NISTIR 7459

Design of the HLPR Chair

Home Lift Position and Rehabilitation Chair

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Introduction

Reference [1] says “today, approximately 10 percent of the world’s population is over 60; by 2050 this proportion will have more than doubled” and “the greatest rate of increase is amongst the oldest old, people aged 85 and older.” She follows by adding that this group is subject to both physical and cognitive impairments more than younger people. These facts have a profound impact on how the world will maintain the elderly independent as long as possible from caregivers. Both physical and cognitive diminishing abilities address the body and the mental process of knowing, including aspects such as awareness, perception, reasoning, intuition and judgment. Assistive technology for the mobility impaired includes the wheelchair, lift aids and other devices, all of which have been around for decades. However, the patient typically or eventually requires assistance to use the device; whether it’s someone to push them in a wheelchair, to lift them from the bed to a chair or to the toilet or for guiding them through cluttered areas. With fewer caregivers and more elderly, there is a need for improving these devices to provide them independent assistance.

Wheelchairs

There has been an increasing need for wheelchairs over time. L.H.V. van der Woude [2] states that mobility is fundamental to health, social integration and individual well-being of the humans. Henceforth, mobility must be viewed as being essential to the outcome of the rehabilitation process of wheelchair dependent persons and to their successful (re-)integration into society and to a productive and active life. Thrun [3] said that, if possible, rehabilitation to relieve the dependence on the wheelchair is ideal for this type of patient to live a longer, healthier life. Van der Woude continues stating that many lower limb disabled subjects depend upon a wheelchair for their mobility. Estimated numbers for Europe and USA are respectively 2.5 million and 1.25 million. The quality of the wheelchair, the individual work capacity, the functionality of the wheelchair/user combination, and the effectiveness of the rehabilitation program do indeed determine the freedom of mobility.

Patient Lift

Just as important as wheelchairs are the lift devices and people who lift patients into wheelchairs and other seats, beds, automobiles, etc. The need for patient lift devices will also increase as generations get older. When considering if there is a need for patient lift devices, several references state the positive, for example:

- “The question is, what does it cost not to buy this equipment? A back injury can cost as much as $50,000, and that’s not even including all the indirect costs. If a nursing home can buy these lifting devices for $1,000 to $2,000, and eliminate a back injury that costs tens of thousands of dollars, that’s a good deal,” [4]
- 1 in every 3 nurses become injured from the physical exertion put forth while moving non-ambulatory patients; costing their employers $35,000 per injured nurse. [5]
- 1 in 2 non-ambulatory patients fall to the floor and become injured when being transferred from a bed to a wheelchair. - [6]
- "Nursing and personal care facilities are a growing industry where hazards are known

and effective controls are available," said OSHA Administrator John Henshaw. "The industry also ranks among the highest in terms of injuries and illnesses, with rates about 2 1⁄2 times that of all other general industries..." [7]

- “Already today there are over 400,000 unfilled nursing positions causing healthcare providers across the country to close wings or risk negative outcomes. Over the coming years, the declining ratio of working age adults to elderly will further exacerbate the shortage. In 1950 there were 8 adults available to support each elder 65+, today the ratio is 5:1 and by 2020 the ratio will drop to 3 working age adults per elder person.” [8]

In 2005, NIST ISD began the Healthcare Mobility Project to target this staggering healthcare issue of patient lift and mobility. ISD researchers looked at currently available technology through a survey of patient lift and mobility devices [9]. That report showed that there is need for technology that includes mobility devices that can lift and maneuver patients to other seats and technology that can provide for rehabilitation to help the patient become independent of the wheelchair.

An additional area investigated in the survey was intelligent wheelchairs. NIST has been studying intelligent mobility for the military, transportation, and the manufacturing industry for nearly 30 years through the Intelligent Control of Mobility Systems (ICMS) Program. [10] Toward a standard control system architecture and advanced 3D imaging technologies, as being researched within the ICMS Program, and applying them to intelligent wheelchairs, NIST has begun outfitting the HLPR Chair with computer controls. Although throughout the world there are or have been many research efforts in intelligent wheelchairs, including: [11, 12, 13, 14] and many others, the authors could find no sources applying standard control methods nor application of the most advanced 3D imagers prototyped today to intelligent wheelchairs. Therefore, NIST began developing the HLPR Chair [15] to investigate these specific areas of mobility, lift and rehabilitation, as well as advanced autonomous control.

This paper includes mechanical and electrical designs for the HLPR Chair in its prototype stage with designs dating back to December 2005. An initial prototype HLPR Chair concept, called RoboChair, was completed in July 2004.

Introduction References

[1] Pollack, Martha, “Intelligent Technology for Adaptive Aging” Presentation, AAAI-04 American Association for Artificial Intelligence Conference Keynote Address, 2004

[2] L.H.V. van der Woude , M.T.E. Hopman and C.H. van Kemenade, “Biomedical Aspects of Manual Wheelchair Propulsion: The State of the Art II,” Volume 5, Assistive Technology Research Series, 1999, 392 pp., hardcover

[3] Thrun, Sebastian, Visit to Stanford University to discuss healthcare mobility devices, August 2006.

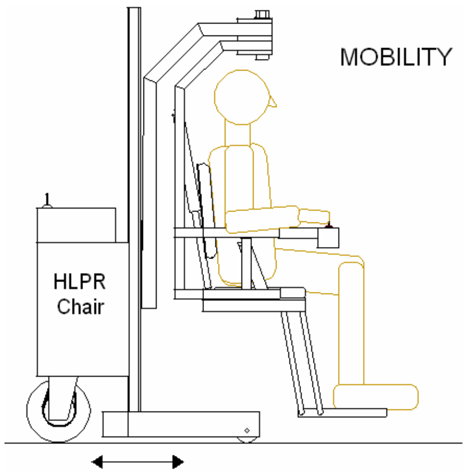
[4] Marras, William, “Lifting Patients Poses High Risk for Back Injuries,” Ohio State University, http://researchnews.osu.edu/archive/resthome.htm. 1999.

[5] Blevins, Healthcare Statistics: Blevins Medical, Inc., http://www.patientlift.net/282164.html. 2006

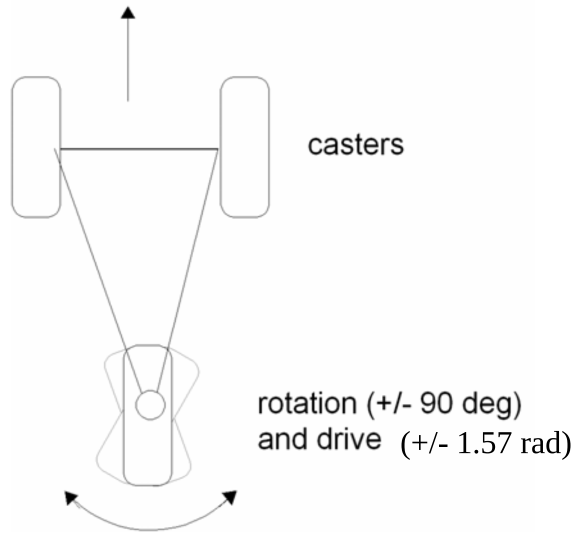
[6]U.S. Bureau of Labor Statistics, from Blevins website: http://www.patientlift.net/282164.html, 1994.

[7] John Henshaw, http://www.osha.gov/SLTC/ nursinghome/solutions.html, Occupational Safety and Health Administration, 2005
[8] Wasatch Digital iQ, "InTouch Health's Remote Presence Robot Used by Healthcare Experts," http://www.wasatchdigitaliq.com/parser.php?nav=article&article_id=43, Santa Barbara, CA & Salt Lake City --(Business Wire)--June 16, 2003.
[9] Bostelman, Roger; Albus, James, "Survey of Patient Mobility and Lift Technologies Toward Advancements and Standards" NISTIR #7384, 2006.
[10] NIST Intelligent Control of Mobility Systems Program website: http://www.isd.mel.nist.gov/ research_areas/mobility/index.htm
[11] Kuno, Y., Murashima, T., Shimada, N., Shirai, Y., "Intelligent Wheelchair Remotely Controlled by Interactive Gestures," International Conference on Pattern Recognition, vol. 04, no. 4, p. 4672, 2000.
[12] Patel, S., Jung, S-H., Ostrowski, J., Rao, R., Taylor, C., "Sensor based door navigation for a nonholonomic vehicle," GRASP Laboratory, University of Pennsylvania, Proceedings of the 2002 IEEE International Conference on Robotics and Automation, Washington, DC, May 2002.
[13] Song W.-K.; Lee H.; Bien Z., "KAIST - KARES: Intelligent wheelchair-mounted robotic arm system using vision and force sensor," Robotics and Autonomous Systems, vol. 28, no. 1, pp. 83-94(12), 31, Publisher: Elsevier Science, July 1999.
[14] Yanco, H., Hazel, A., Peacock, A., Smith, S. and Wintermute, H. "Initial Report on Wheelesley: A Robotic Wheelchair System," Department of Computer Science, Wellesley College, 1995
[15] Bostelman, R., Albus, J., "HLPR Chair – A Service Robot for the Healthcare Industry," 3rd International Workshop on Advances in Service Robotics, Vienna, Austria, July 7, 2006

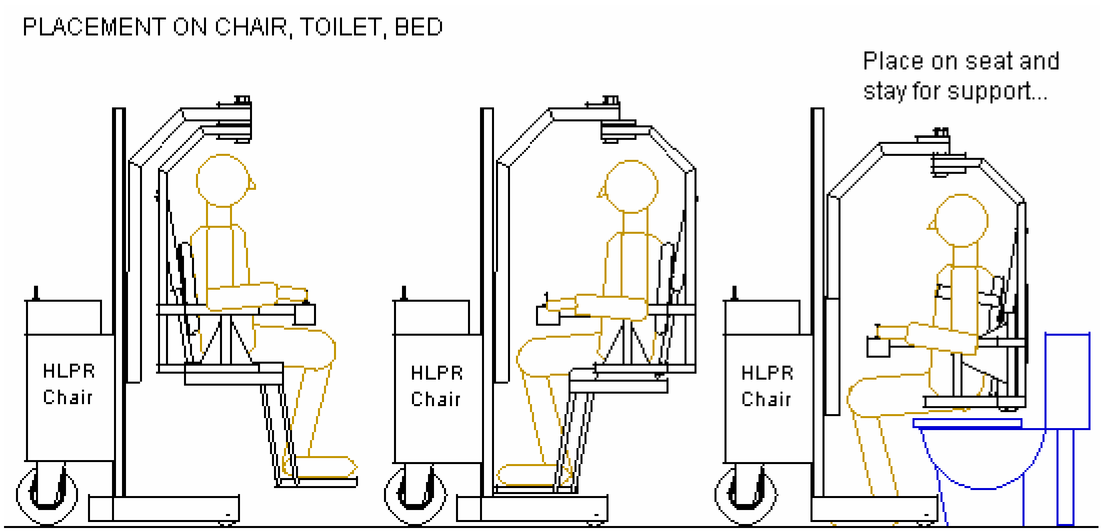
Concept



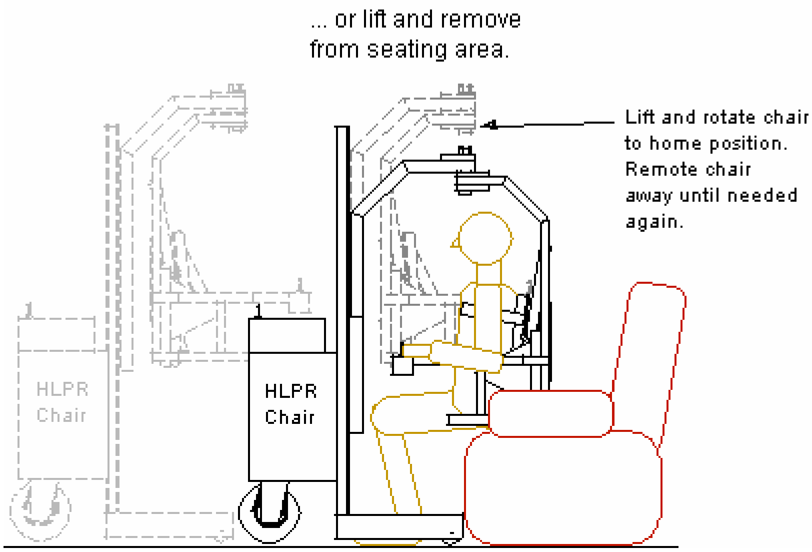
HLPR Chair is shown in the powered chair configuration with controls that the patient can use to drive the chair or a nurse/caregiver can use the controls from behind the chair to mobilize the patient.



Top view of the HLPR Chair rear steering and drive wheel and fixed front casters configuration.

