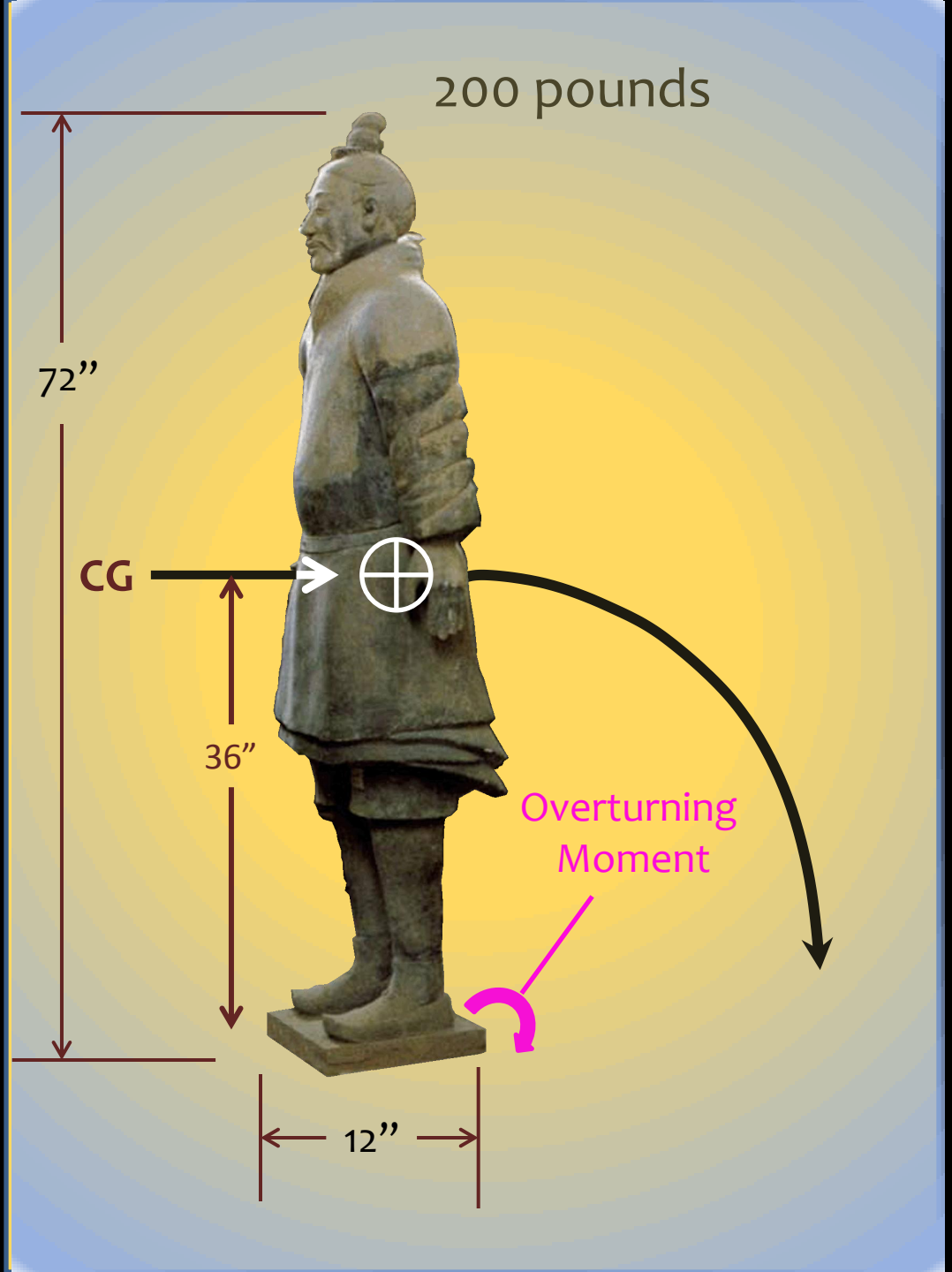

Earthquake mitigation for
CHINA'S TERRACOTTA WARRIORS


CHINA
Xi'an

Very Approximate Structural Analysis Of Terracotta



Bracketing Base

Mounting Legs

Leg Mount

Newton noticed quite simply that the more mass something has the more force it takes to move it. I.E. his second law (in laymen's terms): The amount of force needed to move an object is equal to the object's mass times its change in velocity or it's acceleration,

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

$$F=ma$$

Approximate Analysis Of Terracotta Warrior structural dynamic in a large seismic event at the Asian Art Museum.

F =MA

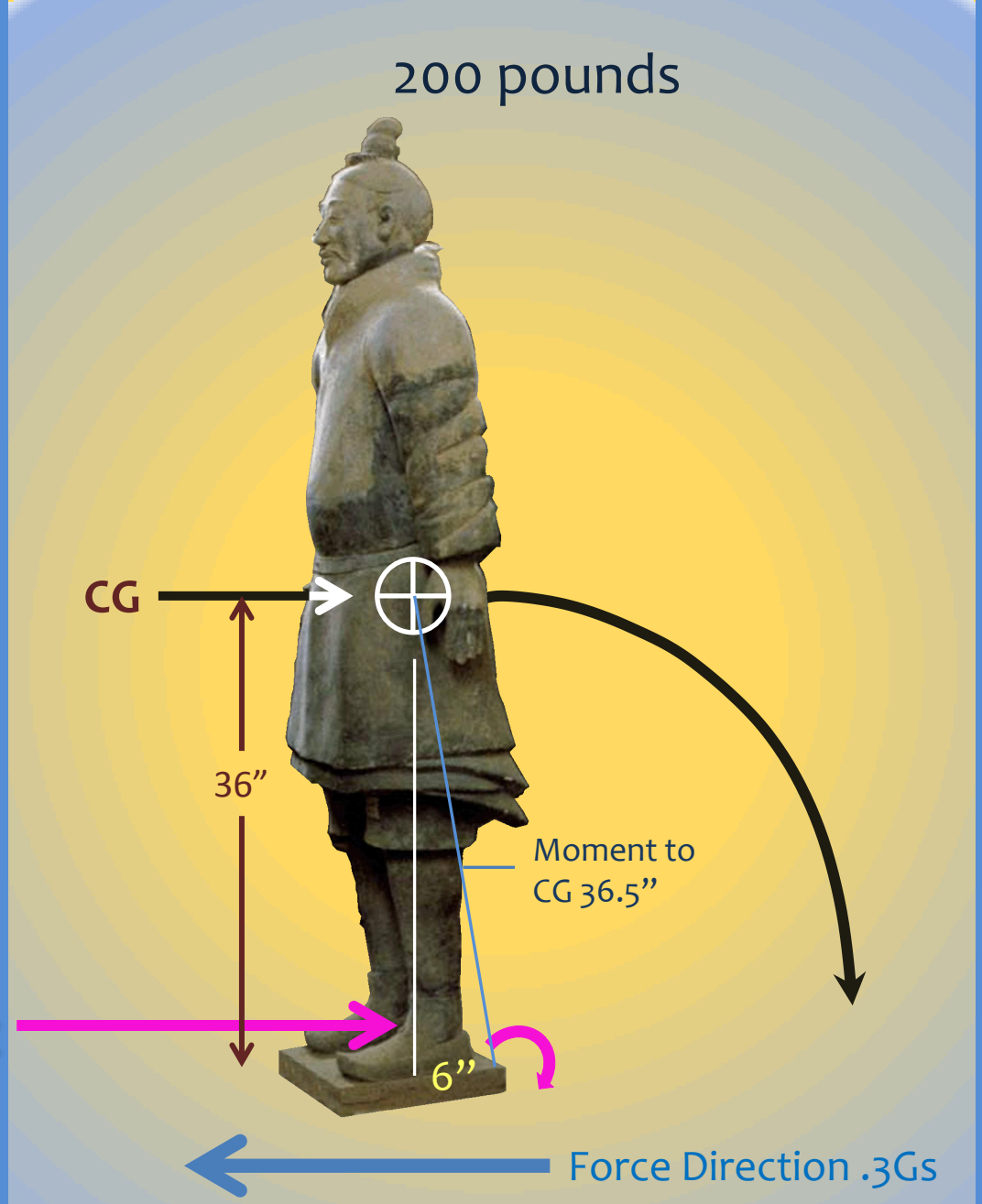
Force = 200 pounds x .3 gravities

Force = 60 pounds

Moment force is calculated from the center of gravity.

Moment Force = 60 (36.5)
Moment Force = 2190 pounds

Overturning Moment



Moment Force @ .3Gs: 36.5” x 200#s(.3G)= 2190 inch pounds

For every action there is an equal and opposite reaction.

An object is said to be stable when the gravitational resistance is greater than the lateral force.

