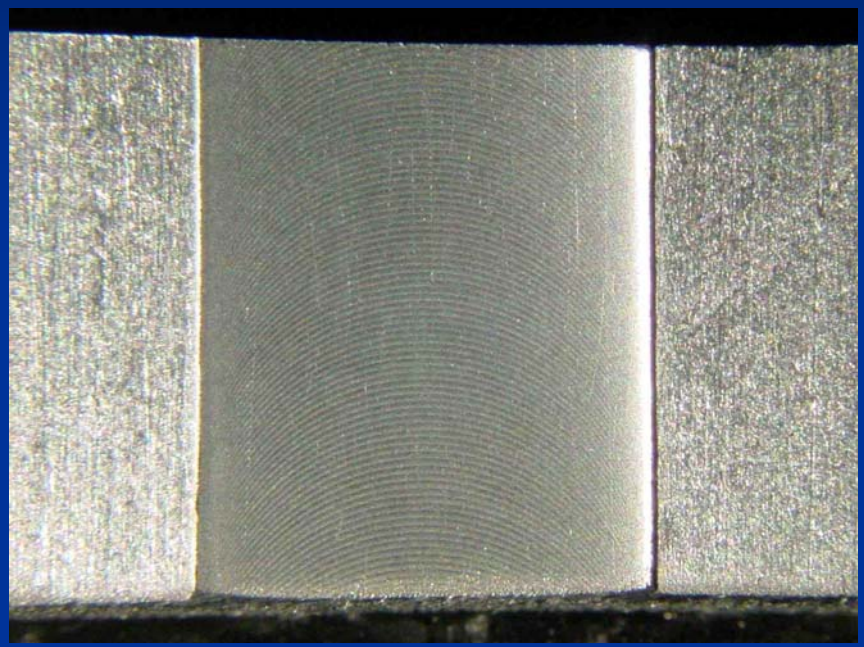
- Patented in 1991 by The Welding Institute
- Advantages
  - Lower temperature: no melting
  - Defect free weld
  - Weld zone has the same composition as bulk metal
- Disadvantages
  - Pieces must be clamped
  - 'Keyholes' at the ends of the weld