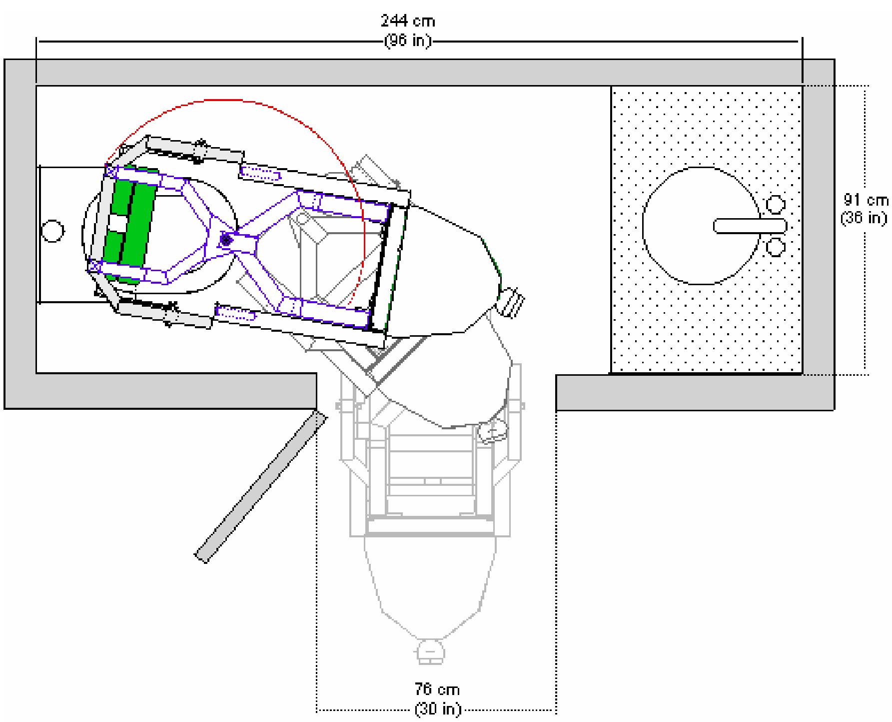


(a)

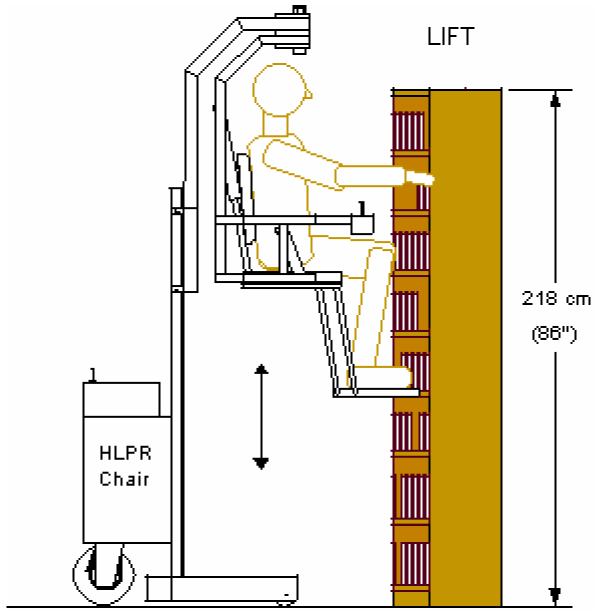


(b)

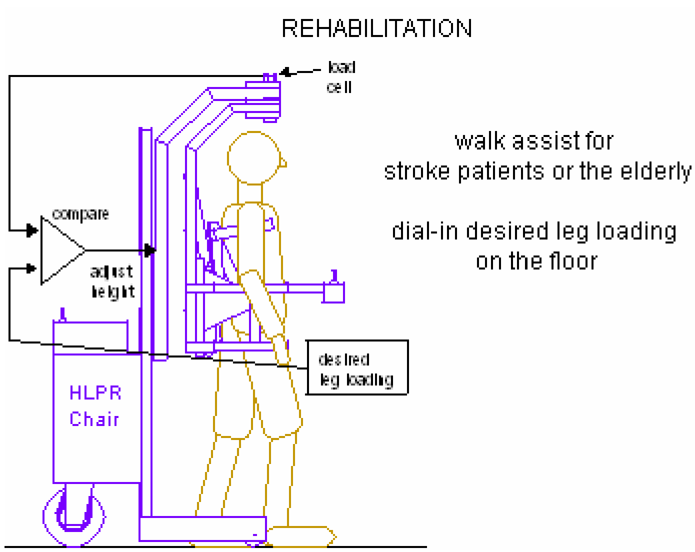
(a) HLPR Chair can be used to carry a patient to a chair or toilet, rotate the patient ready to place them on the seat, remove the footrest, raise the torso lifts and patient above the HLPR Chair seat, remove the HLPR Chair seat from beneath the patient, and place the patient on the target chair or toilet. (b) HLPR Chair can be used for patient placement on a comfortable chair. Additionally, controls can be designed to allow the patient to command using voice or remote interface to control the HLPR Chair go away until or come when needed.



Top view showing HLPR Chair accessing a toilet in a bathroom. The red arc shows the maximum radius of seat frame rotation needed.



HLPR Chair allows lift, currently up to 0.9 m (36 in) above mobility configuration height.

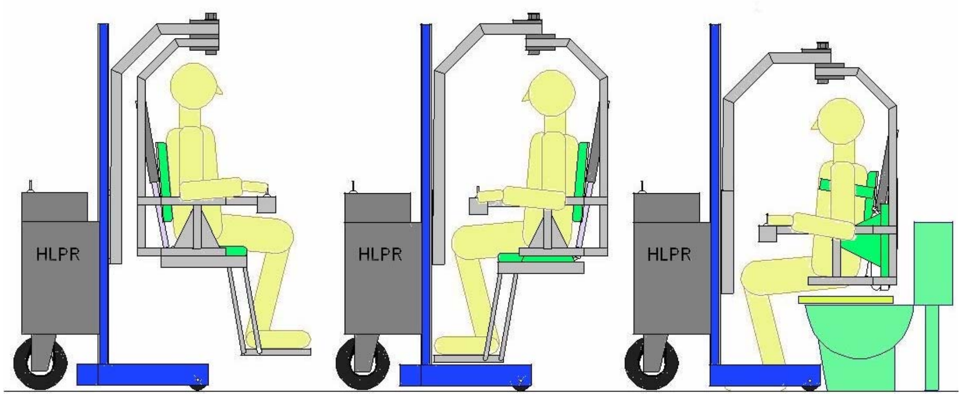


HLPR Chair can be used for patient rehabilitation and incorporate future legs load control.

Prototype

Photograph 1 of the HLPR Chair prototype.

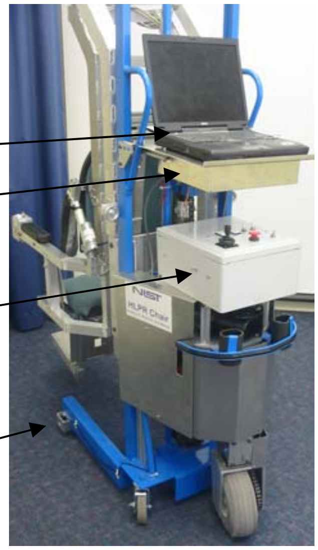
Photograph 2 (left) of the HLPR Chair in the mobility configuration showing the side view and Photograph 3 (right) front view relative to a typical doorway.



Graphic showing the concept of placing a patient onto a toilet or chair with the HLPR Chair. The patient drives to the target seat (left), manually rotates near or over the seat (middle) while the torso lifts support the patient and the seat retracts, and then is lowered onto the seat - toilet, chair or bed (right)

Photographs 4, 5, and 6 (lt. to rt.) of the HLPR Chair prototype in the same configurations as in the graphic above placing a patient on a toilet.

Photograph 7 of the HLPR Chair prototype shown in the patient lift position.



Photograph 8 of the HLPR Chair with recently added front wheel encoders, development computer and interface electronics.

Photograph 9 of the HLPR Chair prototype in the rehabilitation/walking configuration. Summer Interns (Alex Page and Robert Vlacich) demonstrate the patient and nurse configuration as part of their official duties.

Specifications

Size:	
Mobility Configuration	145 cm long x 58 cm wide x 178 cm high
	(57” long x 23” wide x 70” high)
	with 57 cm (22 ½”) seat ht. above floor
Full Lifted Configuration	145 cm long x 58 cm wide x 241 cm high
	(57” long x 23” wide x 95” high)
	with 125 cm (49”) seat ht. above floor – currently
	can be adjusted to lift 91 cm (36”)
Weight (unloaded)	136 kg (300 Lbs.)
Payload:	136 kg (300 Lbs.) (designed)
	91 kg (200 Lbs.) (tested to date)
Tilt	0.06 rad (10 deg)
Max. Speed	0.7 mps (28 ips)
Turning Radius	86 cm (34”) centered about the rider
Chair Rotate Angle	0.5 rad (90 deg) CCW to 1 rad (180 deg) CW
Wheels:	
Rear Drive/Steer	10” diameter pneumatic
Front Caster	5” diameter solid
Ground Clearance	4.4 cm (1 ¾”)
Battery	2-12Vdc dry cells (series 24V)
Per-Charge Range	unknown to date
Battery weight	11.6 kg (26 Lbs) each
Drive Train	1 motor chain drive, 1 gearmotor direct steer
Battery Chargers	two (one per battery), off-board

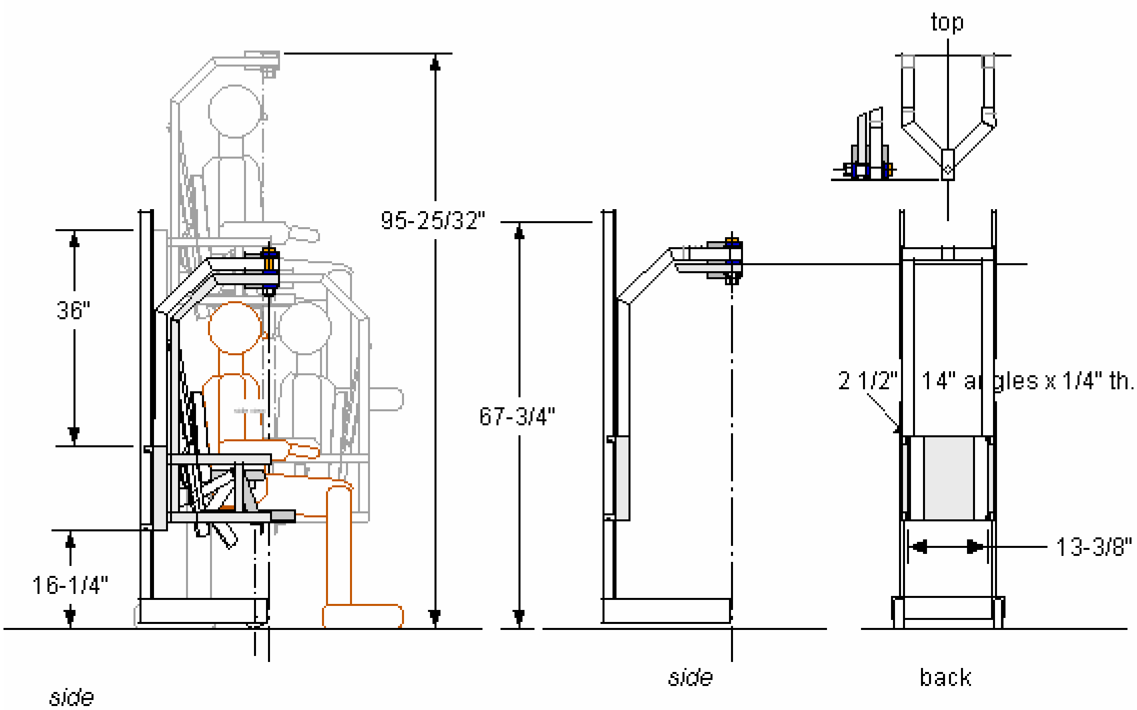
Mechanical Design

Manual Fork Lift Base Frame[1]

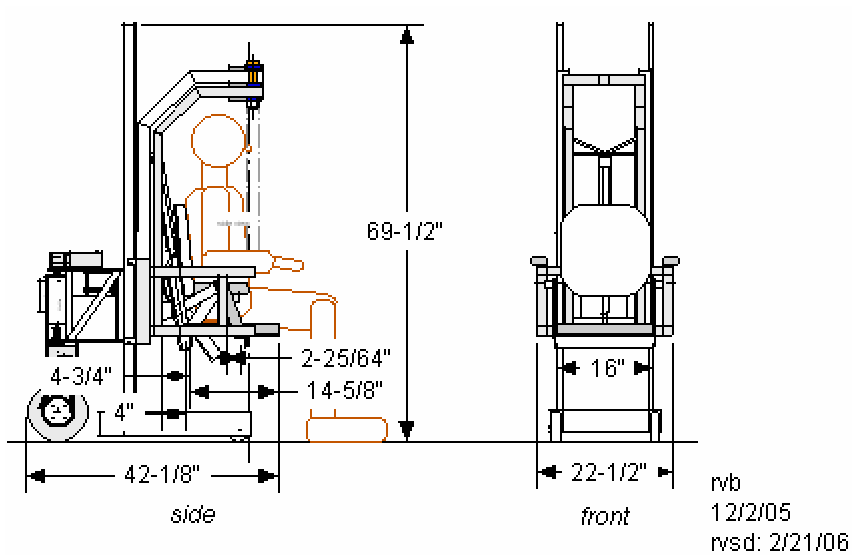
Hydraulic Lift
    Foot operated hydraulic pump makes raising the load a simple task.
    Foot pedal release results in controlled lowering to reduce the risk of accidents.
    Wheels are on swivel casters and lock into position for load lifting and lowering.
    Two forks lower to 10.8 cm (4.3 in) above the floor and raise loads up to 137 cm (54 in) to get your machinery or heavy objects at an accessible level.
    227 kg (500 Lbs) capacity.

For the HLPR Chair Design, the hydraulic piston was replaced with an electric ball screw actuator with 454 kg (1000 Lbs) lift capacity and 0.45 m (18 in) stroke. The fork lift chain design allows a 2:1 lift height for 0.9 m (36 in) fork (chair) lift with half the payload or 227 kg (500 Lbs).

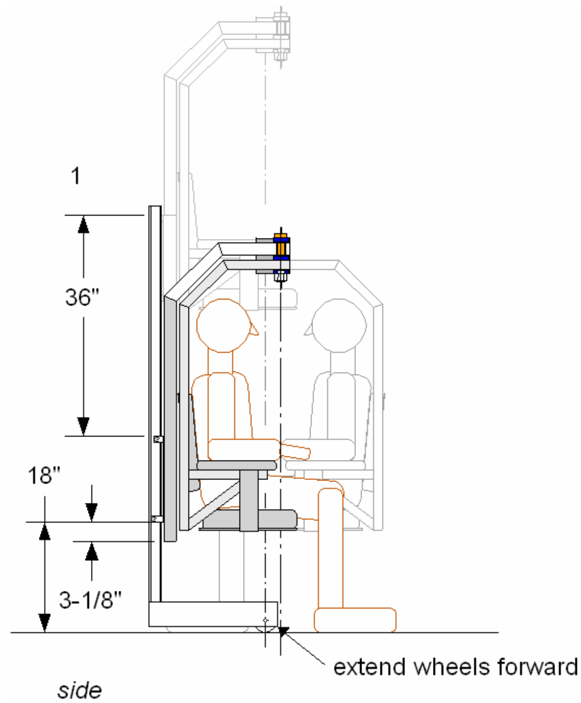
[1] NIST does not endorse products or organizations.



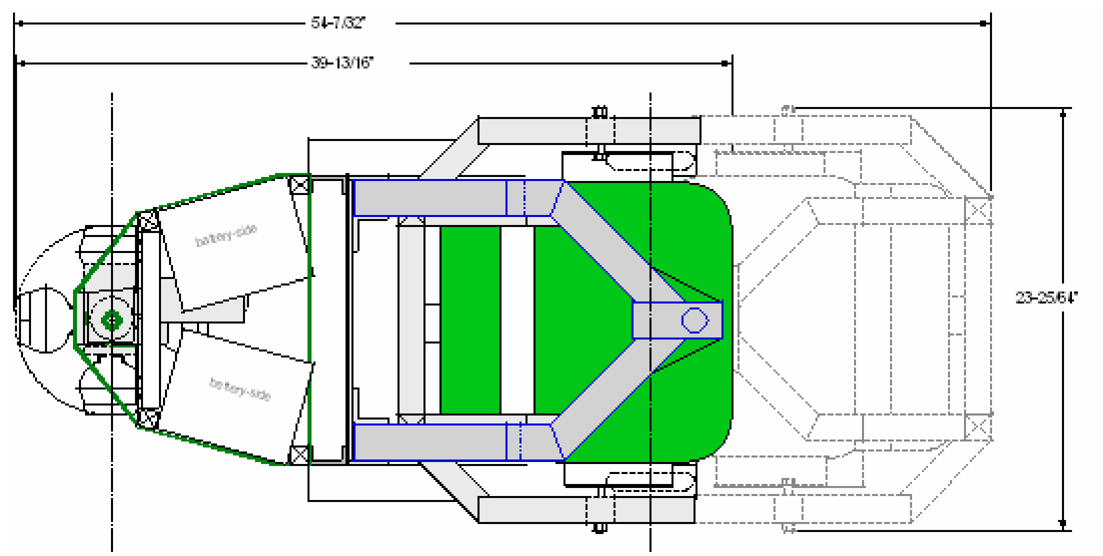
Left (side) view shows 0.9 m (36 in) base and seat frame travel and maximum system height. Center side view shows 37.4 cm (95 25/32 in). Center (side) and right (back) views show only the base frame with the forklift frame components with the seat frame removed and the rotation (top) joint view.