$Wd > Fh$

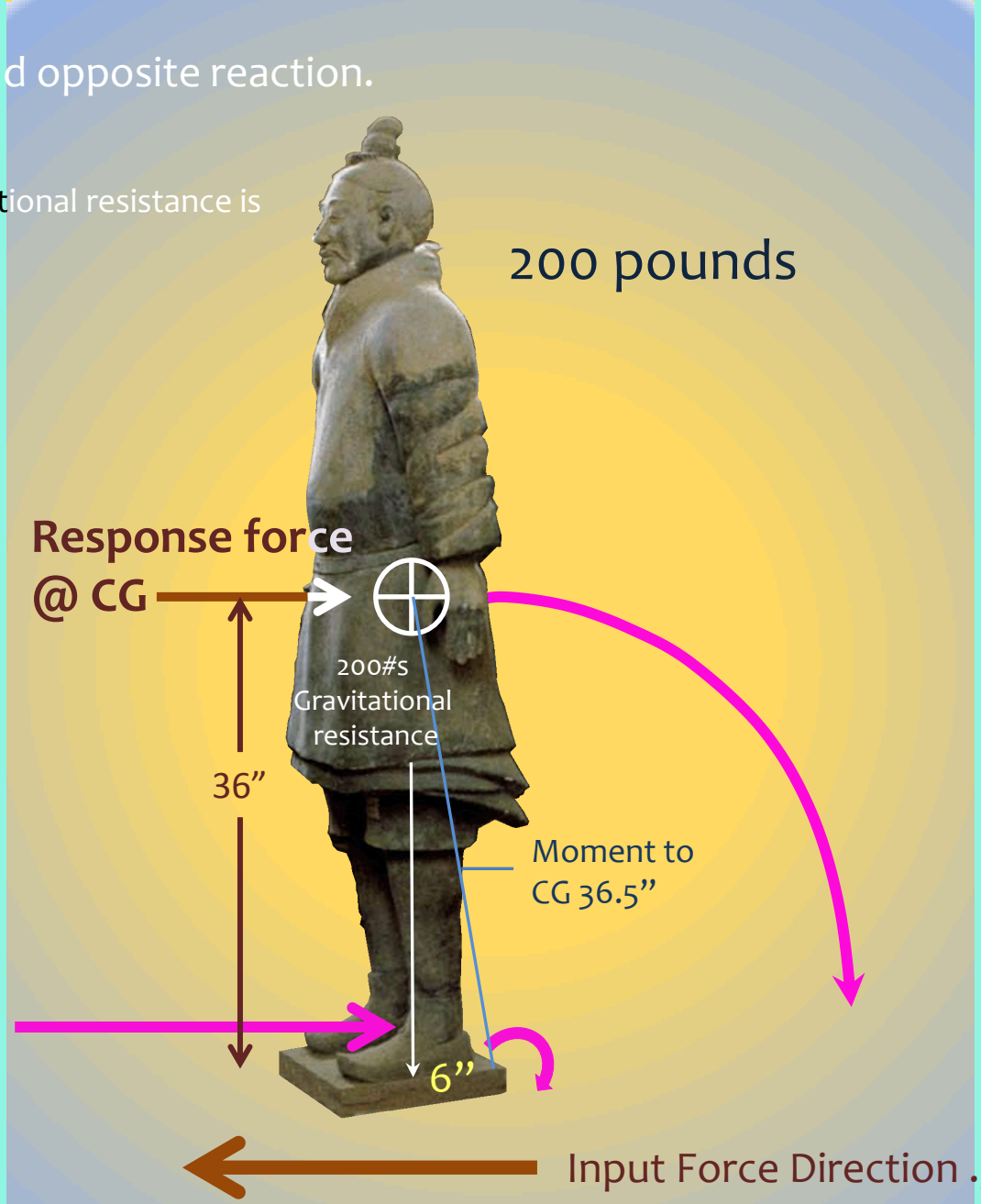
Weight = 200 pounds
Depth to CG = 6 inches

200 pounds x 6 inches = 1200 inch pounds

Force = 60 pounds
height = 36 inches

60 pounds x 36 inches = 2160 inch pounds

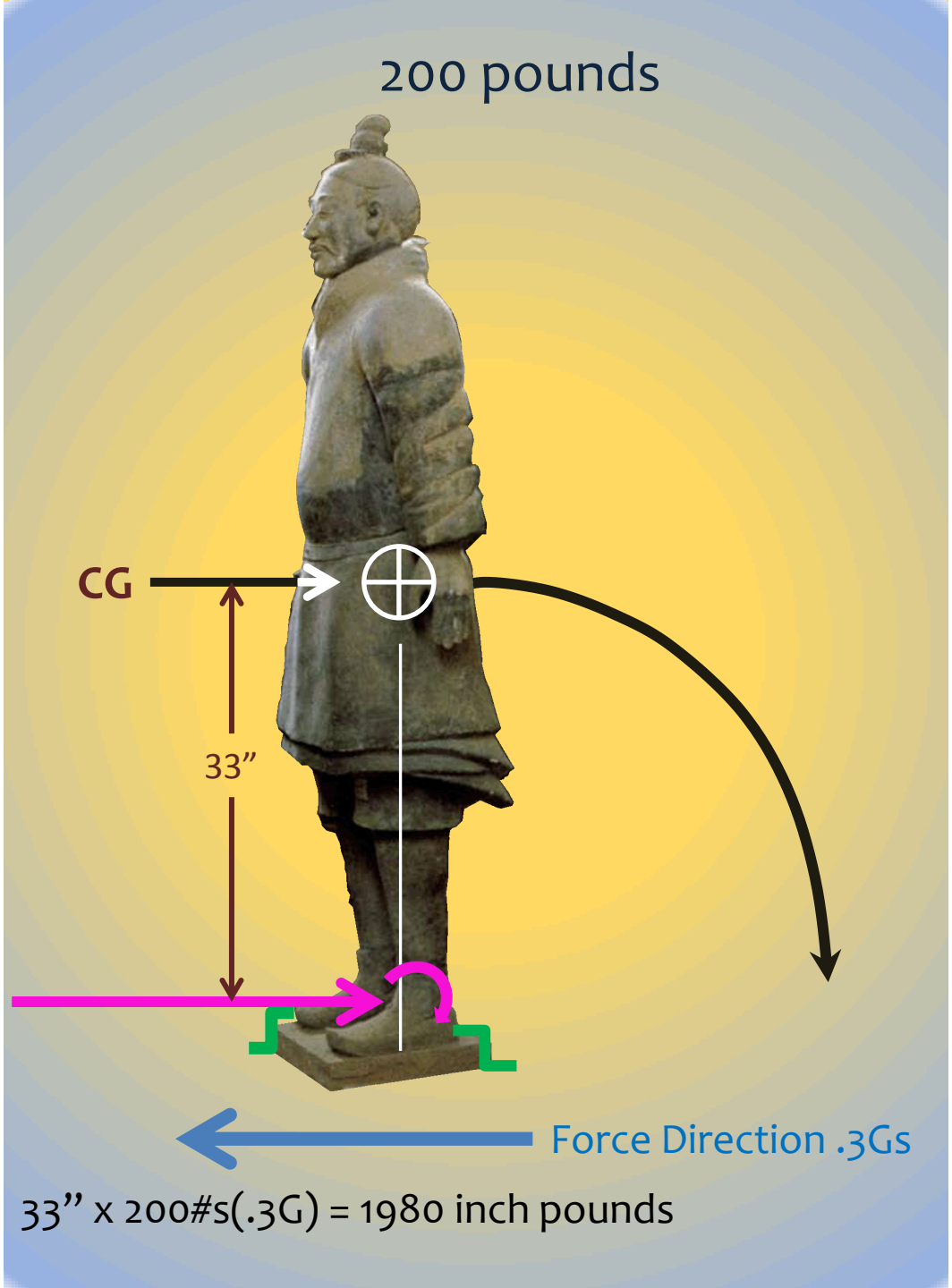
Overturning Moment



1200 pounds < 2160 pounds signifies an unstable shape

The likely place the object will rupture in a seismic event if the feet are bracketed.