# Friction Stir Weld

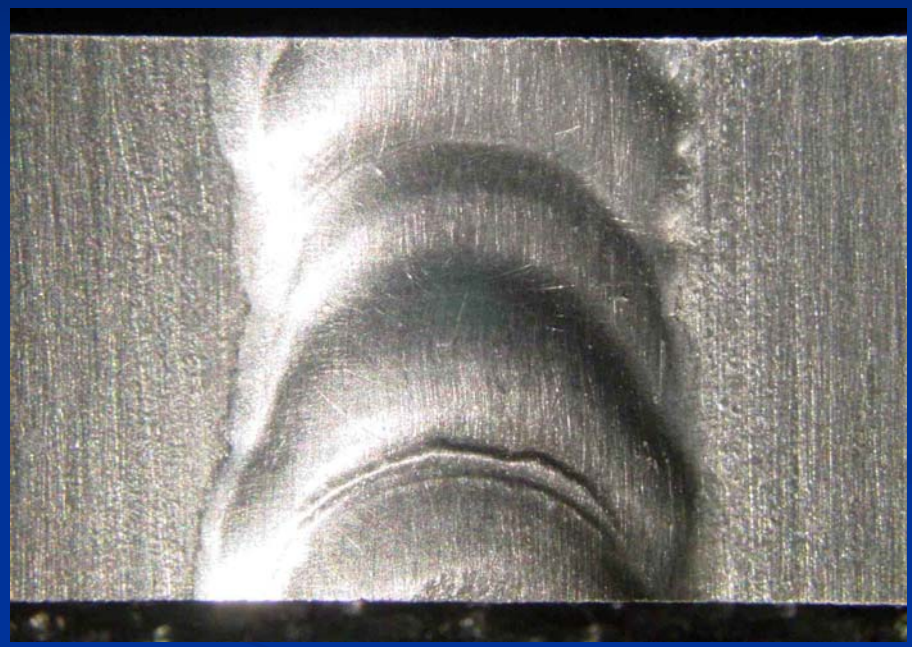


FSW Tool Profile

# Picture of welds and samples

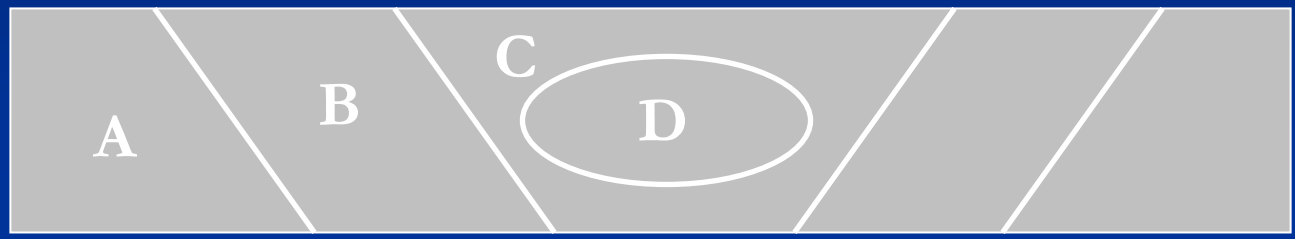


Friction Stir Weld



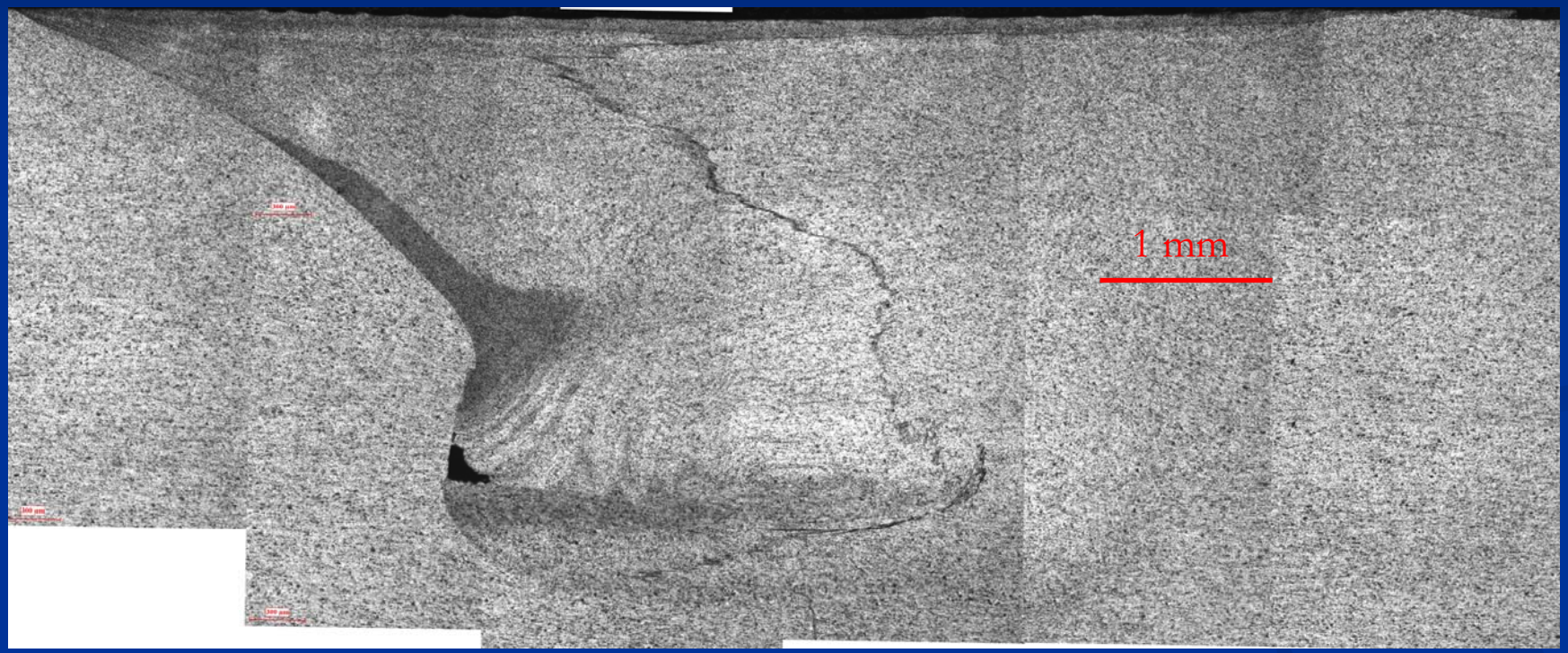
TIG Weld

# Microstructure of FSW




- A: Bulk Metal
- B: Heat affected zone (HAZ)
- C: Thermo-mechanically affected zone (TMAZ)
- D: Weld nugget, part of the TMAZ