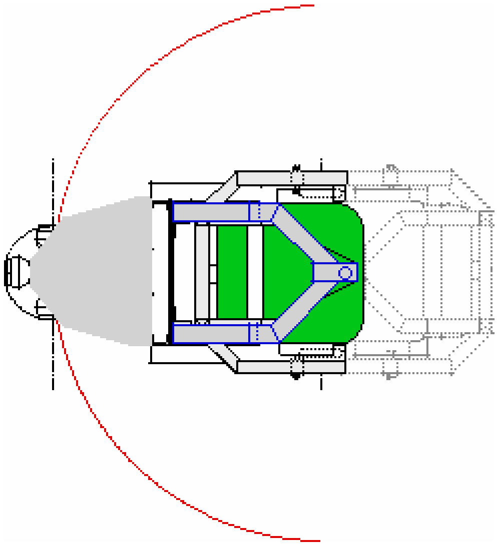
Side and front views of the HLPR Chair with minimal dimensions for length, height, and width while in the mobility configuration.



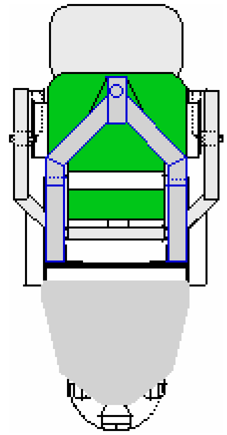
HLPR Chair side view without the rear drive system and suggested front wheel extension to allow the seat rotation point to be within the wheelbase. This modification was not added to the prototype and is not necessary with appropriate counterweight (e.g., drive and battery system) added to the rear.



(a)



(b)

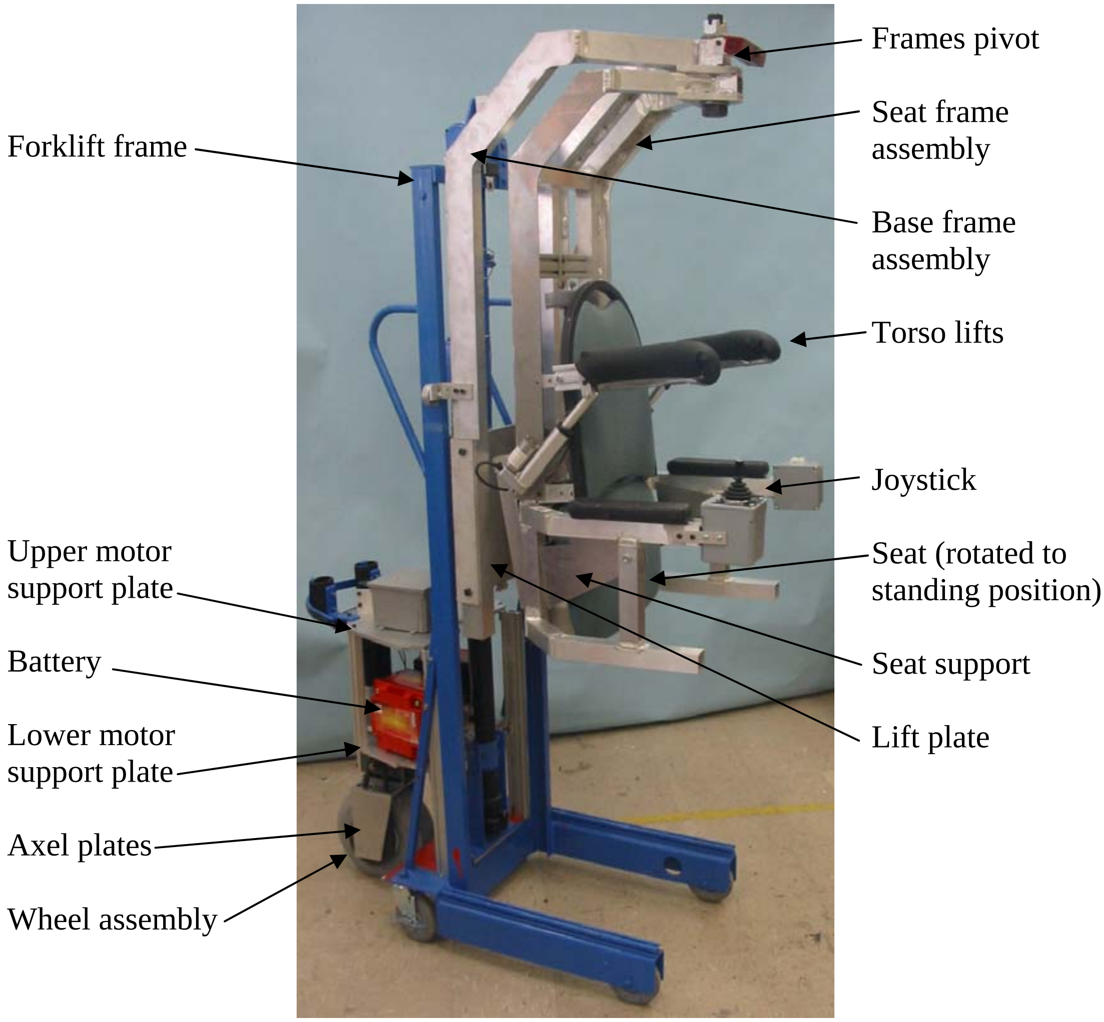


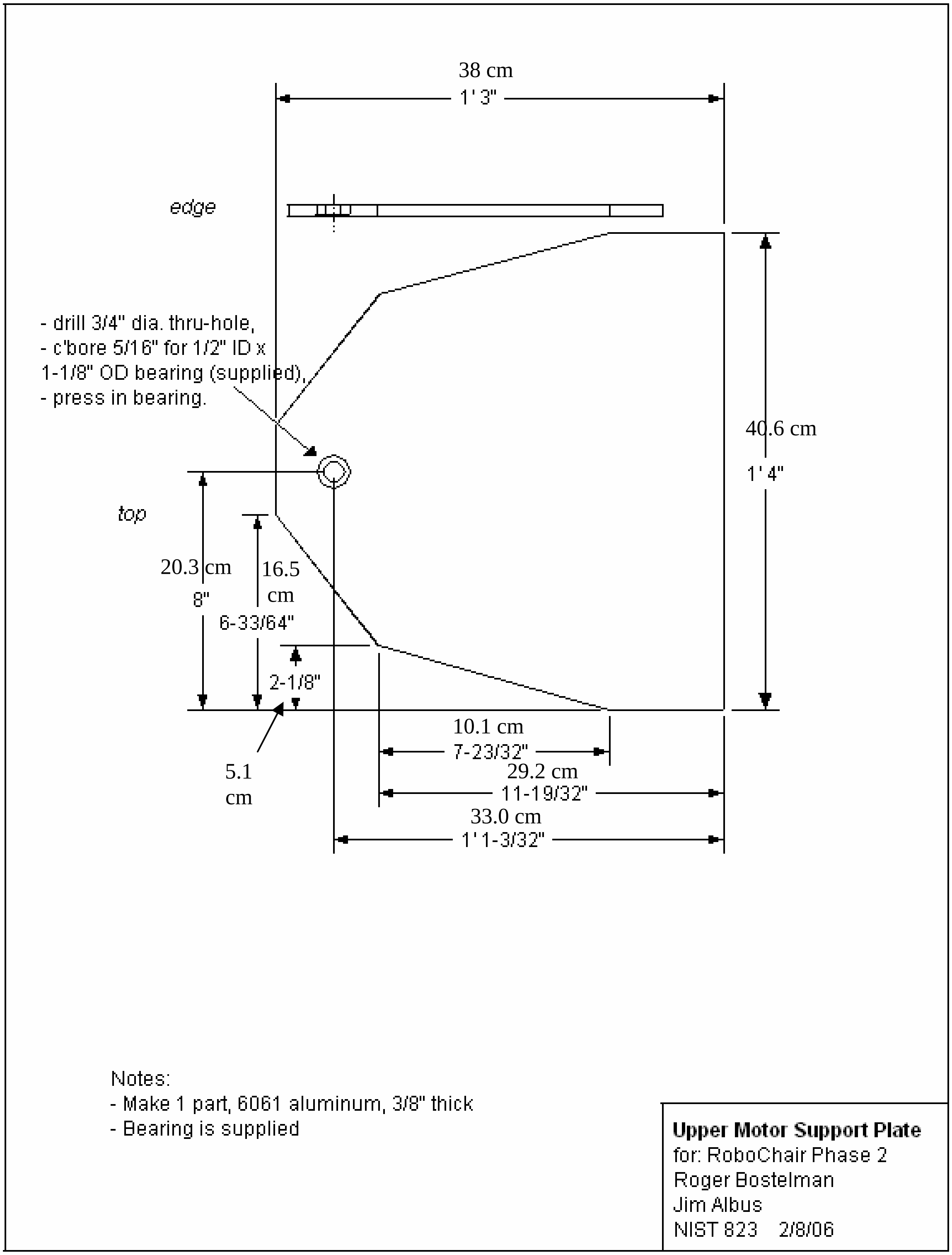
(c)

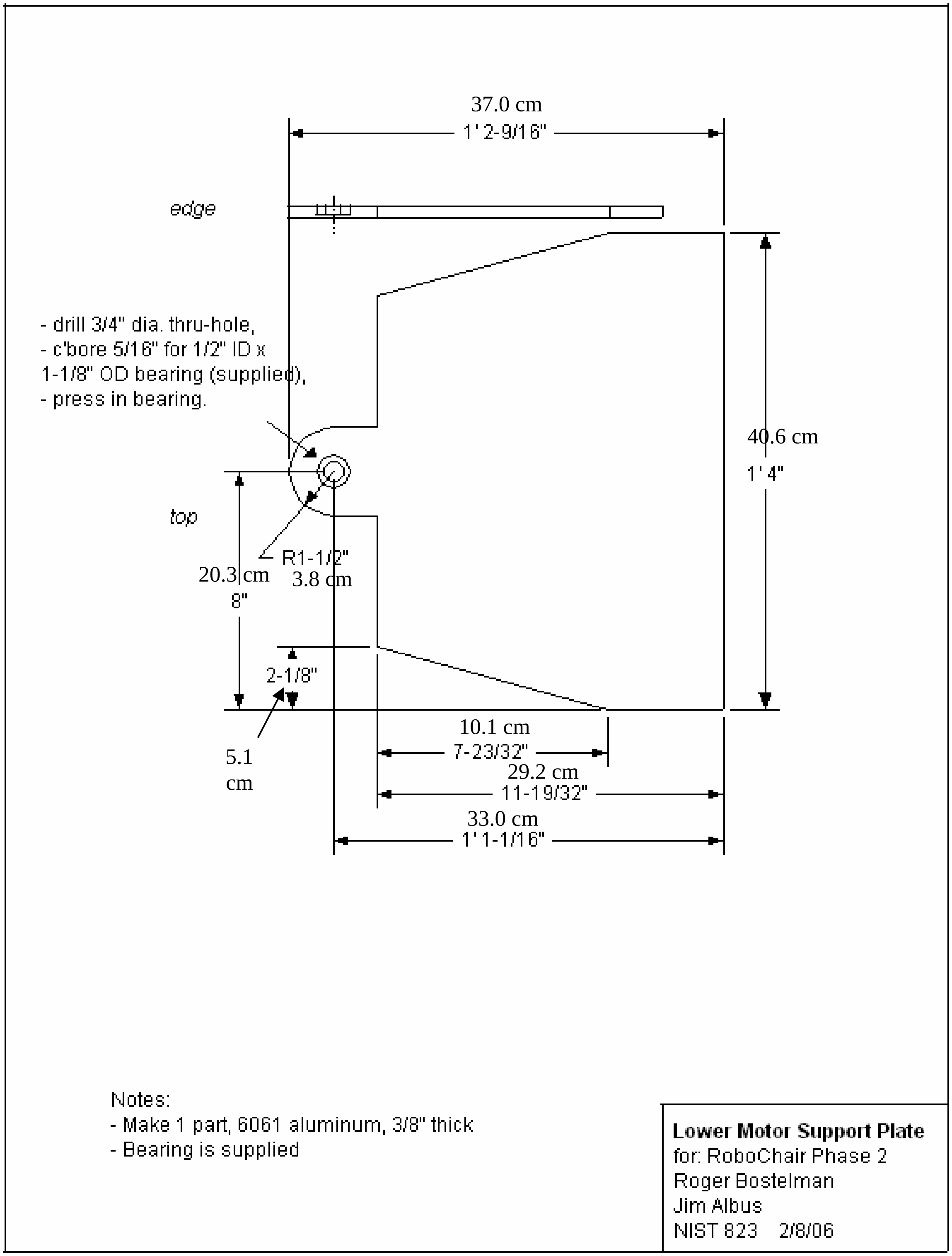
Top views of the HLPR Chair showing (a) Maximum length and width, (b) minimum HLPR Chair rotation about the front casters axle center 76 cm (30 in) and (c) top view of the HLPR Chair.

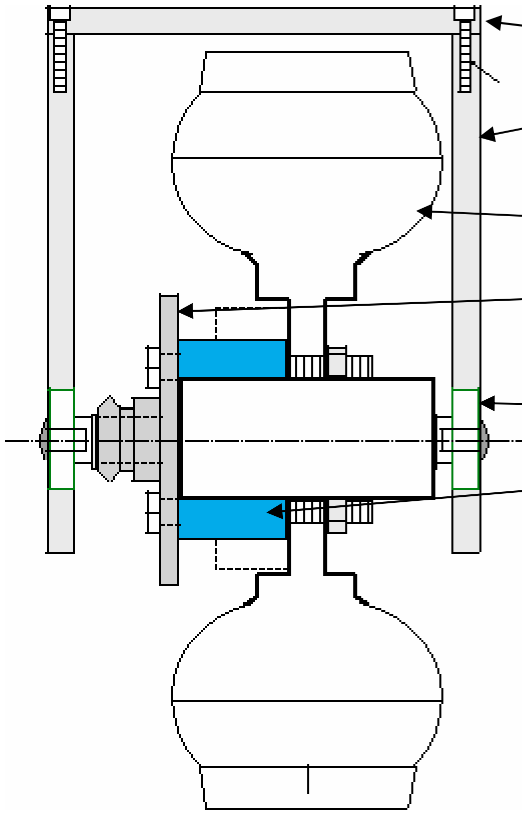
HLPR Chair Component Labels

These labels refer to drawings that follow.