Rupture Moment



Force Moment of Rupture @ .3Gs: 33” x 200#s(.3G) = 1980 inch pounds

Mount Design

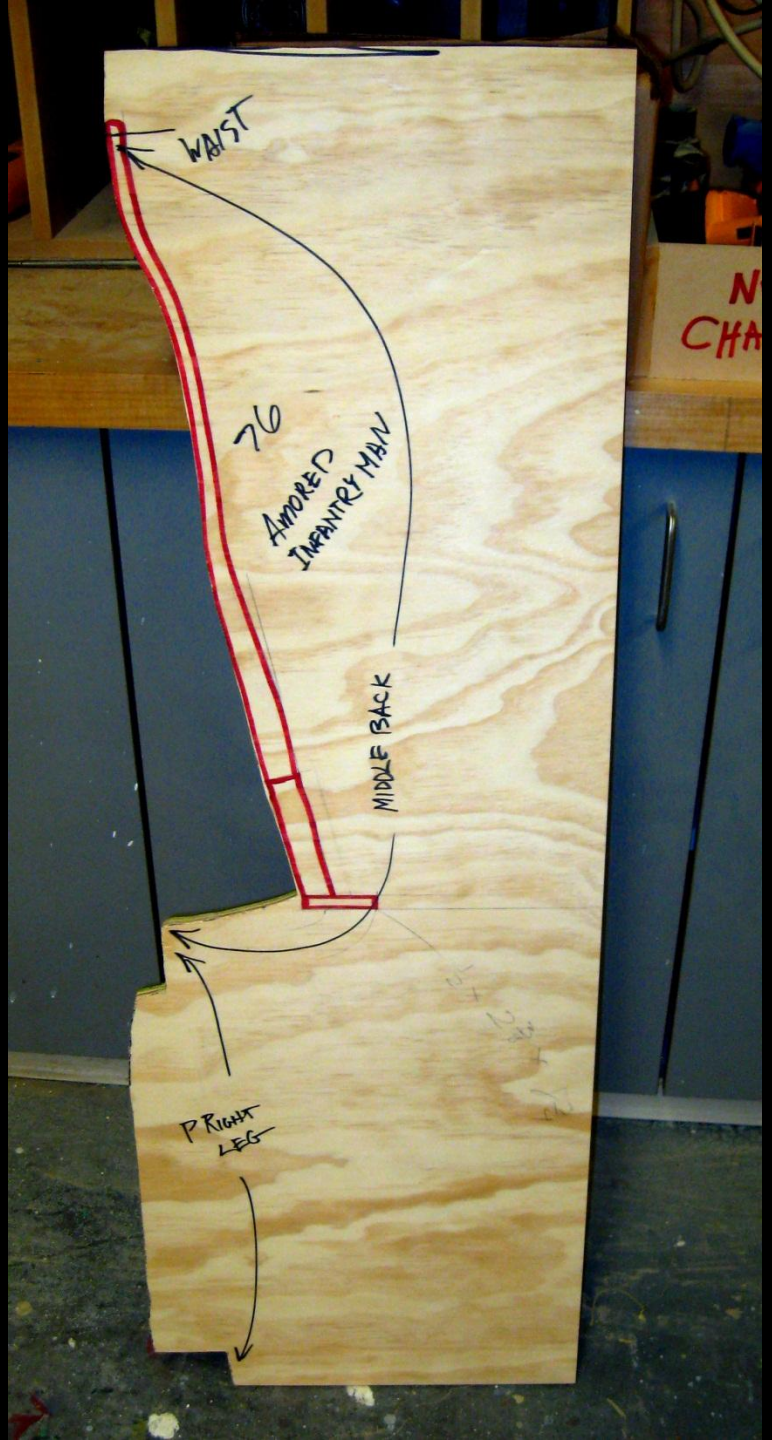
Minneapolis Trip


Q-tip Contour Gauge

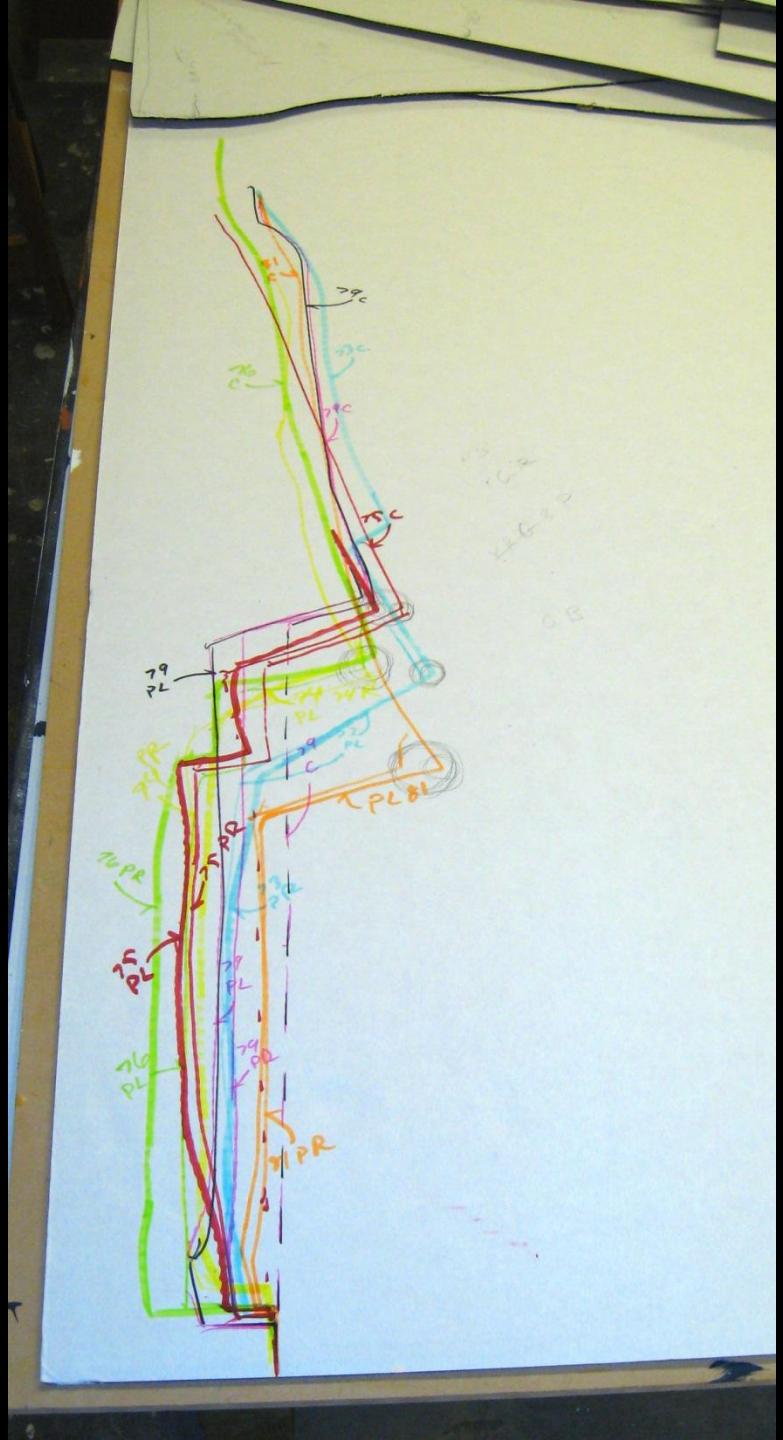

Cardboard Templates

The talented and generous Bill Skodje demonstrating his template making skill.