# Microstructure

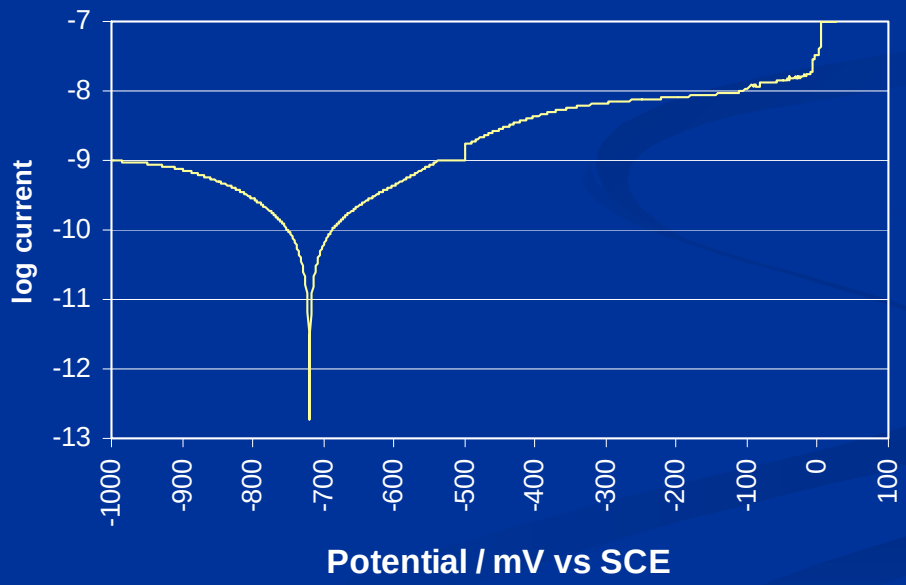


# Materials and Methods

- Al 6061-T6 friction stir welds
- Al 6061-T6 TIG welds with Al 5356 filler material
  - Al 6061 nominal composition: 1.0 % Mg, 0.6% Si, 0.27% Cu, 0.2 % Cr
  - Al 5356 nominal composition: 5.0% Mg, 0.4% Fe, 0.25% Si

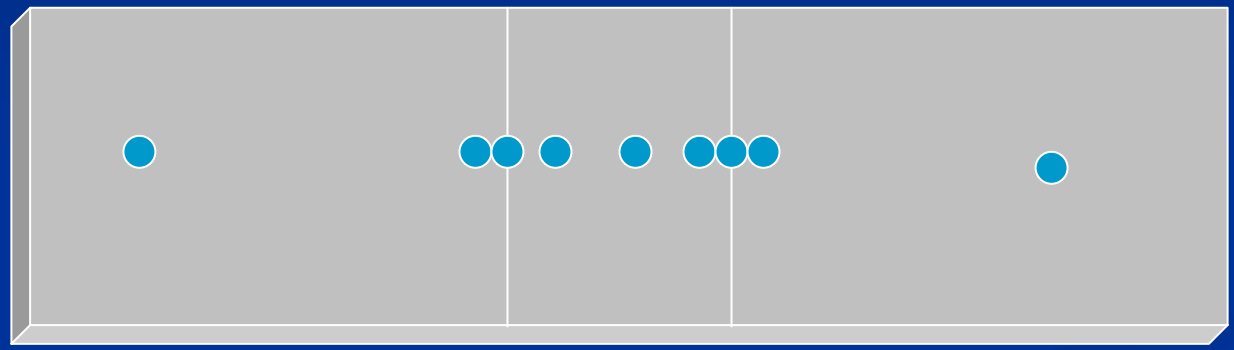
# Materials and Methods

- Polished to 600 grit
- Linear polarization from -1 V vs. SCE to the breakdown potential