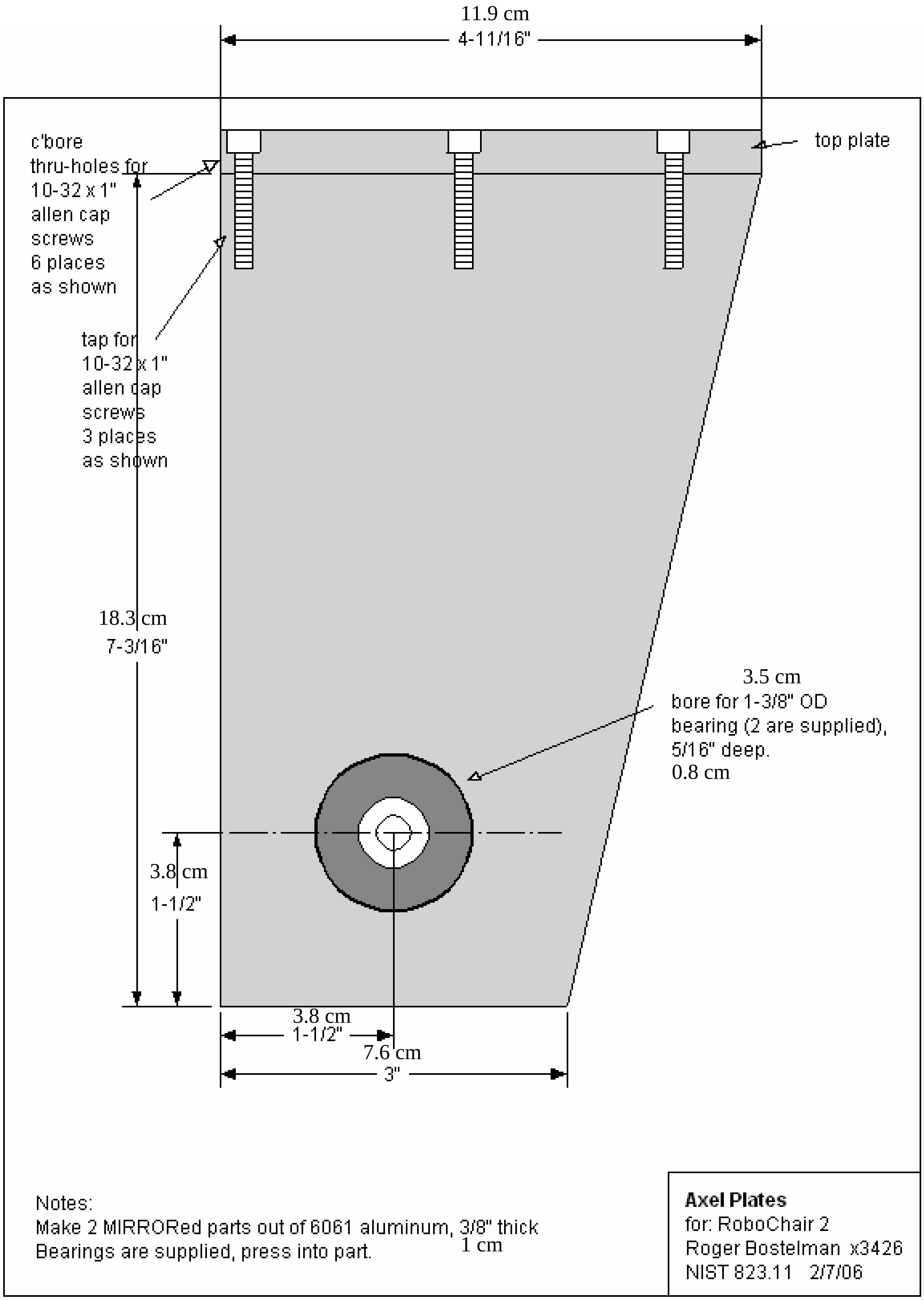


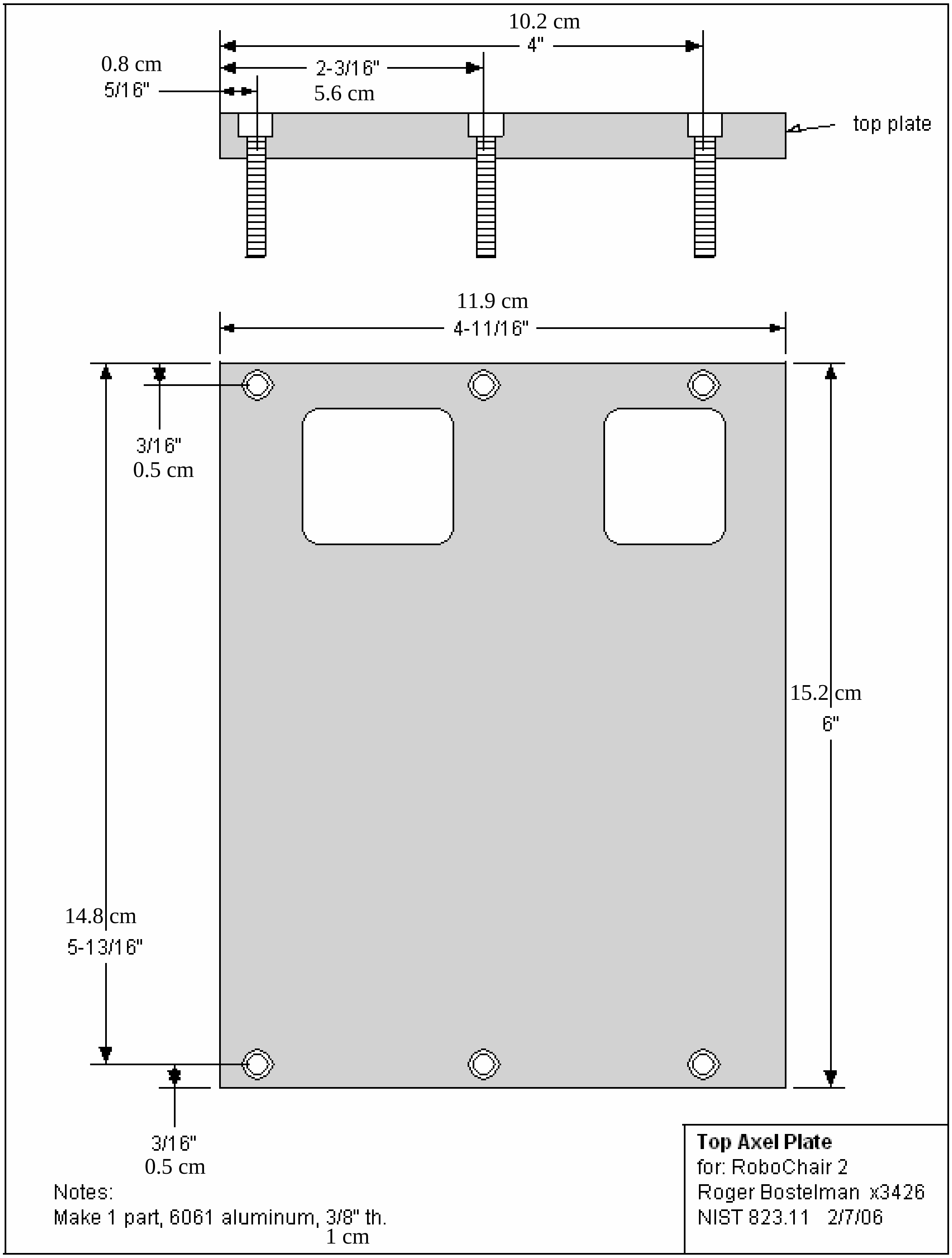

38 cm
1' 3"
edge
- drill 3/4" dia. thru-hole,
- c'bore 5/16" for 1/2" ID x
1-1/8" OD bearing (supplied),
- press in bearing.
40.6 cm
1' 4"
top
20.3 cm
8"
16.5
cm
6-33/64"
2-1/8"
5.1
cm
10.1 cm
7-23/32"
29.2 cm
11-19/32"
33.0 cm
1' 1-3/32"
Notes:
- Make 1 part, 6061 aluminum, 3/8" thick
- Bearing is supplied
Upper Motor Support Plate
for: RoboChair Phase 2
Roger Bostelman
Jim Albus
NIST 823 2/8/06

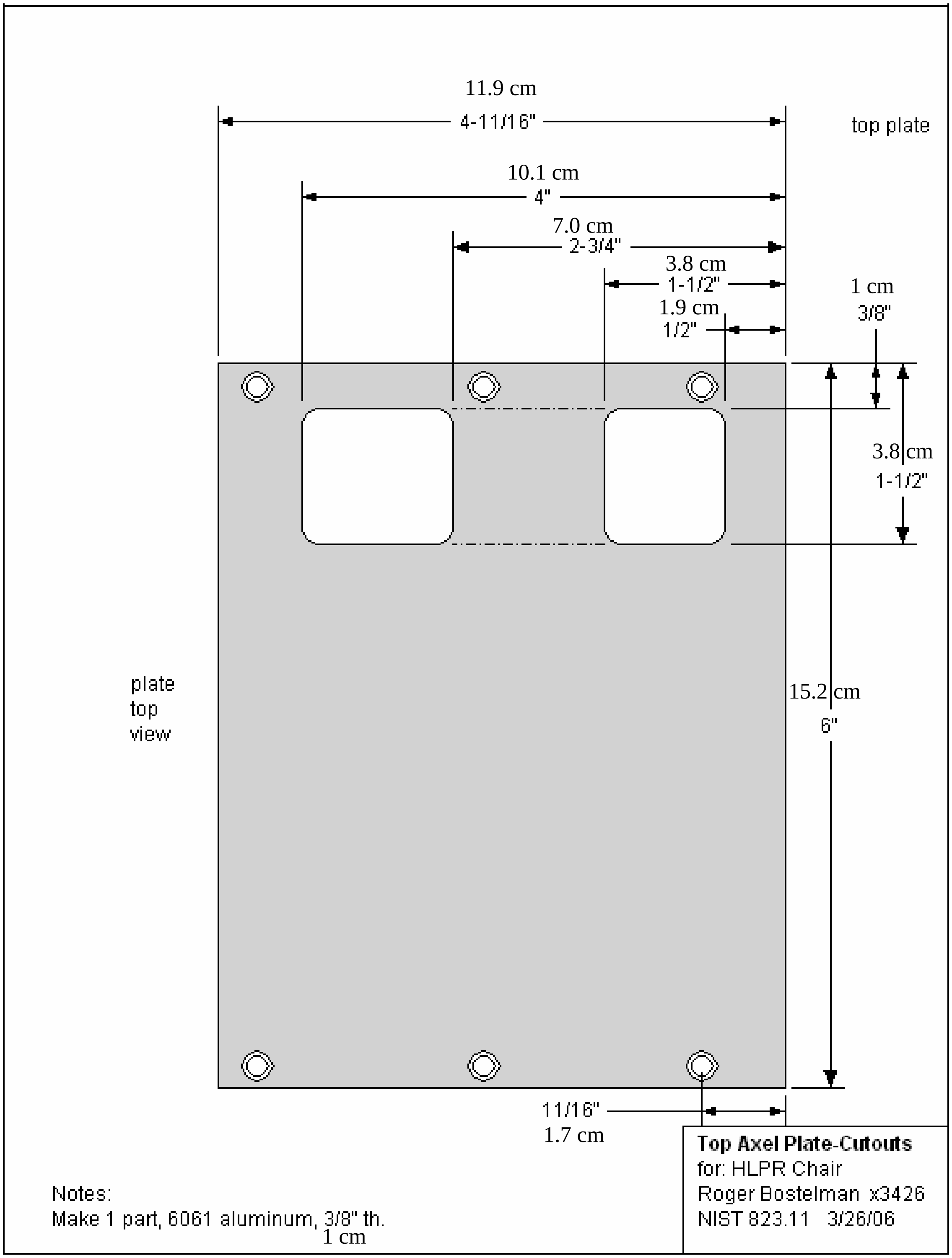

37.0 cm
1' 2-9/16"
edge
- drill 3/4" dia. thru-hole,
- c'bore 5/16" for 1/2" ID x
1-1/8" OD bearing (supplied),
- press in bearing.
40.6 cm
1' 4"
top
R1-1/2"
3.8 cm
20.3 cm
8"
2-1/8"
5.1
cm
10.1 cm
7-23/32"
29.2 cm
11-19/32"
33.0 cm
1' 1-1/16"
Notes:
- Make 1 part, 6061 aluminum, 3/8" thick
- Bearing is supplied
Lower Motor Support Plate
for: RoboChair Phase 2
Roger Bostelman
Jim Albus
NIST 823 2/8/06