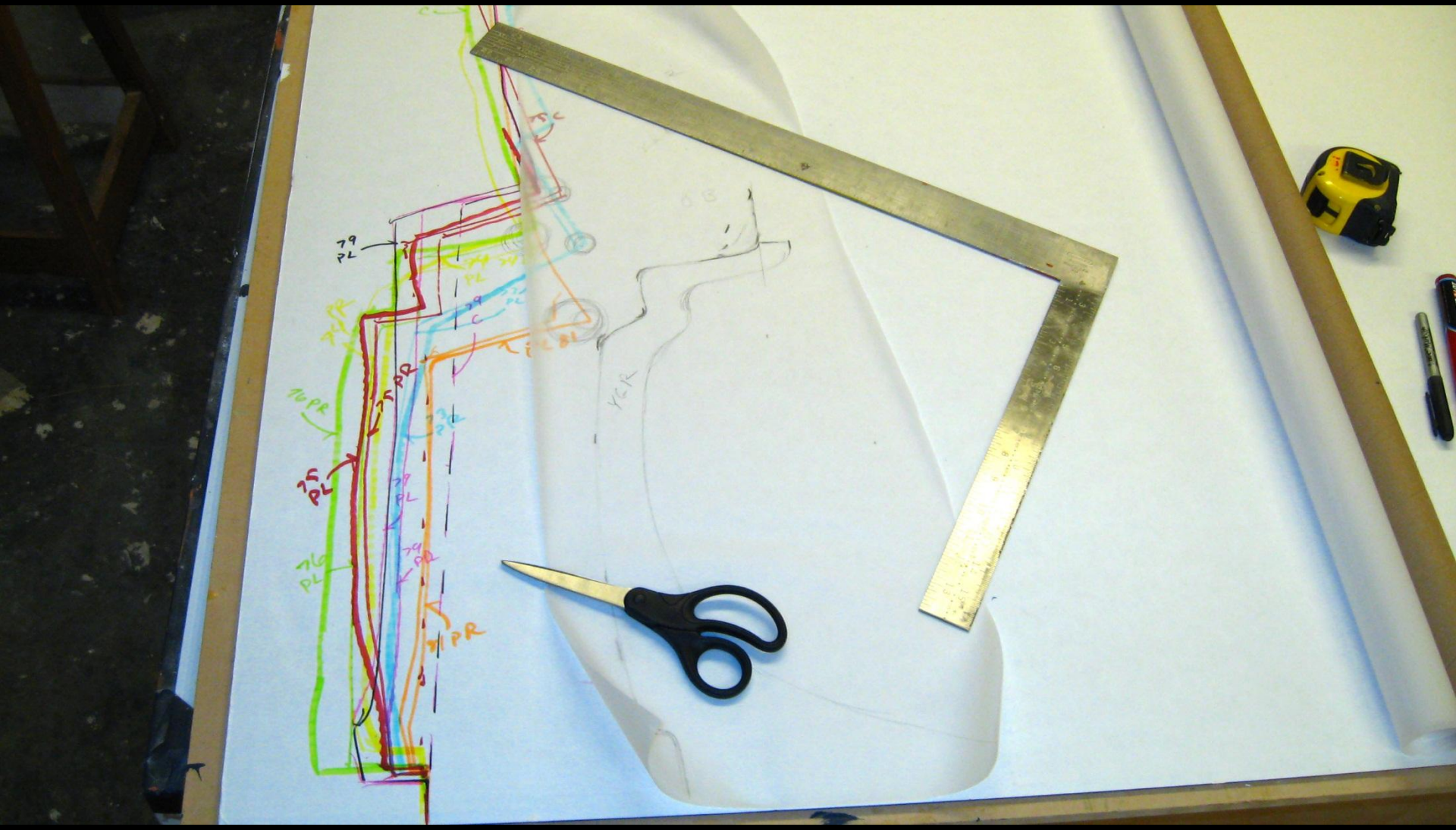
Transfer Shapes to
½” Plywood



Pack and ship templates to San Francisco

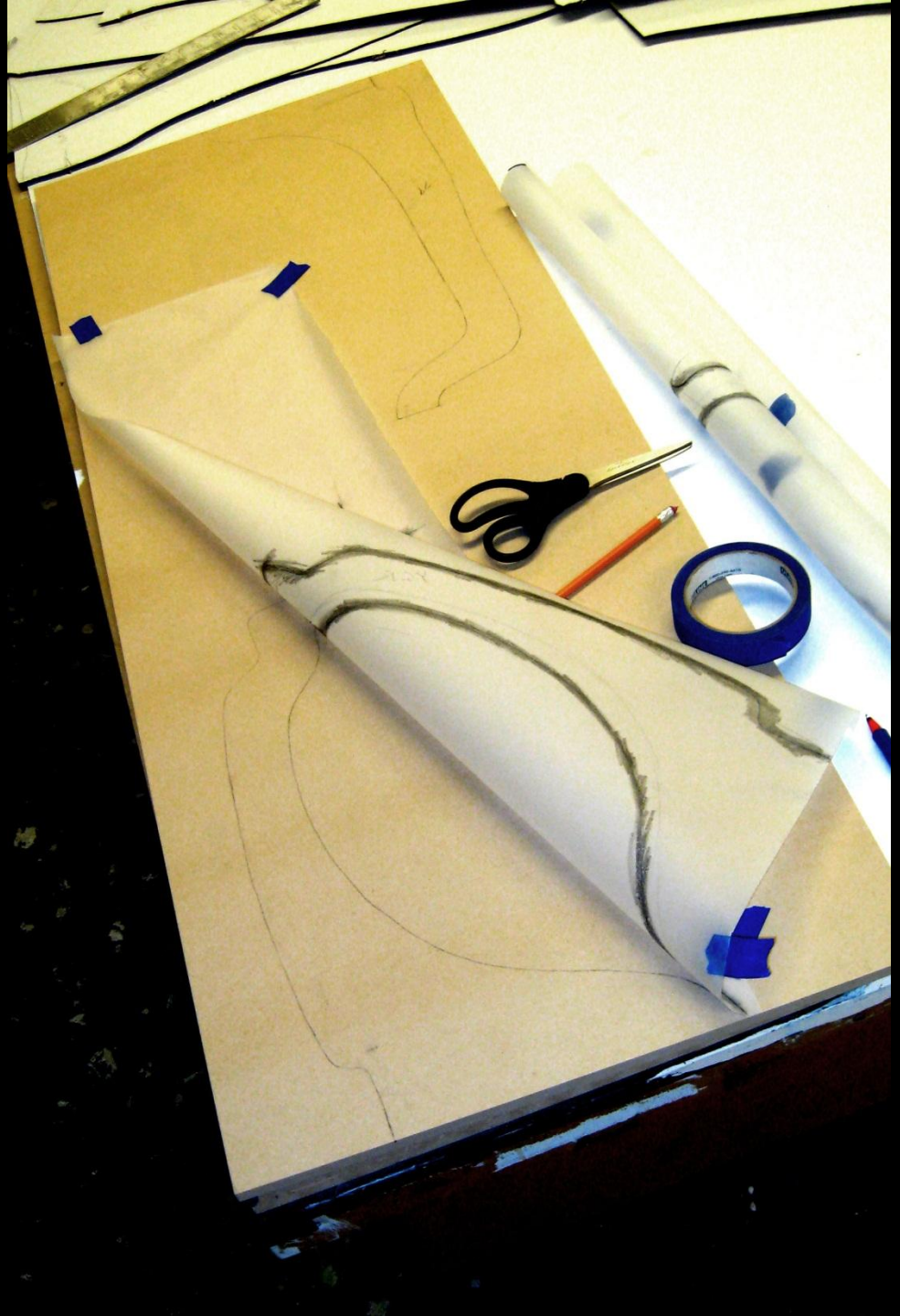


Shape Analysis

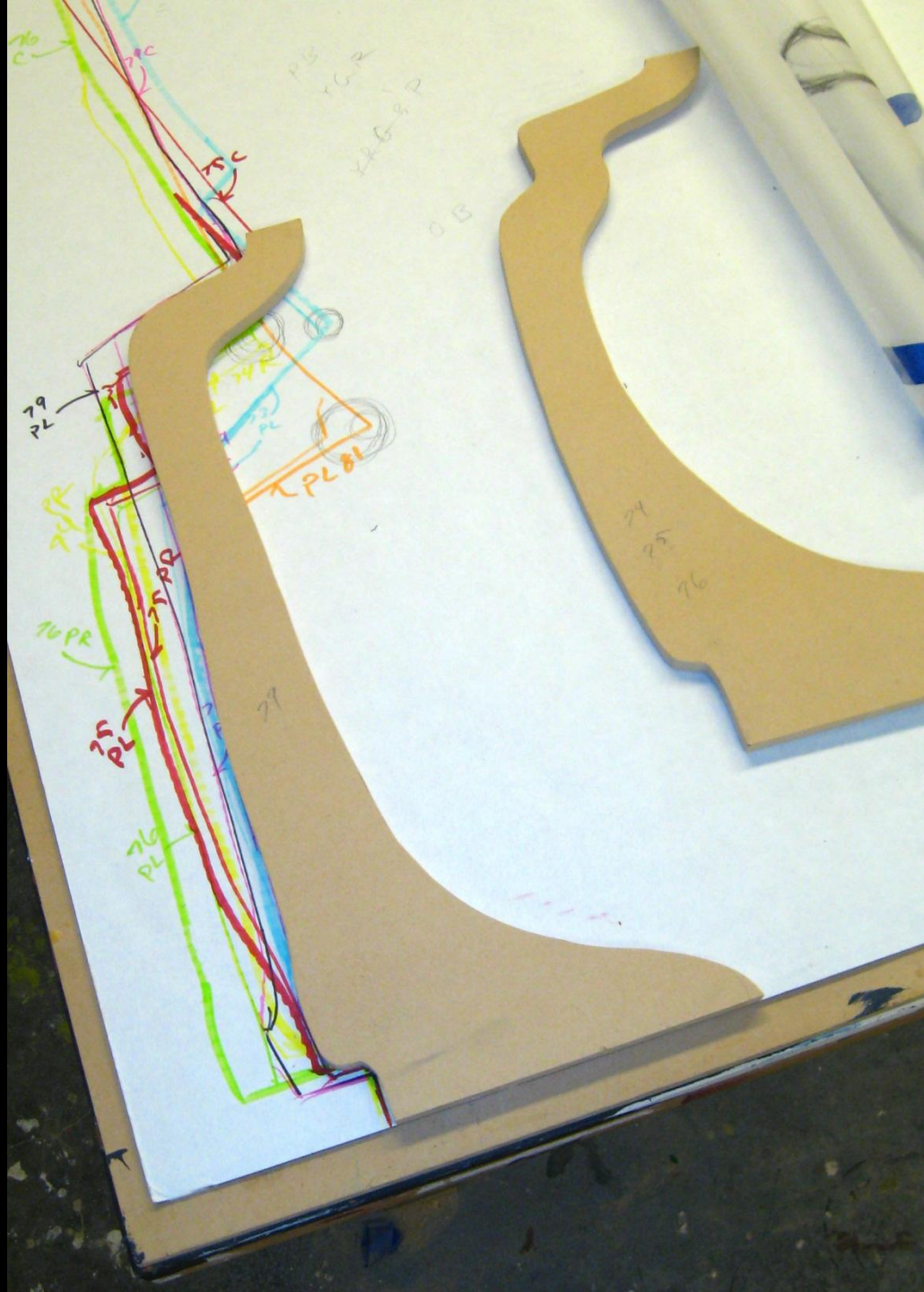


Full scale drawing of mount section.

Carbon Transfer



Full scale wooden mount sections.



Plasma cutting template
¼” smaller than work
To allow for cutting tip
Guide.

Cutting Multiple Templates. Templates burn up easily so it becomes necessary to have duplicates of standardized Templates.

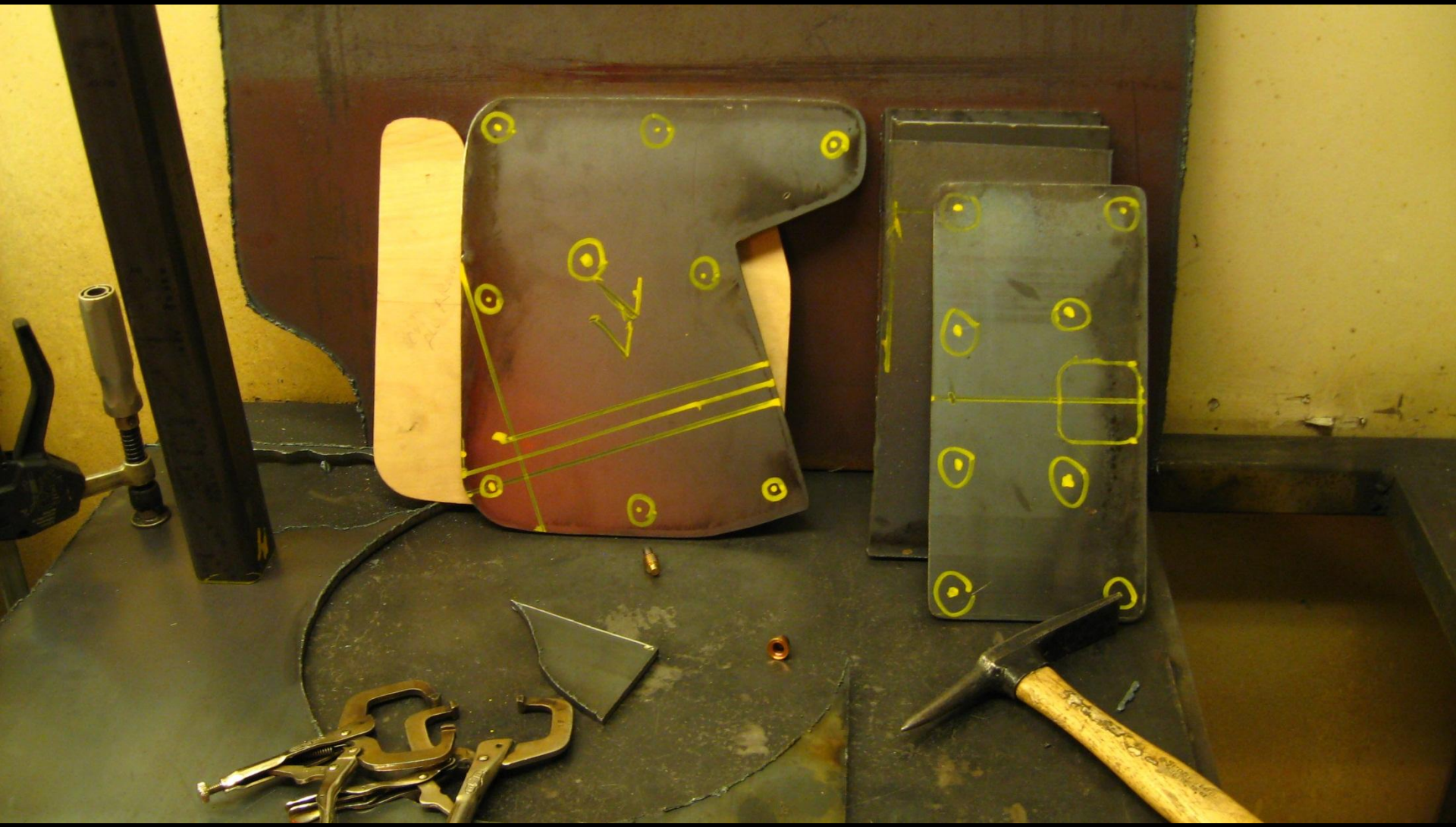
Full scale Warrior Mockups for Test fitting Mounts.