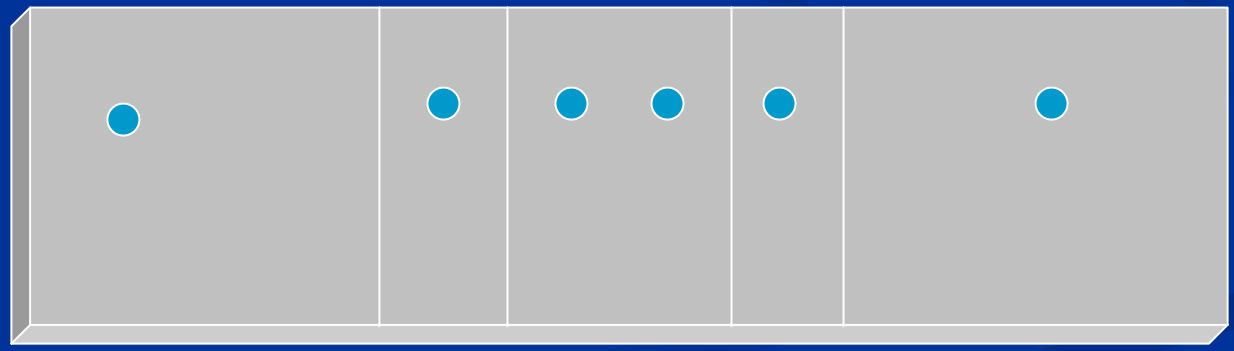


# Materials and Methods

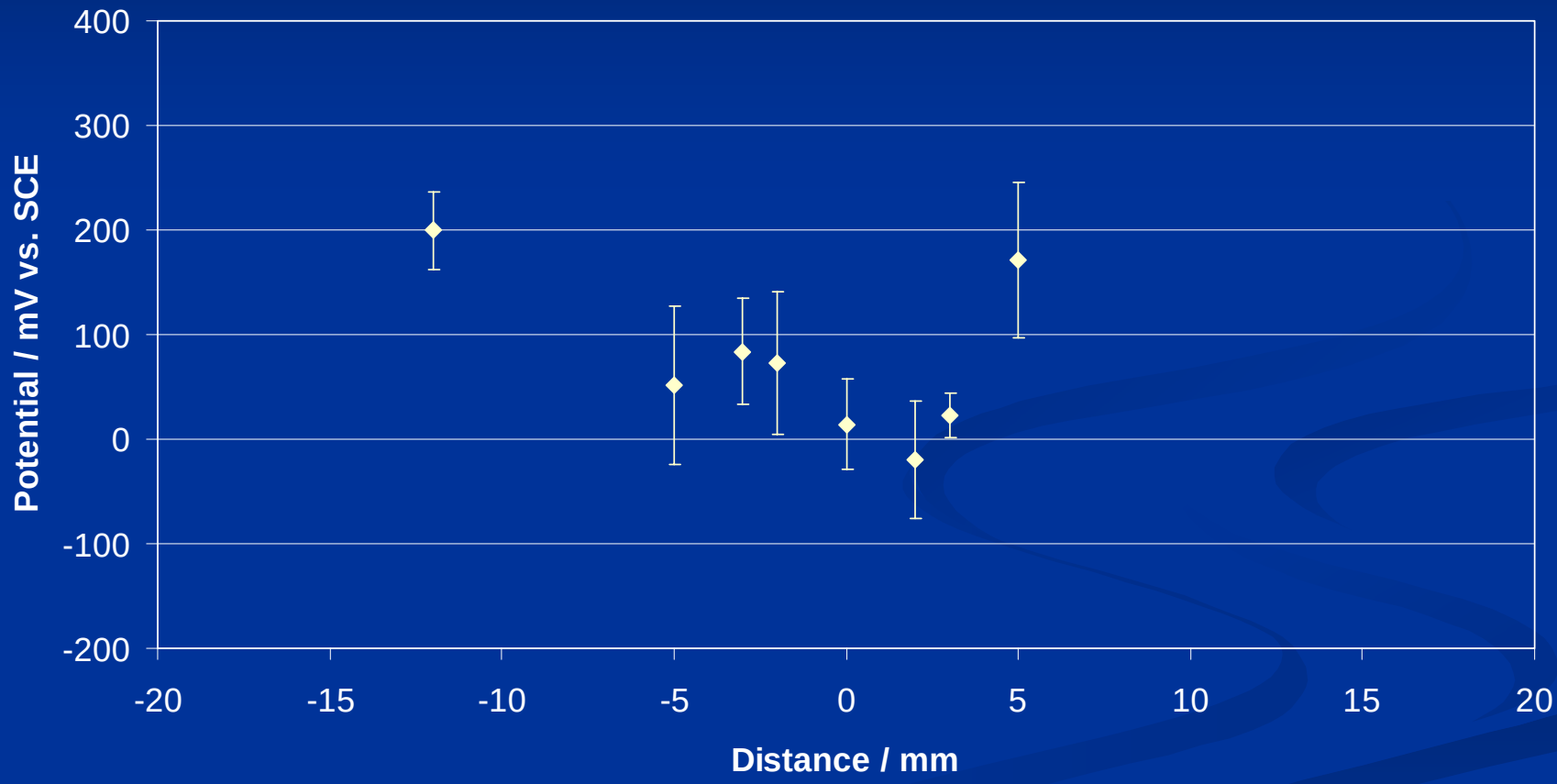
FSW



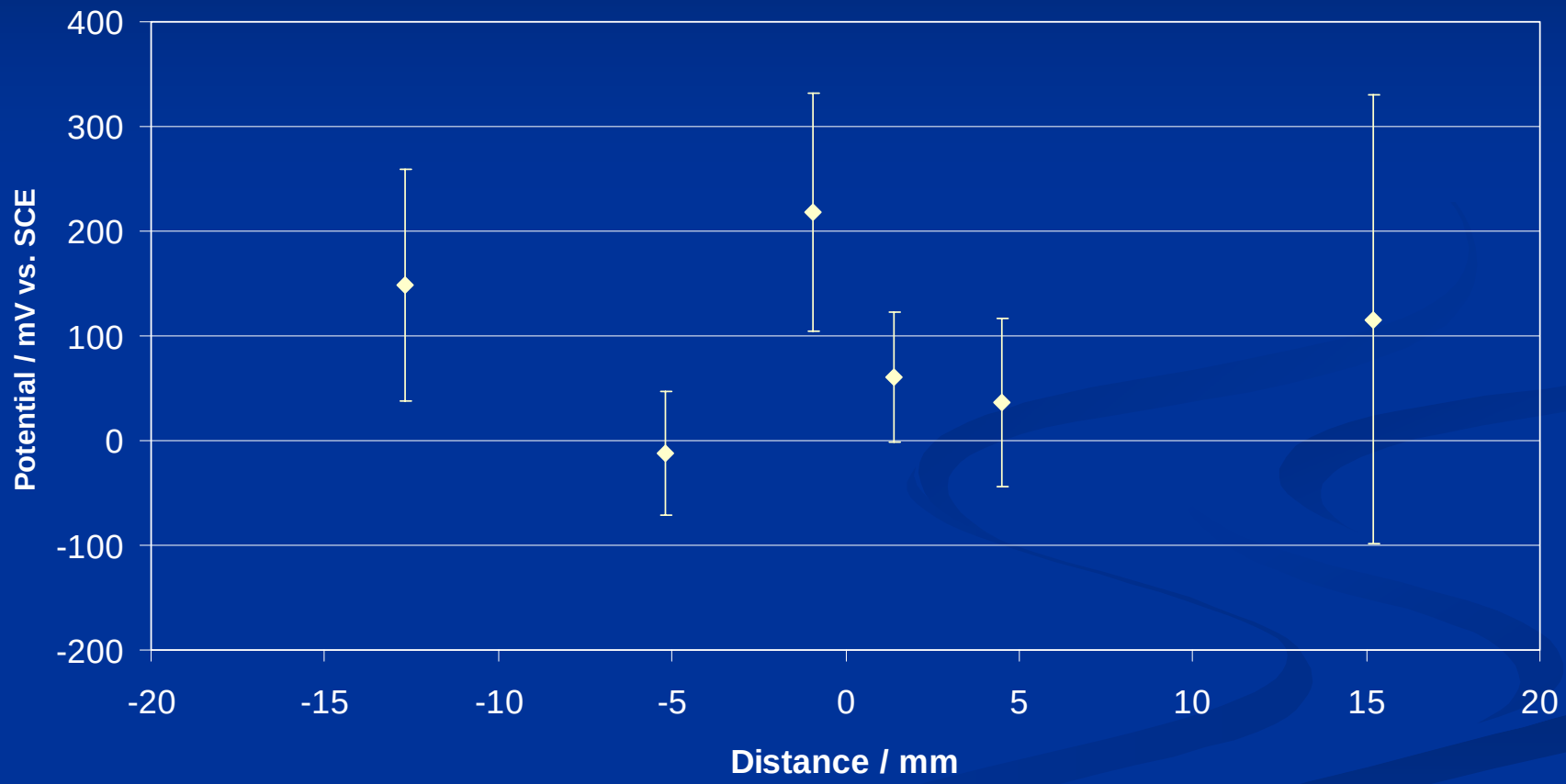
TIG



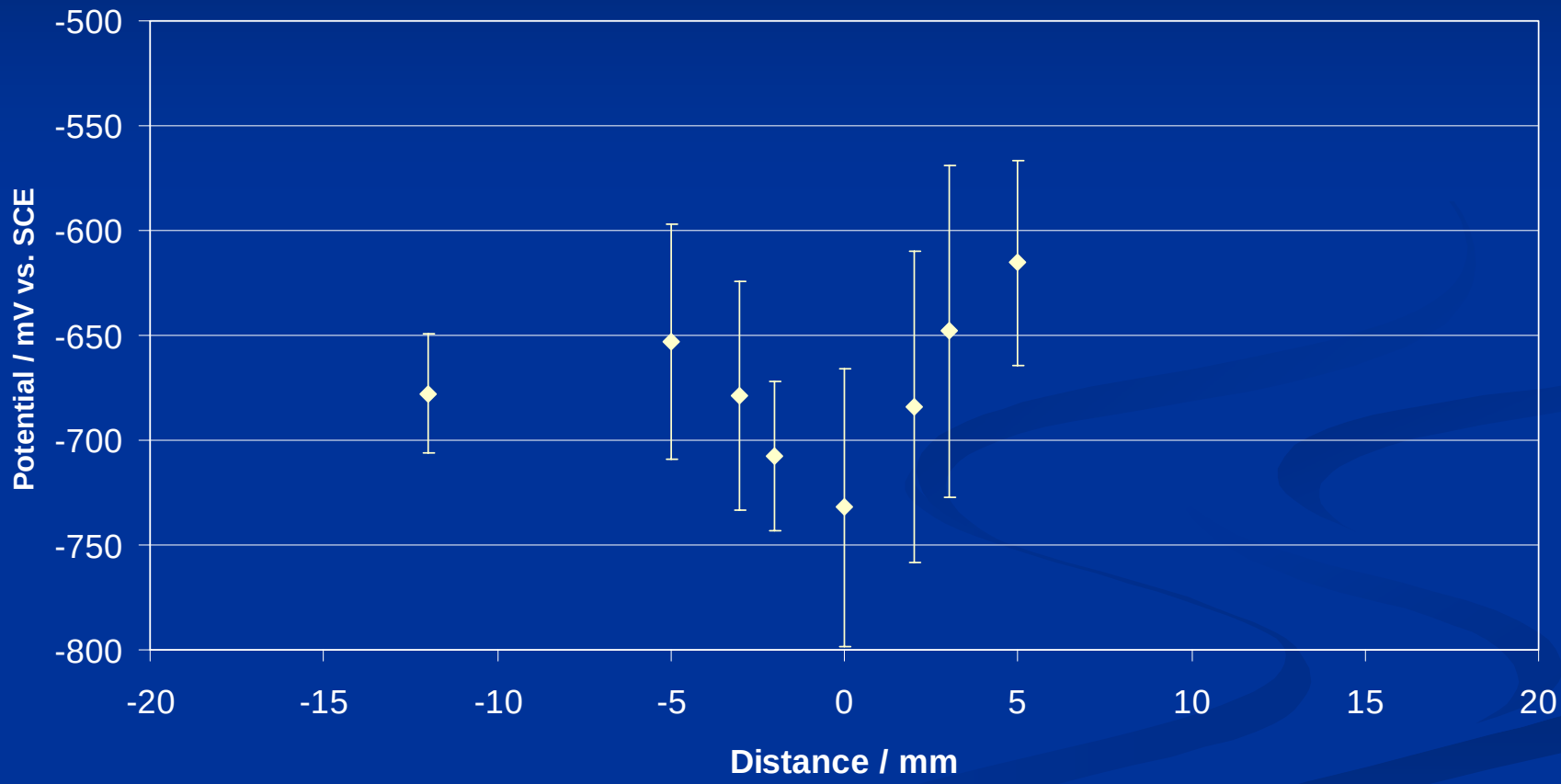
# FSW Breakdown Potential



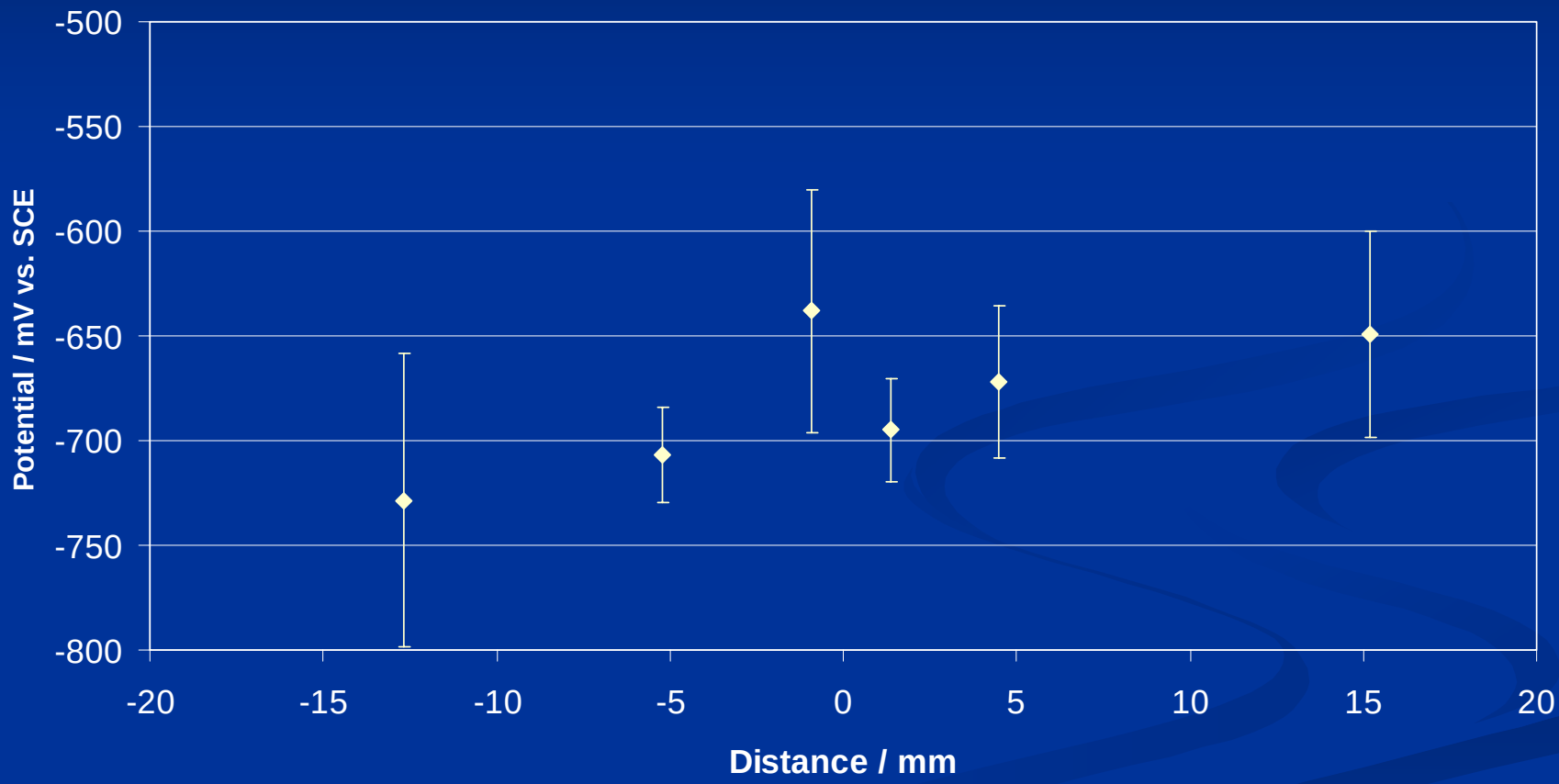
# TIG Breakdown Potential



# FSW Corrosion Potential



# TIG Corrosion Potential



# Summary

- FSW process yields a smaller "affected zone" than TIG process
  - Breakdown potential returns to that of the bulk metal closer to center of weld
  - Breakdown potentials are much more variable for TIG weld
- Corrosion potential does not change across FSW

# Future Work

- Compare micro-electrochemical techniques to large scale techniques
- Use technique to optimize weld parameters
- Work on other system where a high spatial resolution is necessary

# Acknowledgements


- This research is being performed while the author (PEH) holds a National Research Council Research Associateship Award at the NASA Kennedy Space Center
- NASA
  - Code M
- Michael Fuchs of the NASA Prototype Shop for supplying the welded samples