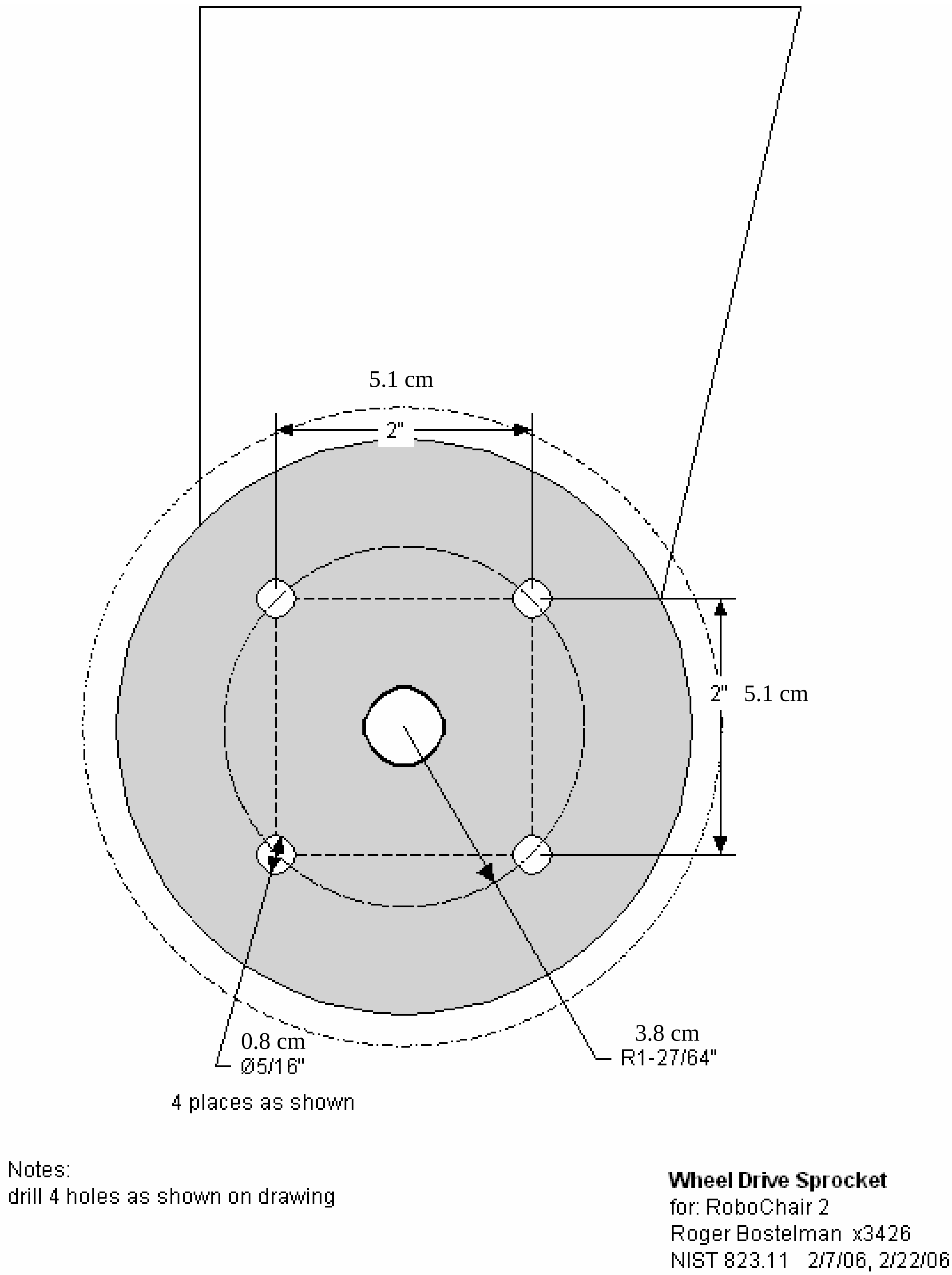


Front view of wheel assembly
(component drawings for this assembly follow)

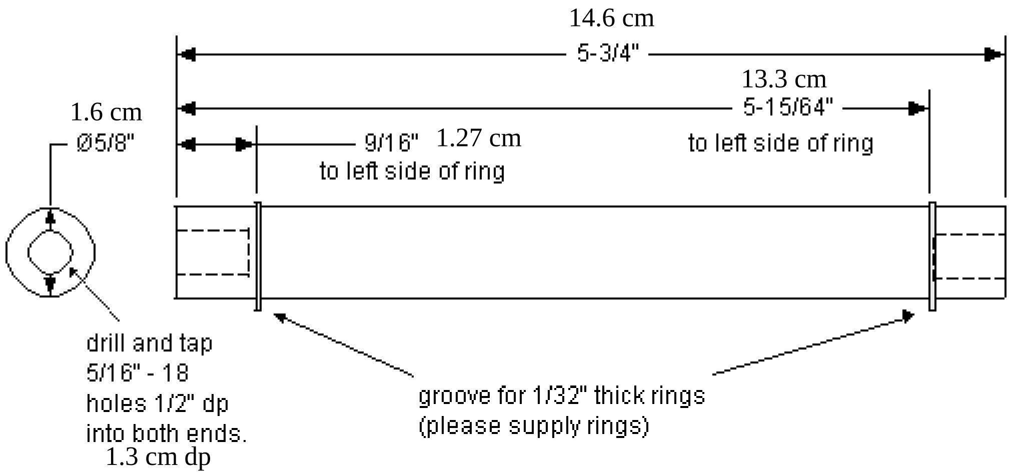

11.9 cm
4-11/16"
c'bore
thru-holes for
10-32 x 1"
allen cap
screws
6 places
as shown
top plate
tap for
10-32 x 1"
allen cap
screws
3 places
as shown
18.3 cm
7-3/16"
3.5 cm
bore for 1-3/8" OD
bearing (2 are supplied),
5/16" deep.
0.8 cm
3.8 cm
1-1/2"
3.8 cm
1-1/2"
7.6 cm
3"
Notes:
Make 2 MIRRORed parts out of 6061 aluminum, 3/8" thick
1 cm
Bearings are supplied, press into part.
Axel Plates
for: RoboChair 2
Roger Bostelman x3426
NIST 823.11 2/7/06


10.2 cm
4"
0.8 cm
5/16"
2-3/16"
5.6 cm
top plate
11.9 cm
4-11/16"
3/16"
0.5 cm
15.2 cm
6"
14.8 cm
5-13/16"
3/16"
0.5 cm
Notes:
Make 1 part, 6061 aluminum, 3/8" th.
1 cm
Top Axel Plate
for: RoboChair 2
Roger Bostelman x3426
NIST 823.11 2/7/06


11.9 cm
4-11/16"
top plate
10.1 cm
4"
7.0 cm
2-3/4"
3.8 cm
1-1/2"
1.9 cm
1/2"
1 cm
3/8"
3.8 cm
1-1/2"
plate
top
view
15.2 cm
6"
11/16"
1.7 cm
Top Axel Plate-Cutouts
for: HLPR Chair
Roger Bostelman x3426
NIST 823.11 3/26/06
Notes:
Make 1 part, 6061 aluminum, 3/8" th.
1 cm

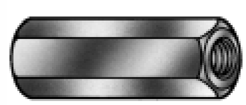

5.1 cm
2"
2"
5.1 cm
0.8 cm
Ø5/16"
4 places as shown
3.8 cm
R1-27/64"
Notes:
drill 4 holes as shown on drawing
Wheel Drive Sprocket
for: RoboChair 2
Roger Bostelman x3426
NIST 823.11 2/7/06, 2/22/06

1)



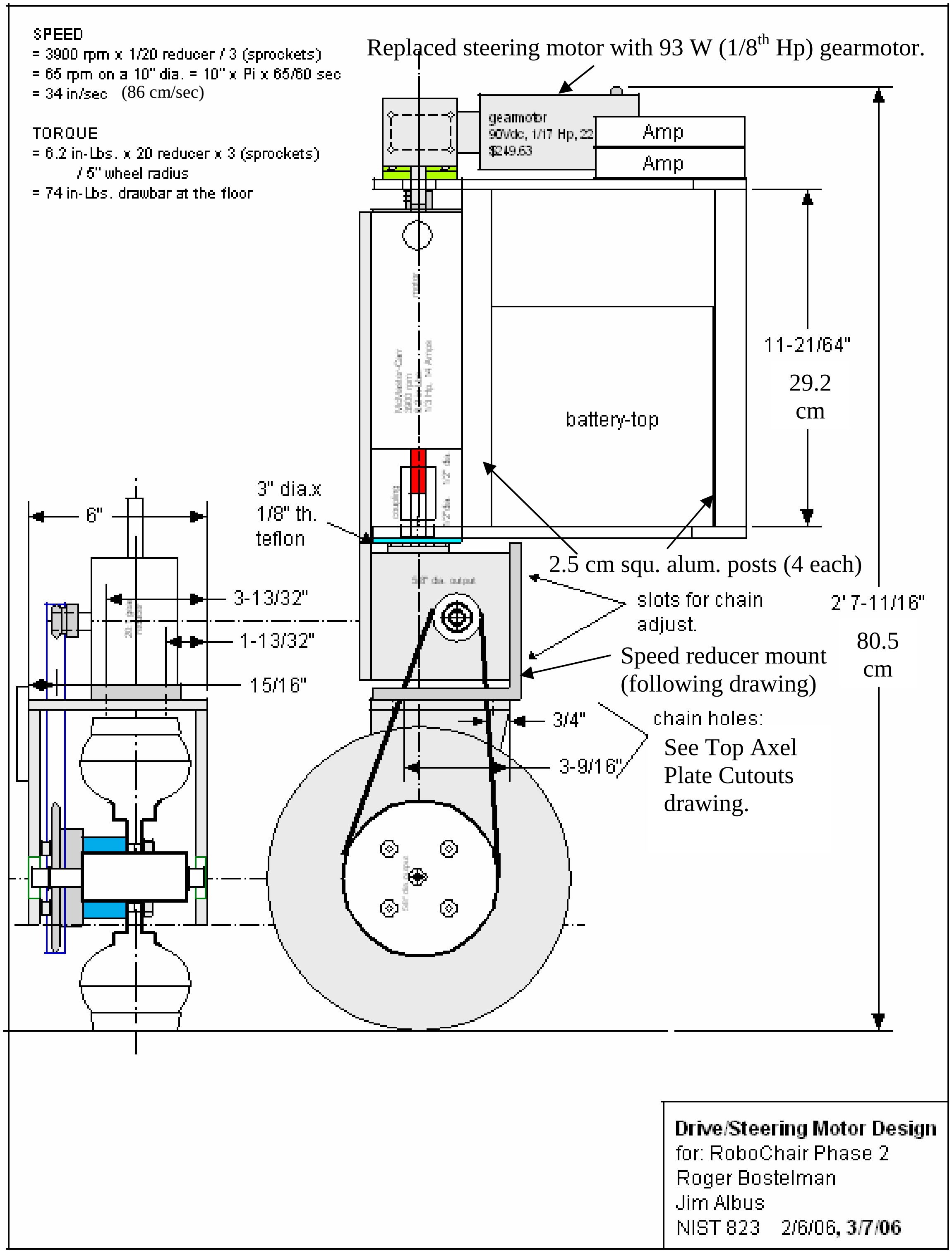
NOTES:
Steel rod, 5/8" dia. 1.6 cm dia.
make 1

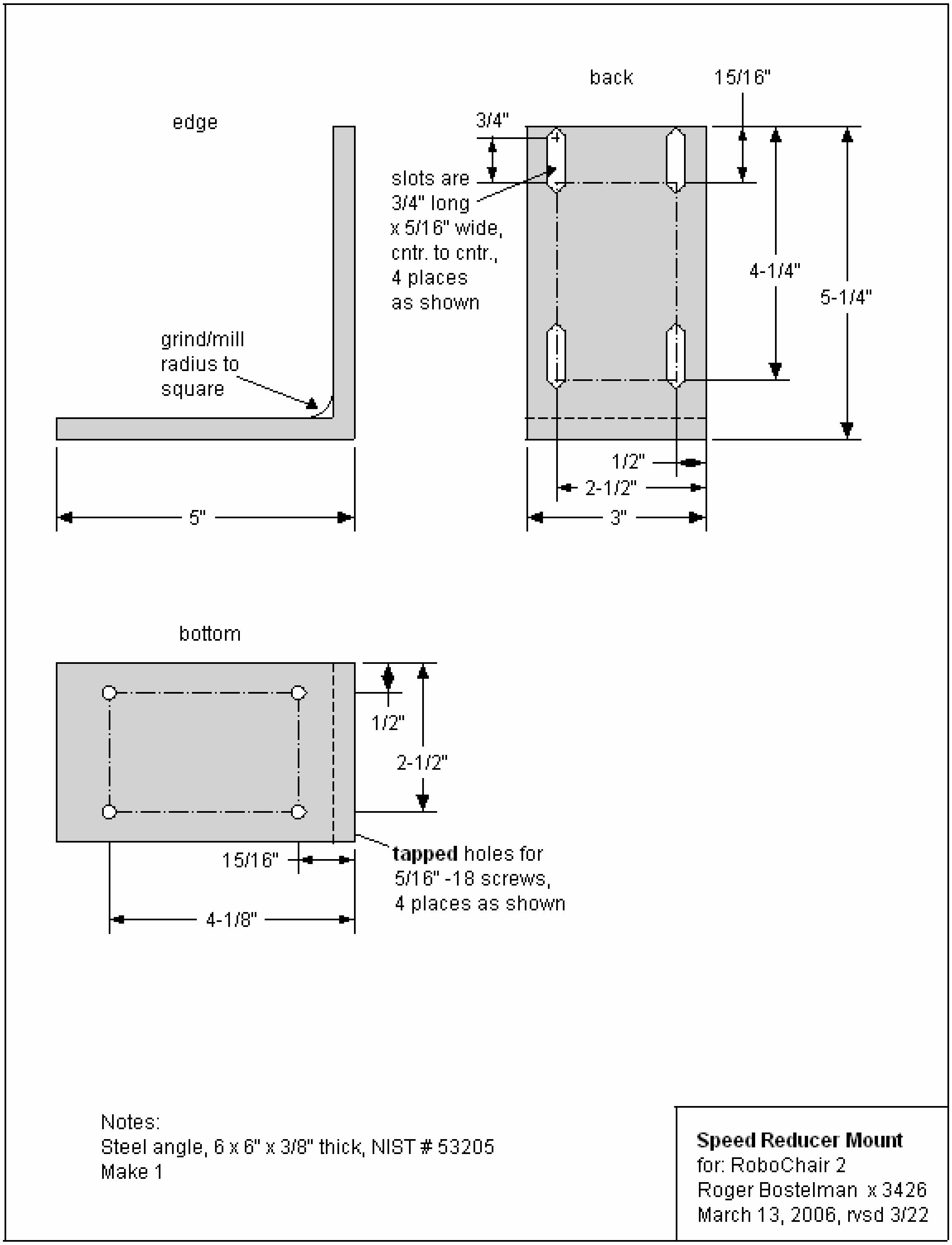
2) **Also, Cut down to 1-1/2" long, the 4 steel nuts supplied.**
3.8 cm