Cutting setup

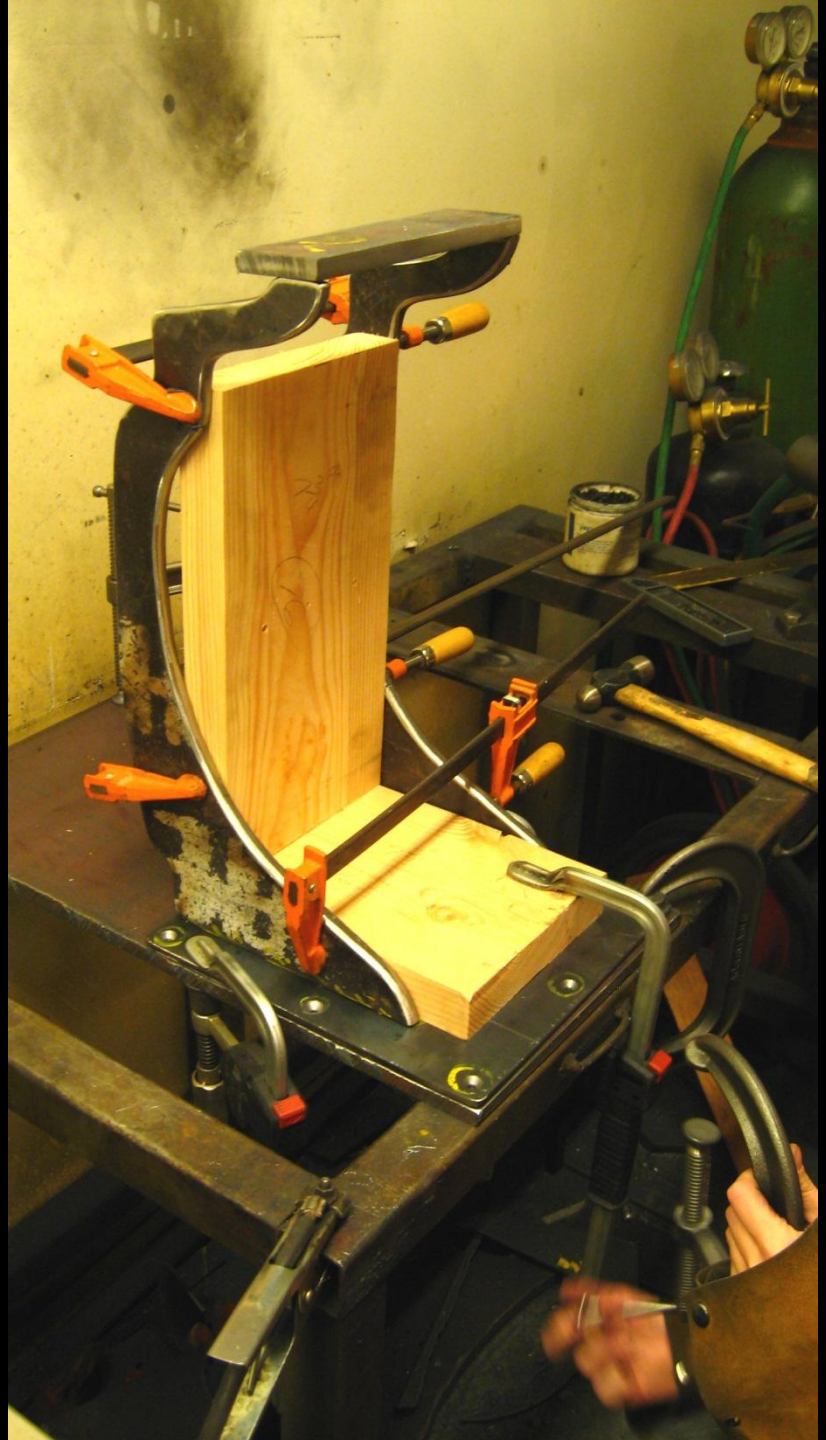
Plasma Cutting

One Week of Cutting

Cleaning off Slag, Beveling and Smoothing out Parts



Milling and Welding Layout



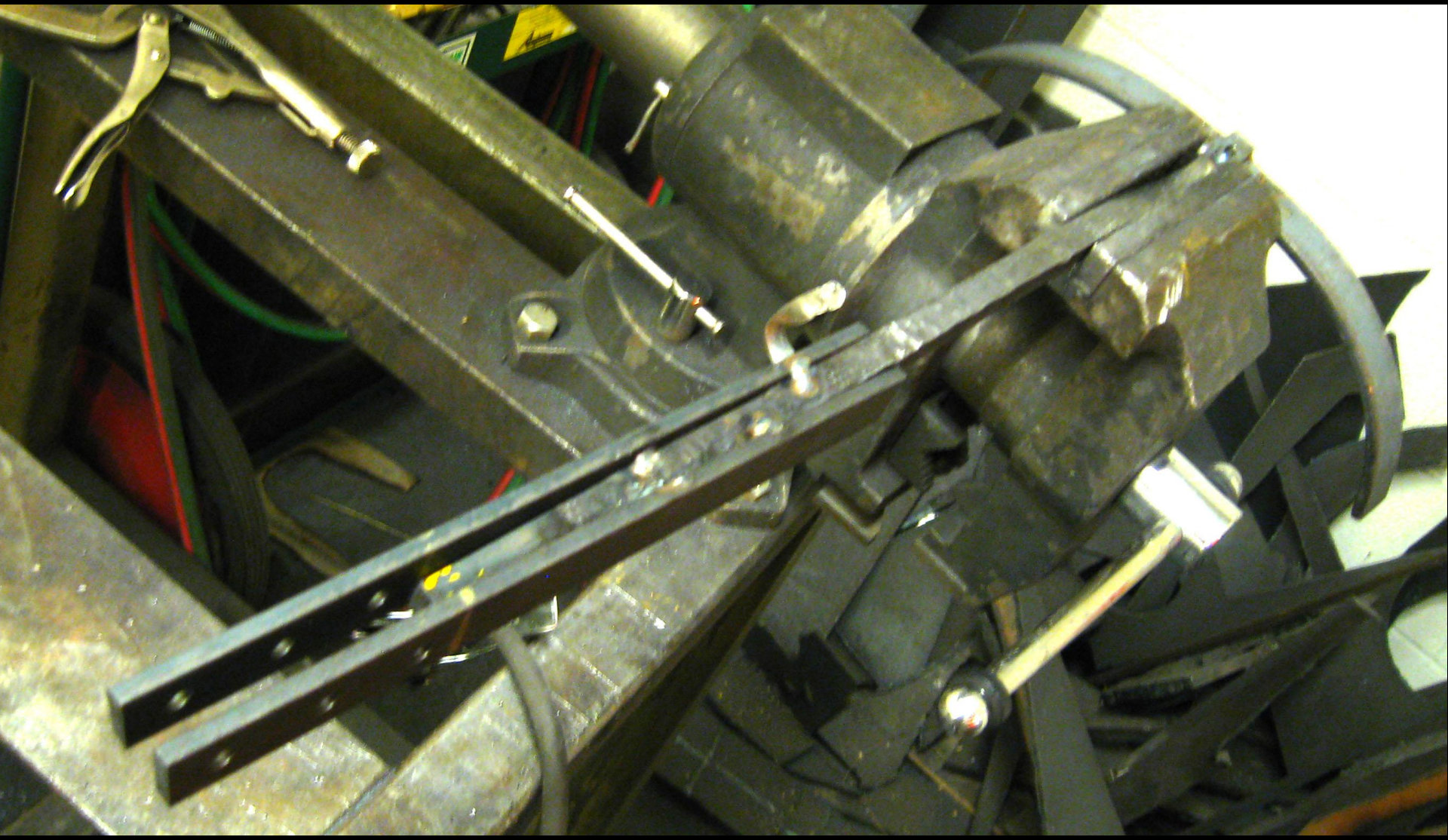
Welding Jig Setup for
Base Section of Mount.


75

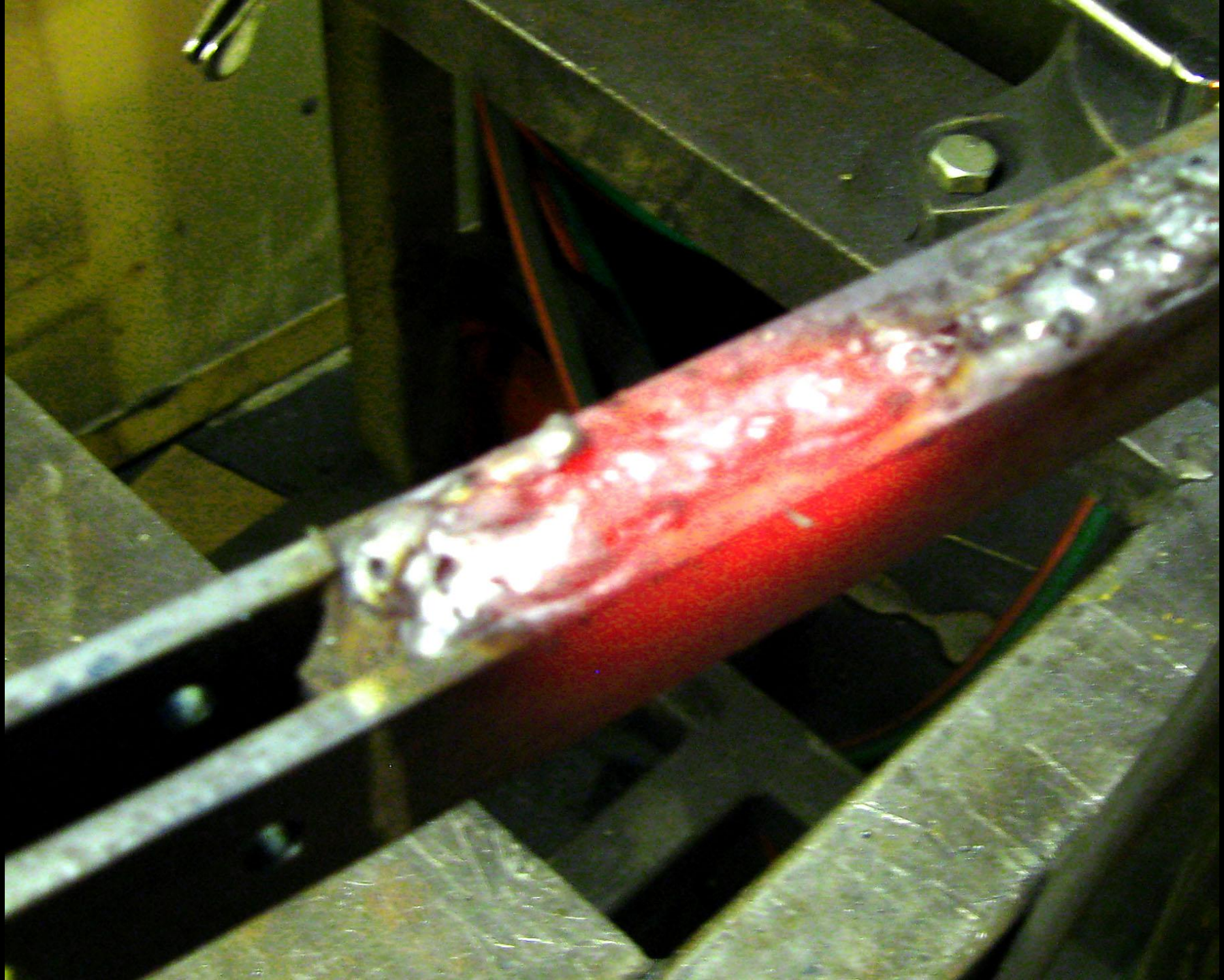
Forming Spine of the General using Template

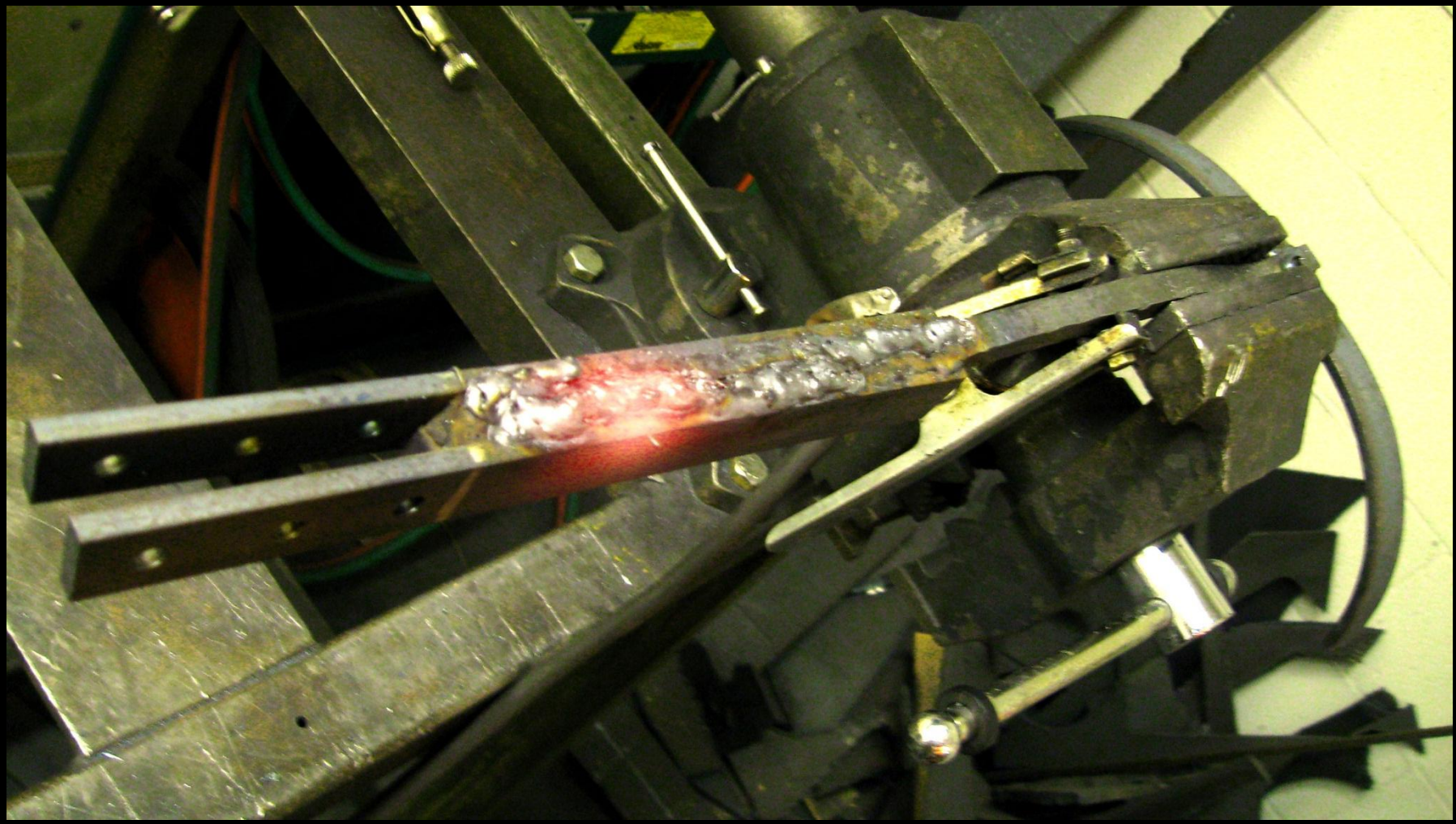

GRANT

Lining up Connector Flanges Using Warrior Mockups



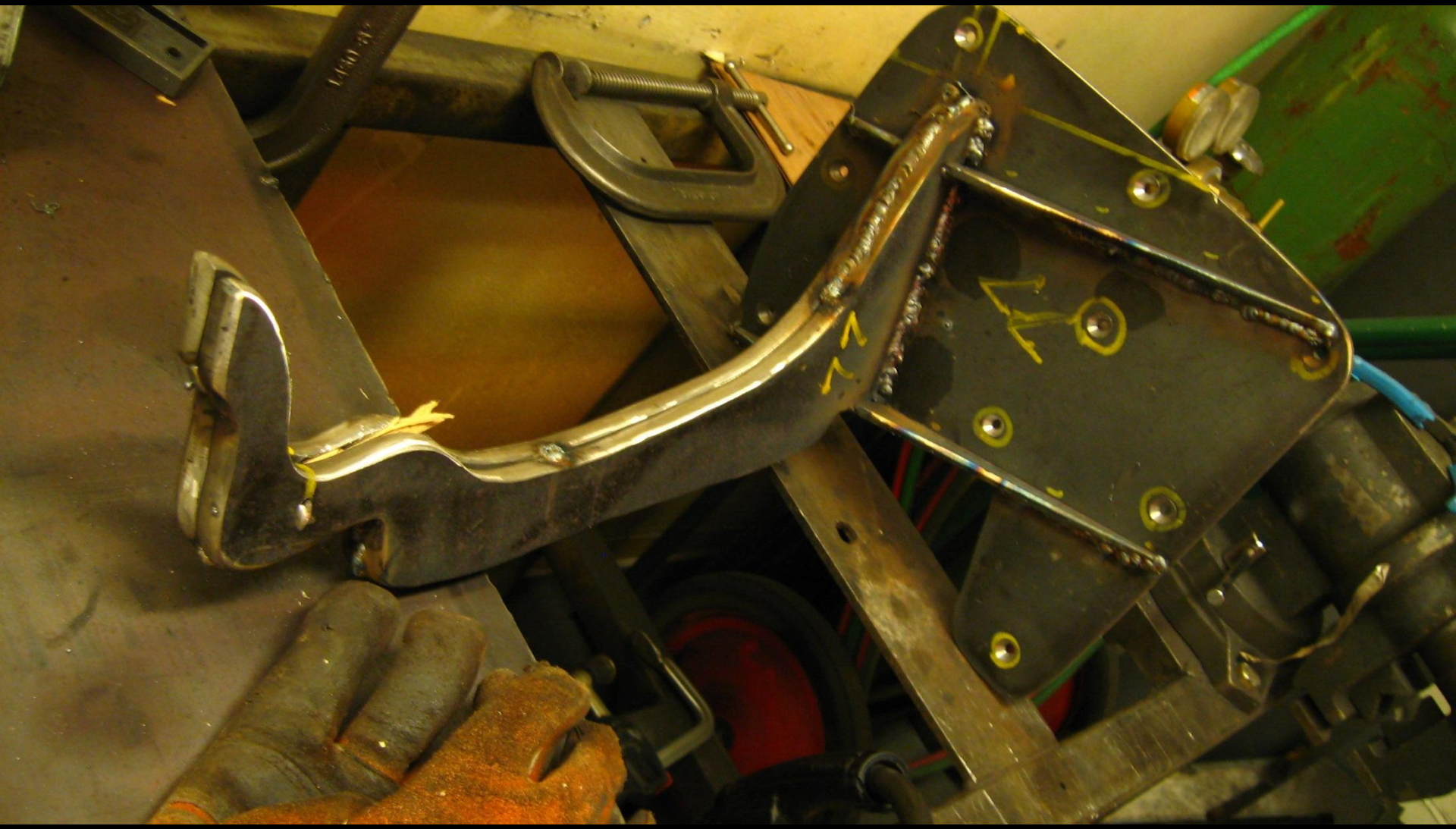
Fill Weld Process for Connector Flanges



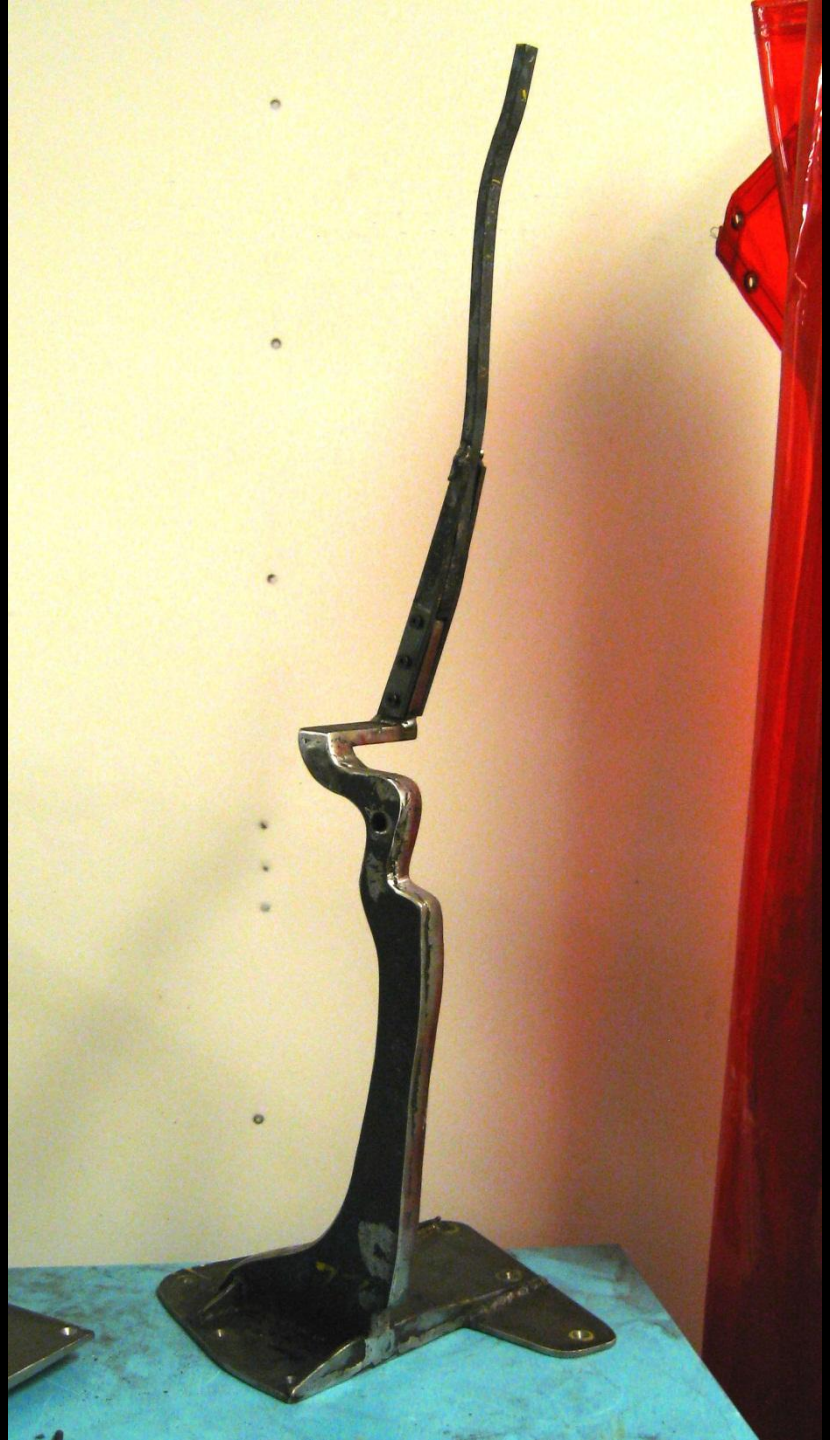


Almost Finished General Mount

Special Base Mount for Standing Archer

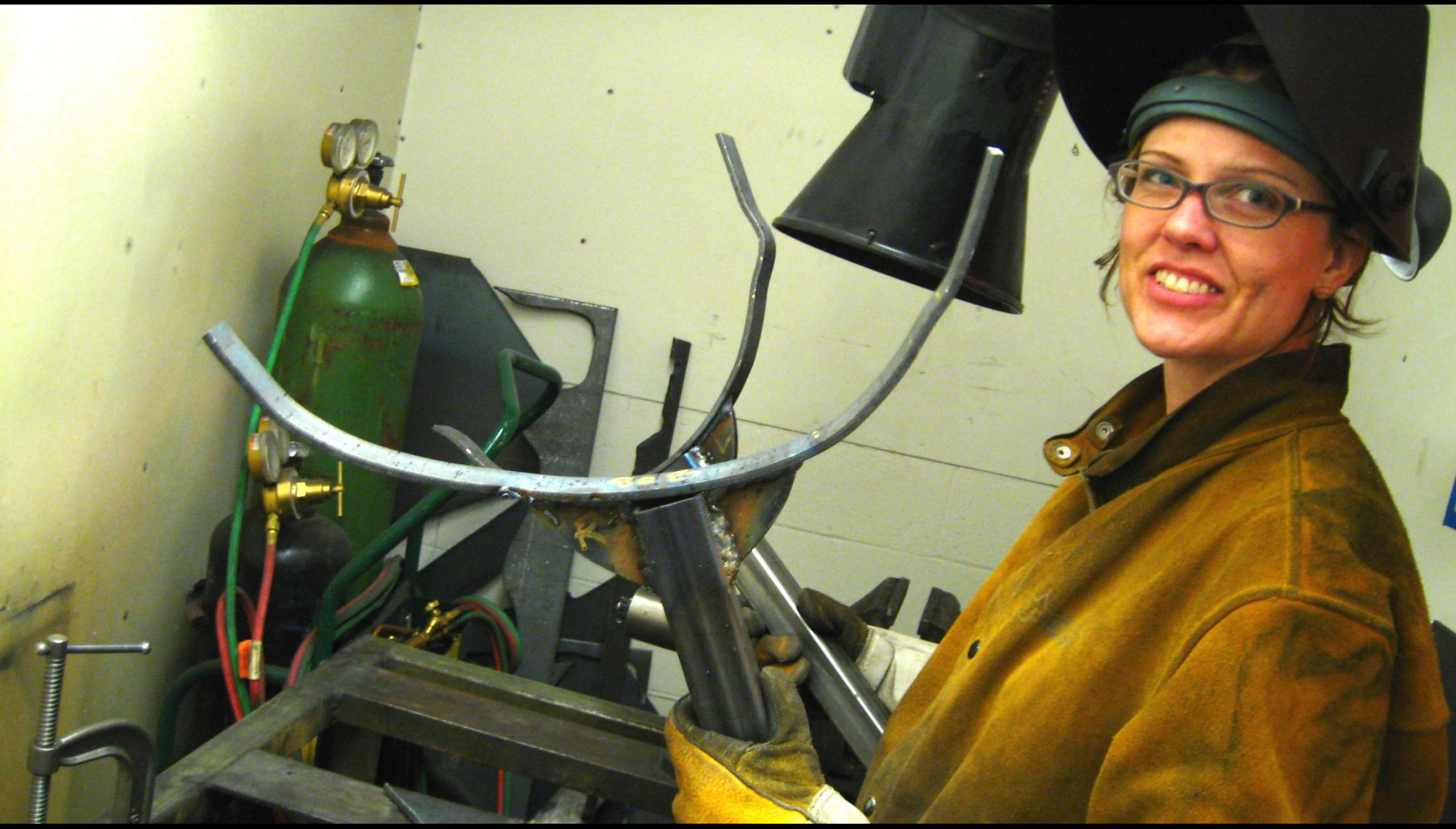