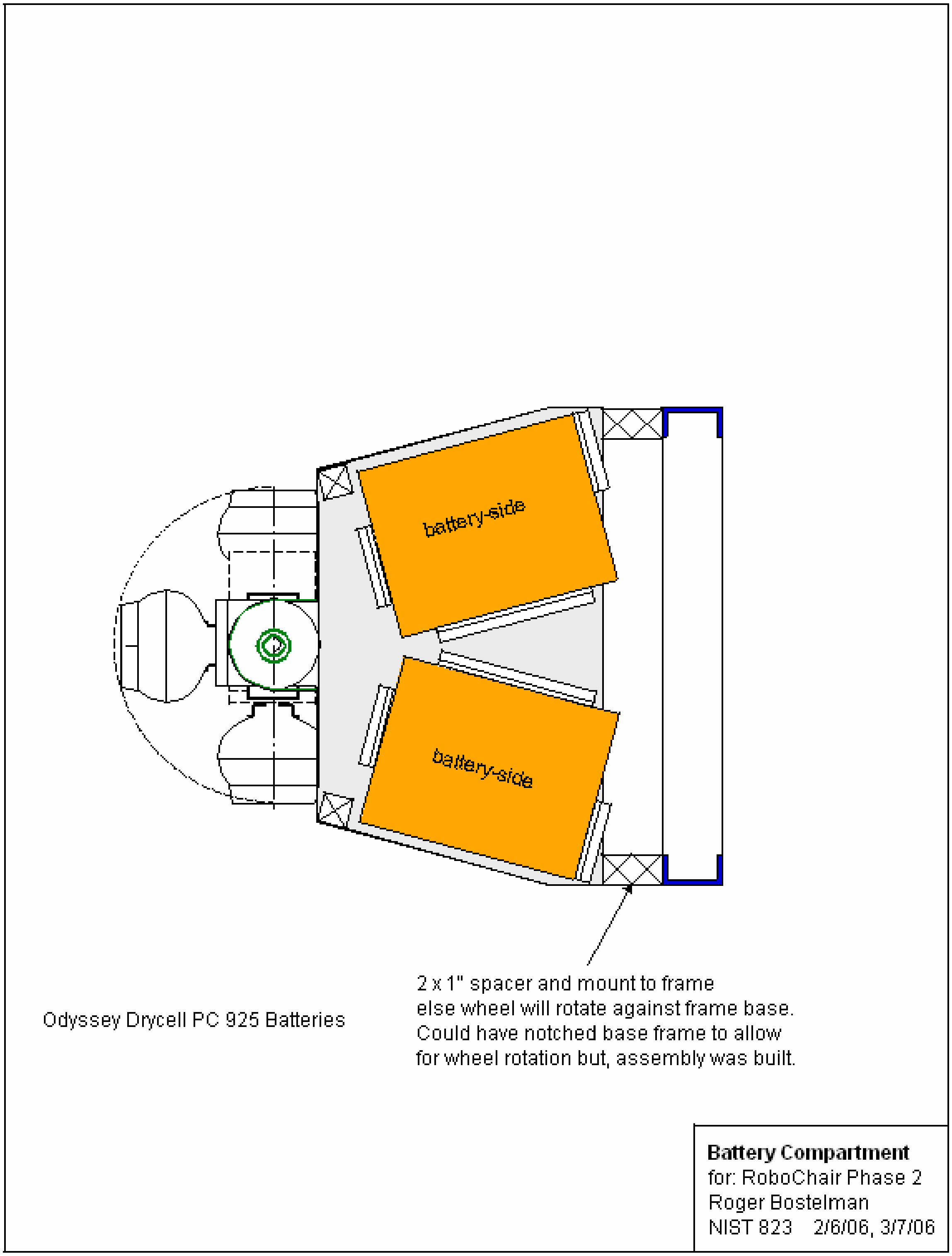


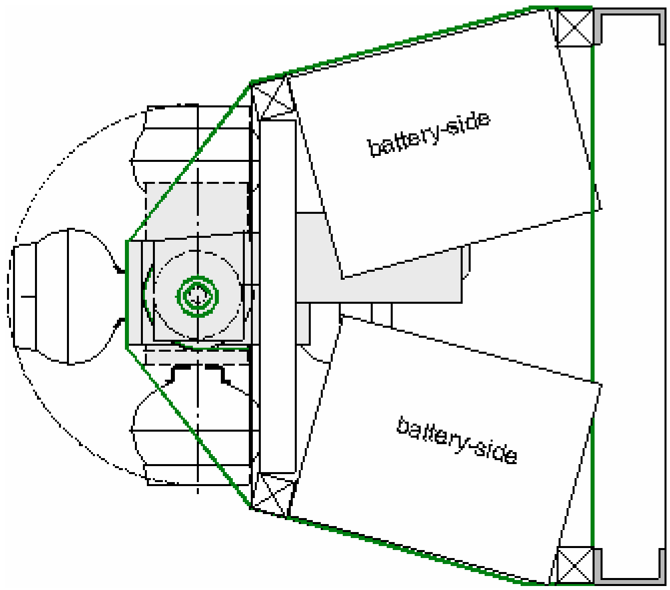
Coupling nut

Wheel Axle, nuts
for: HLPR Chair
Roger Bostelman x3426
NIST 823.11 5/15/07

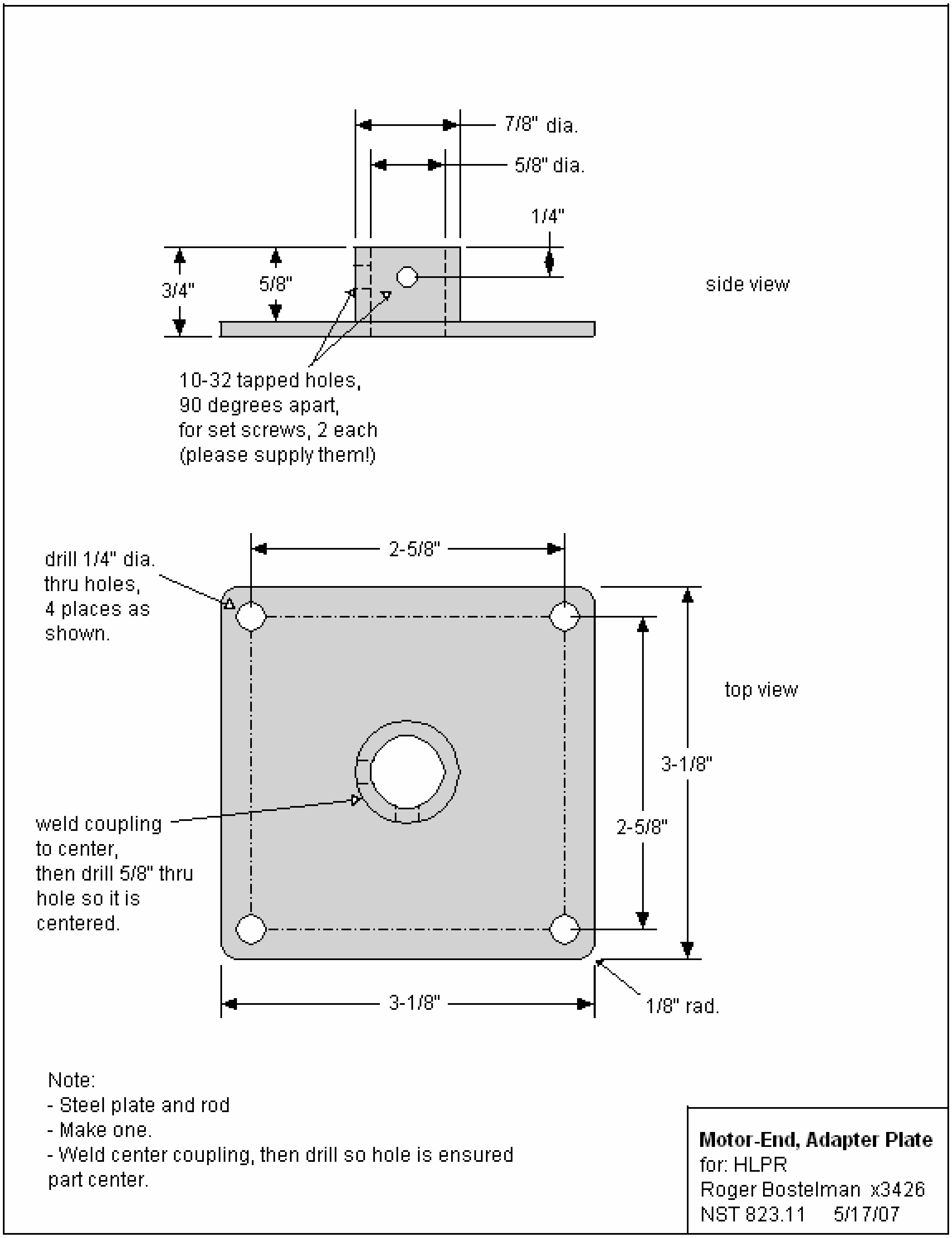

SPEED
= 3900 rpm x 1/20 reducer / 3 (sprockets)
= 65 rpm on a 10" dia. = 10" x Pi x 65/60 sec
= 34 in/sec (86 cm/sec)
TORQUE
= 6.2 in-Lbs. x 20 reducer x 3 (sprockets)
/ 5" wheel radius
= 74 in-Lbs. drawbar at the floor
Replaced steering motor with 93 W (1/8th Hp) gearmotor.
gearmotor
90Vdc, 1/17 Hp, 22
$249.63
Amp
Amp
battery-top
11-21/64"
29.2 cm
3" dia.x 1/8" th. teflon
6"
3-13/32"
1-13/32"
15/16"
2.5 cm squ. alum. posts (4 each)
slots for chain adjust.
Speed reducer mount (following drawing)
2' 7-11/16"
80.5 cm
3/4"
3-9/16"
chain holes:
See Top Axel Plate Cutouts drawing.
Drive/Steering Motor Design
for: RoboChair Phase 2
Roger Bostelman
Jim Albus
NIST 823 2/6/06, 3/7/06

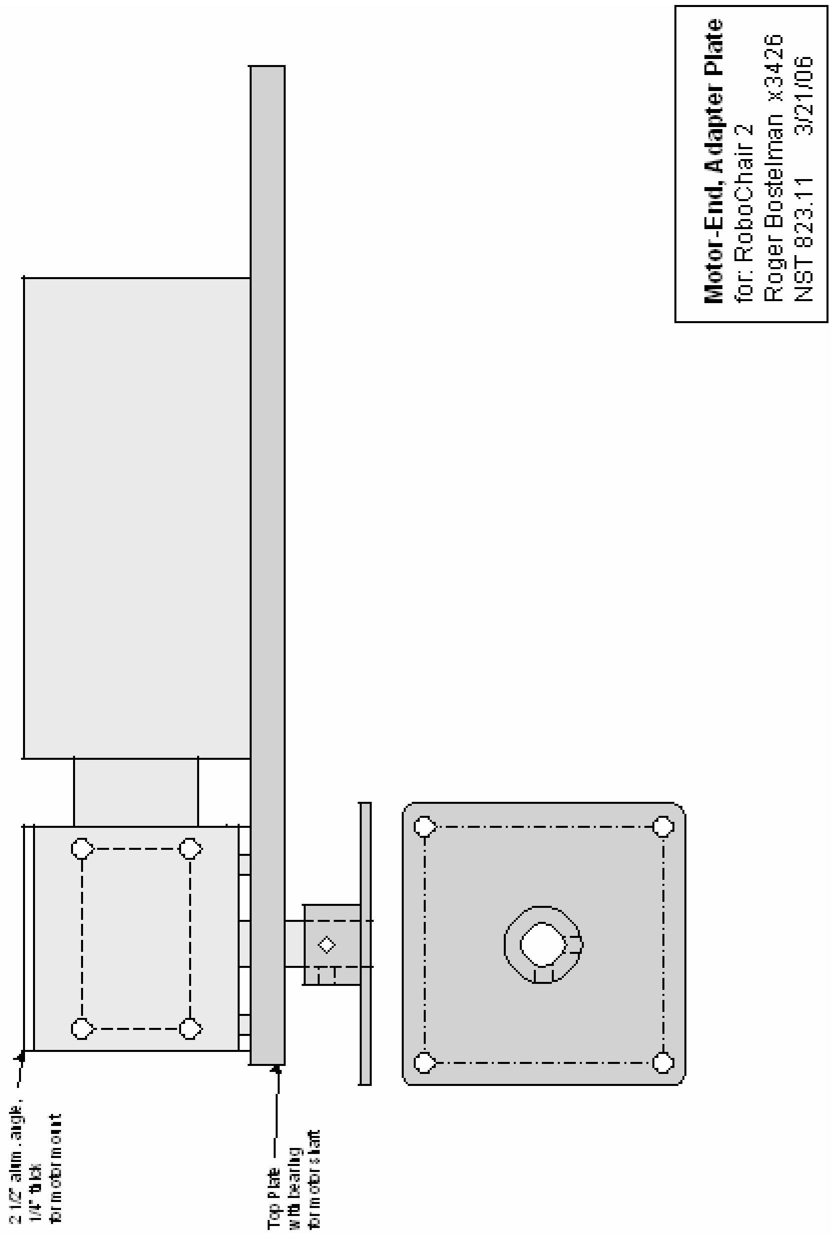

edge
back
bottom
15/16"
3/4"
slots are
3/4" long
x 5/16" wide,
cntr. to cntr.,
4 places
as shown
4-1/4"
5-1/4"
grind/mill
radius to
square
5"
1/2"
2-1/2"
3"
1/2"
2-1/2"
15/16"
4-1/8"
tapped holes for
5/16" -18 screws,
4 places as shown
Notes:
Steel angle, 6 x 6" x 3/8" thick, NIST # 53205
Make 1
Speed Reducer Mount
for: RoboChair 2
Roger Bostelman x 3426
March 13, 2006, rvsd 3/22