Long Gussets not only added strength to the base plates but helped keep the steel from warping during the intense heat of welding.



Spine Connection for Standing Archer


RIGHT TO KNOW
COMPLIANCE CENTER
MATERIAL SAFETY DATA SHEETS
AAM MOUNT MAKERS SHOP
Panasonic



Gina Borg Proud Fabricator of Horse Mounts

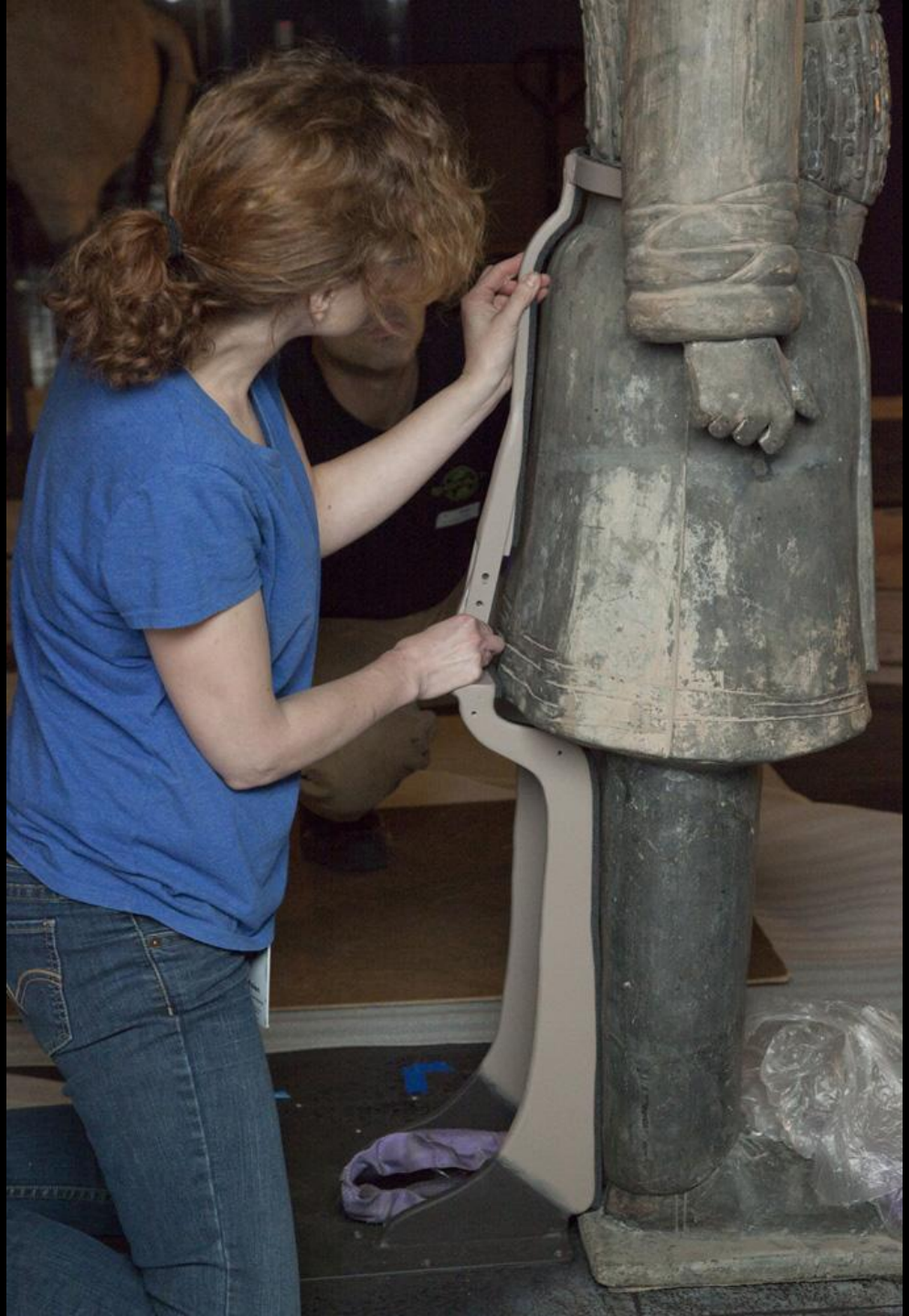
Finished Warrior Mounts Ready for Priming