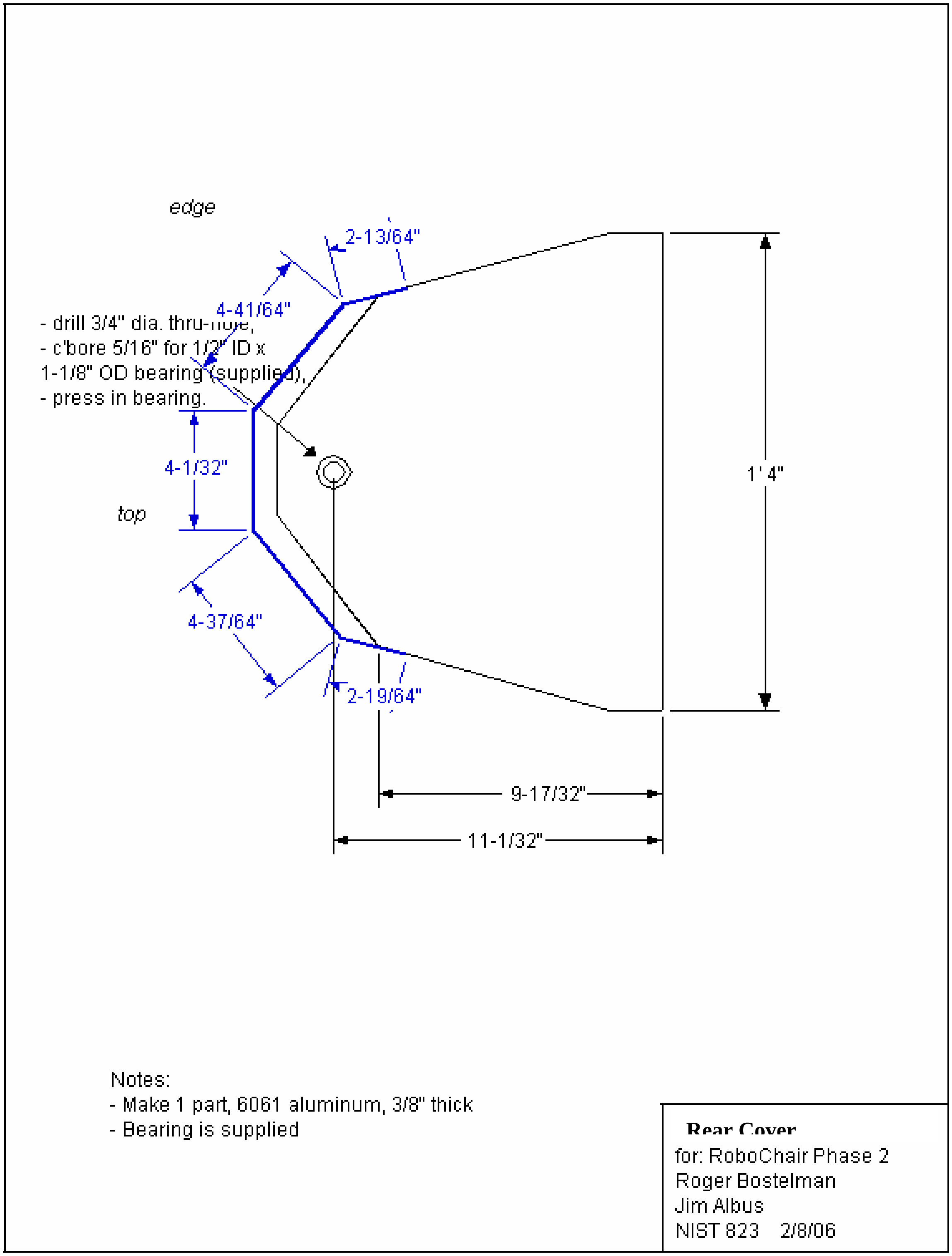

battery-side
battery-side
2 x 1" spacer and mount to frame
else wheel will rotate against frame base.
Could have notched base frame to allow
for wheel rotation but, assembly was built.
Odyssey Drycell PC 925 Batteries
Battery Compartment
for: RoboChair Phase 2
Roger Bostelman
NIST 823 2/6/06, 3/7/06

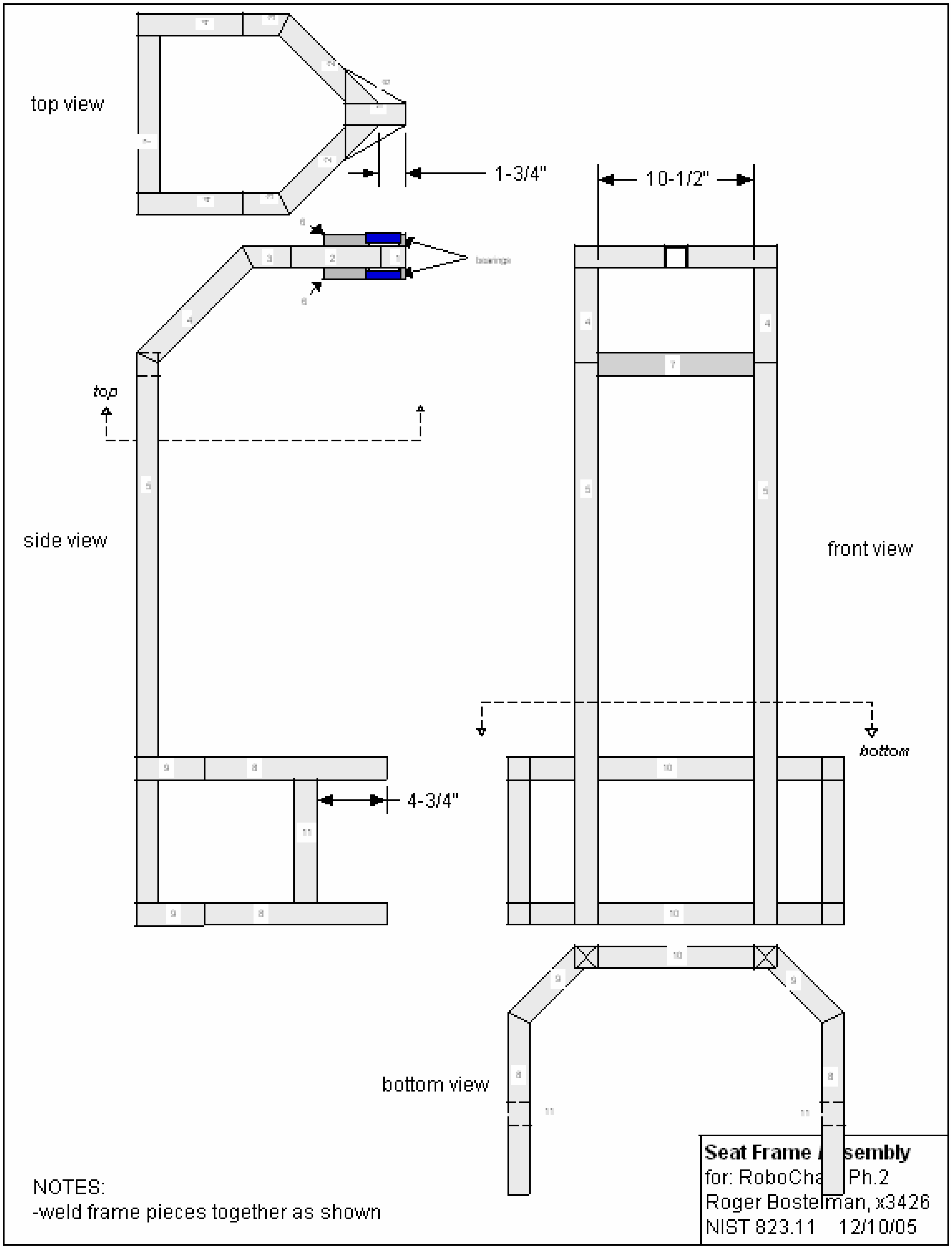


Top view of battery compartment.

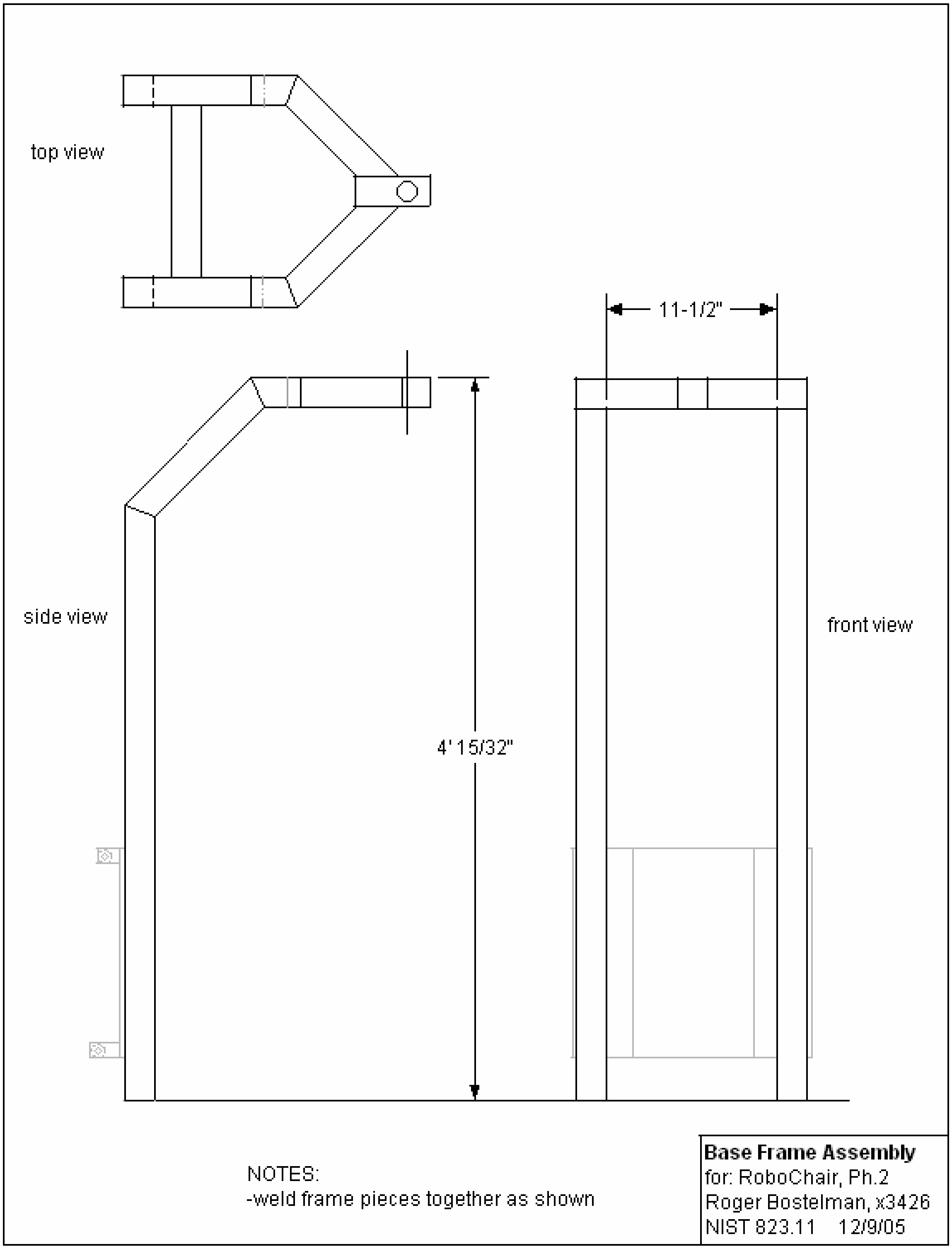

7/8" dia.
5/8" dia.
1/4"
3/4"
5/8"
side view
10-32 tapped holes,
90 degrees apart,
for set screws, 2 each
(please supply them!)
2-5/8"
drill 1/4" dia.
thru holes,
4 places as
shown.
top view
3-1/8"
2-5/8"
weld coupling
to center,
then drill 5/8" thru
hole so it is
centered.
3-1/8"
1/8" rad.
Note:
- Steel plate and rod
- Make one.
- Weld center coupling, then drill so hole is ensured
part center.
Motor-End, Adapter Plate
for: HLPR
Roger Bostelman x3426
NST 823.11 5/17/07


Motor-End, Adapter Plate
for: RoboChair 2
Roger Bostelman x3426
NST 823.11 3/21/06
2 1/2" alum. angle,
1/4" thick
for motor mount
Top Plate
with bearing
for motor shaft

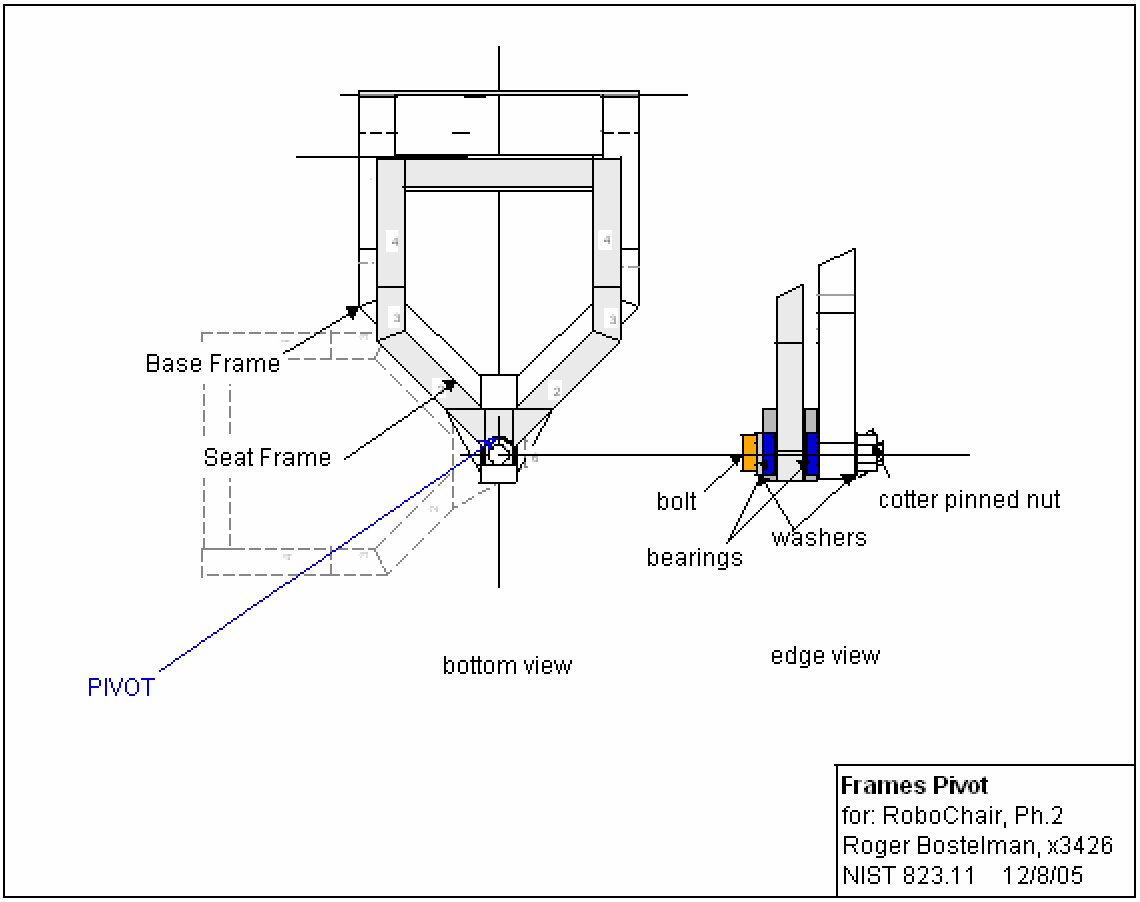

edge
2-13/64"
4-41/64"
- drill 3/4" dia. thru-hole,
- c'bore 5/16" for 1/2" ID x
1-1/8" OD bearing (supplied),
- press in bearing.
4-1/32"
top
4-37/64"
2-19/64"
1' 4"
9-17/32"
11-1/32"
Notes:
- Make 1 part, 6061 aluminum, 3/8" thick
- Bearing is supplied
Rear Cover
for: RoboChair Phase 2
Roger Bostelman
Jim Albus
NIST 823 2/8/06