Lonely Finished Mounts Awaiting
Their respective dancing Partners

Horse Dropping In

Gina Securing Horse

Installing Mount Base



Fine Tuning Waist Mount

Forming and Installing General Arm Mounts

Mounts Final Finishing and Cabling to there Respective Partners

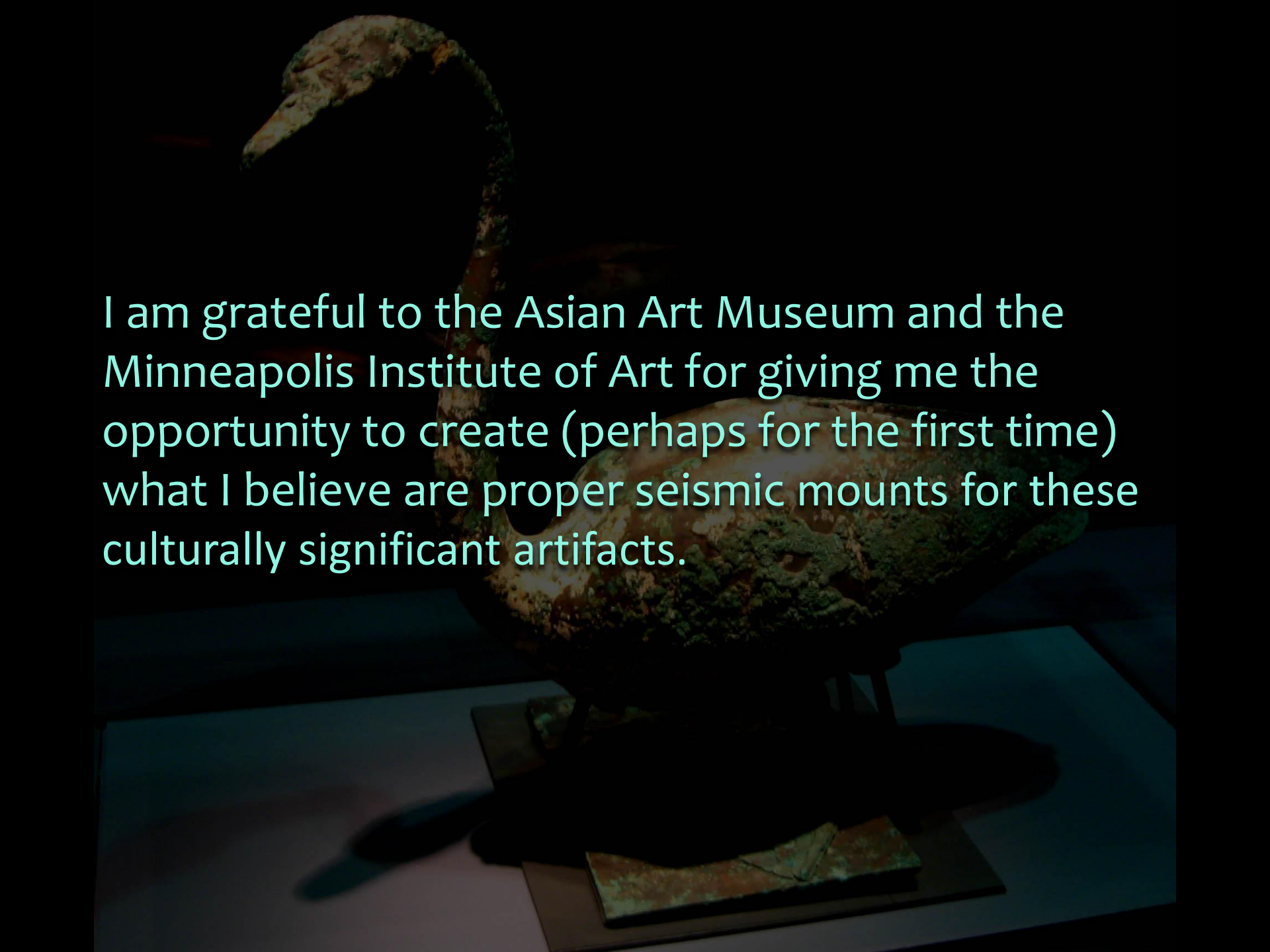

CHARIOT

Mounting the Standing Archer

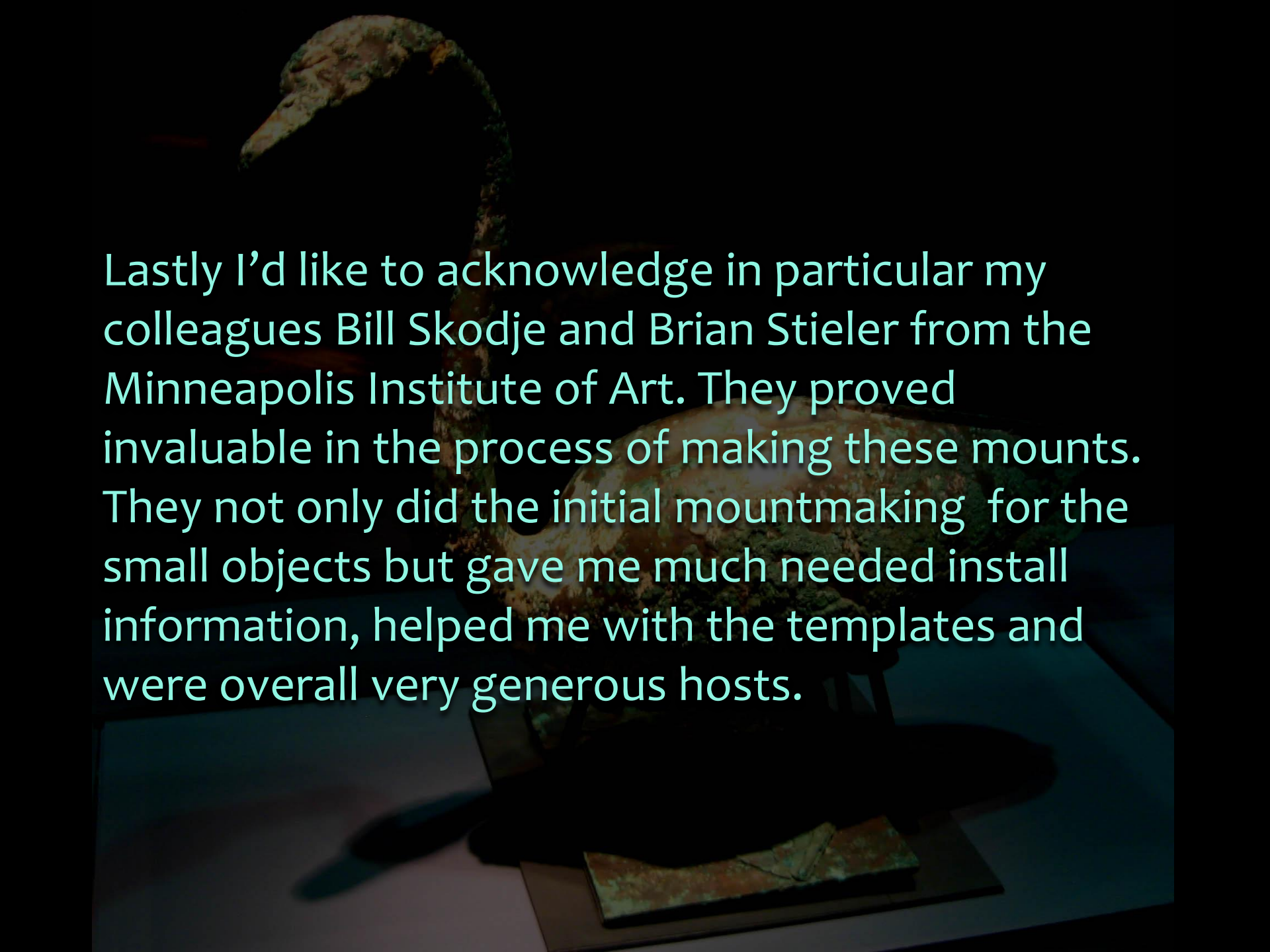

EPILOGUE

The Warriors were not the only objects to be mounted for earthquake purposes in the show. I needed a small army of mountmakers including my colleagues:

Gina Borg, Jason Webster and Adam Nesbit. This knife as an example needed a new mount just to hold it in one piece.



I am grateful to the Asian Art Museum and the Minneapolis Institute of Art for giving me the opportunity to create (perhaps for the first time) what I believe are proper seismic mounts for these culturally significant artifacts.



Lastly I'd like to acknowledge in particular my colleagues Bill Skodje and Brian Stieler from the Minneapolis Institute of Art. They proved invaluable in the process of making these mounts. They not only did the initial mountmaking for the small objects but gave me much needed install information, helped me with the templates and were overall very generous hosts.