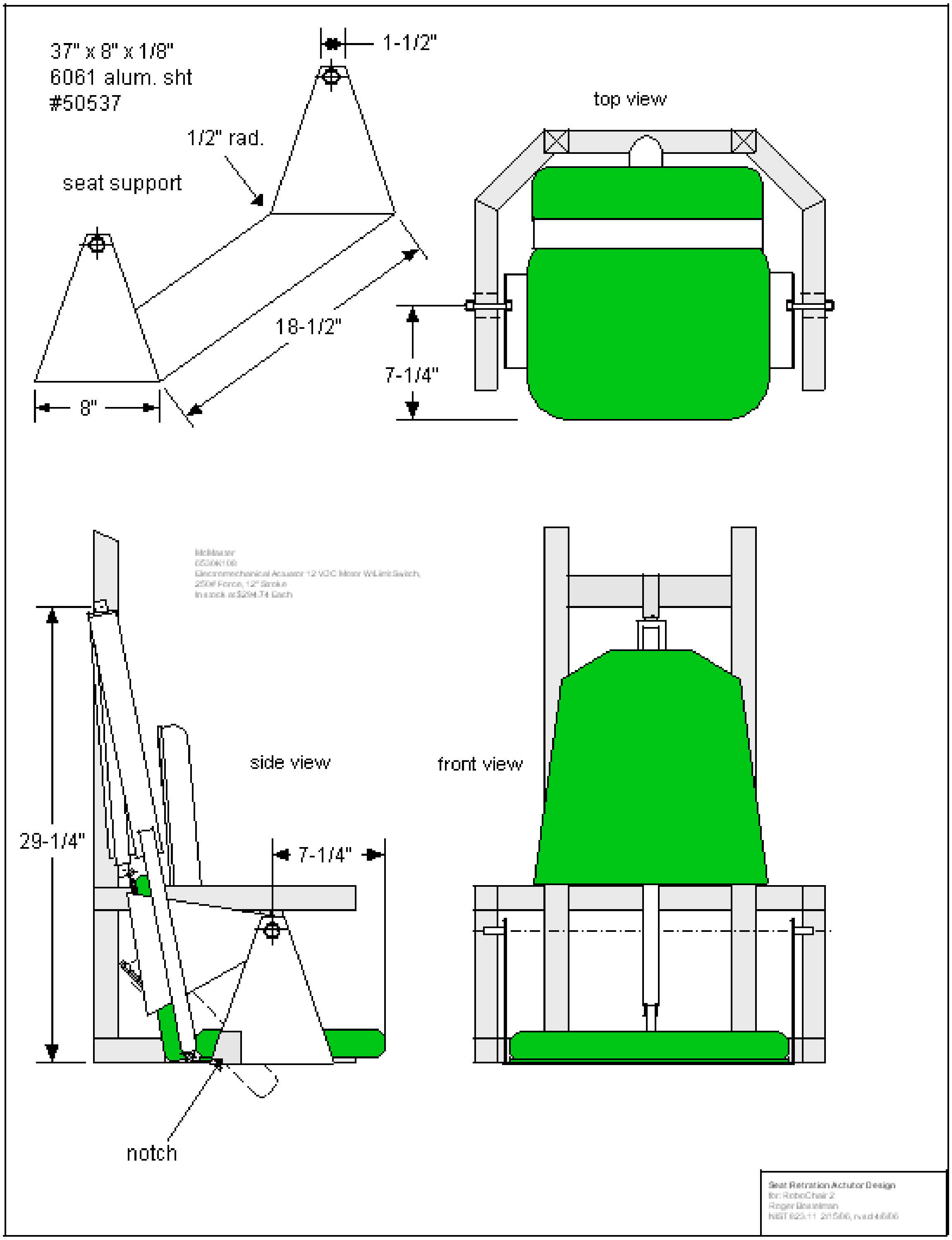
See Modifications to Existing Design section for new version of the seat frame assembly.

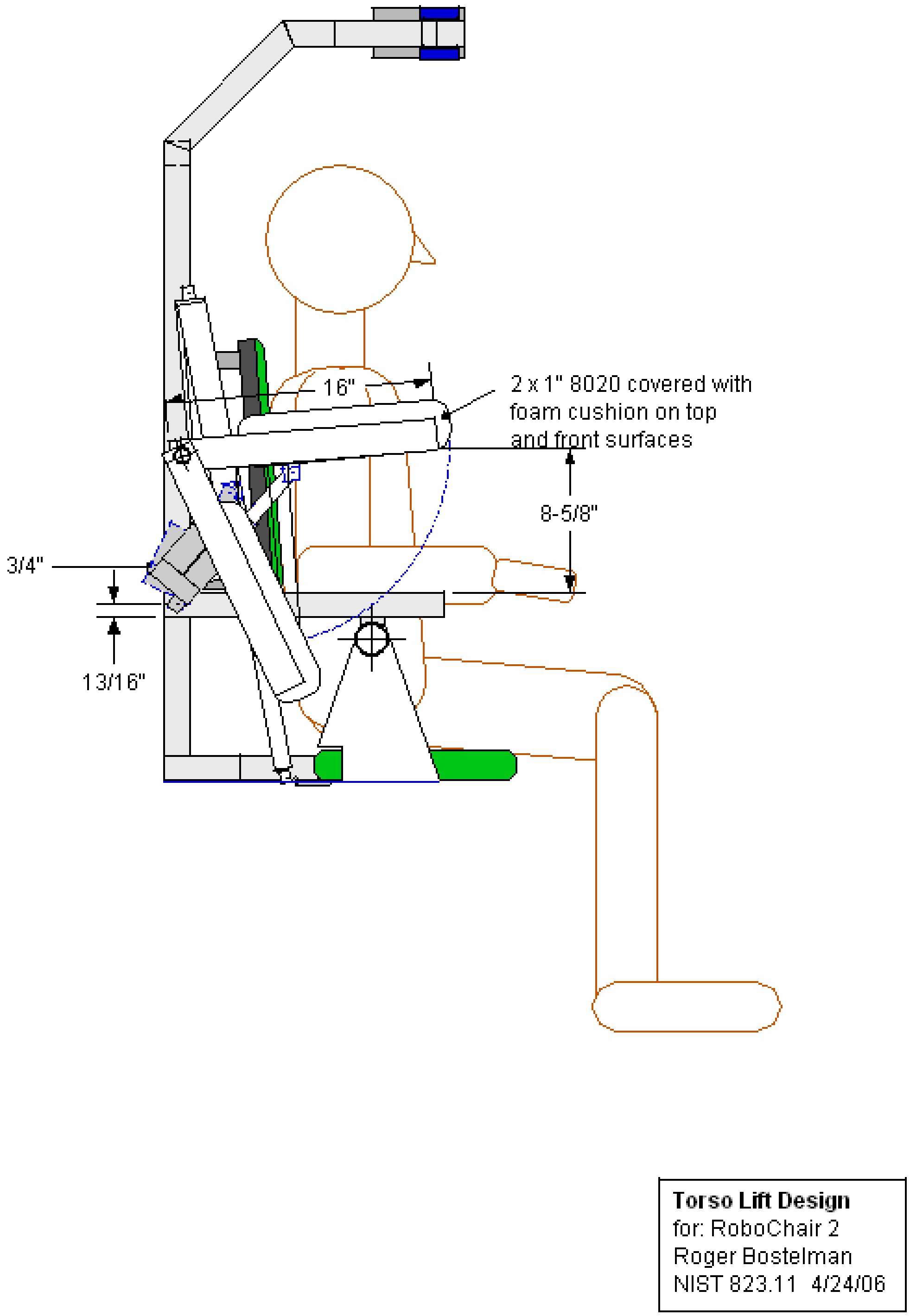


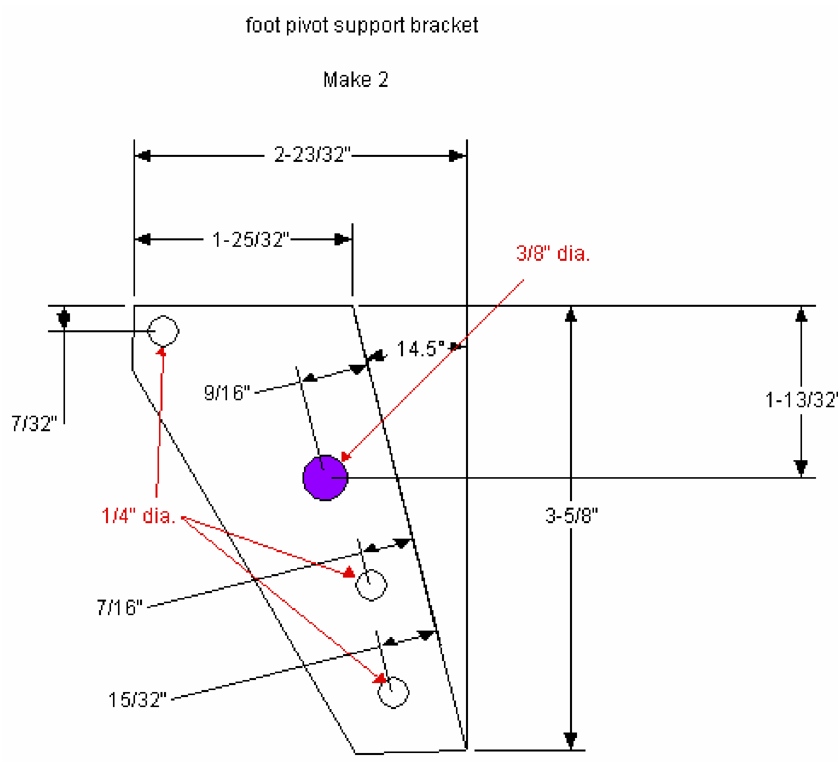
See Modifications to Existing Design section for new version of the base frame assembly.

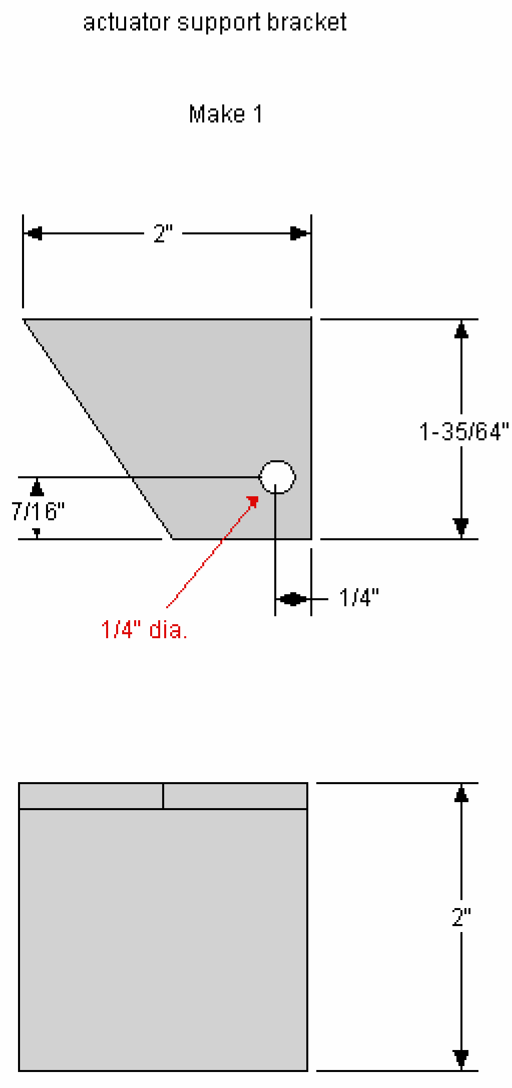


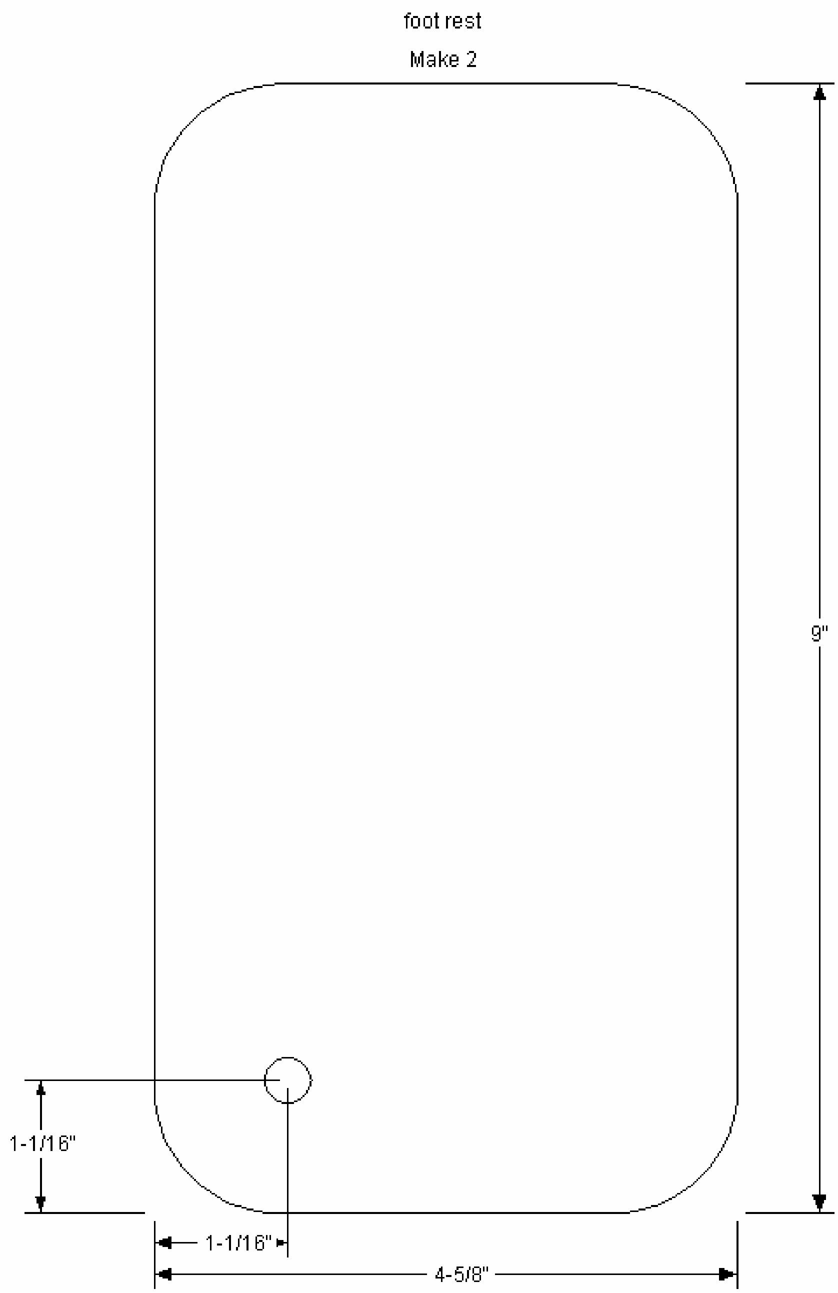
See Modifications to Existing Design section for new version of the frames pivot.

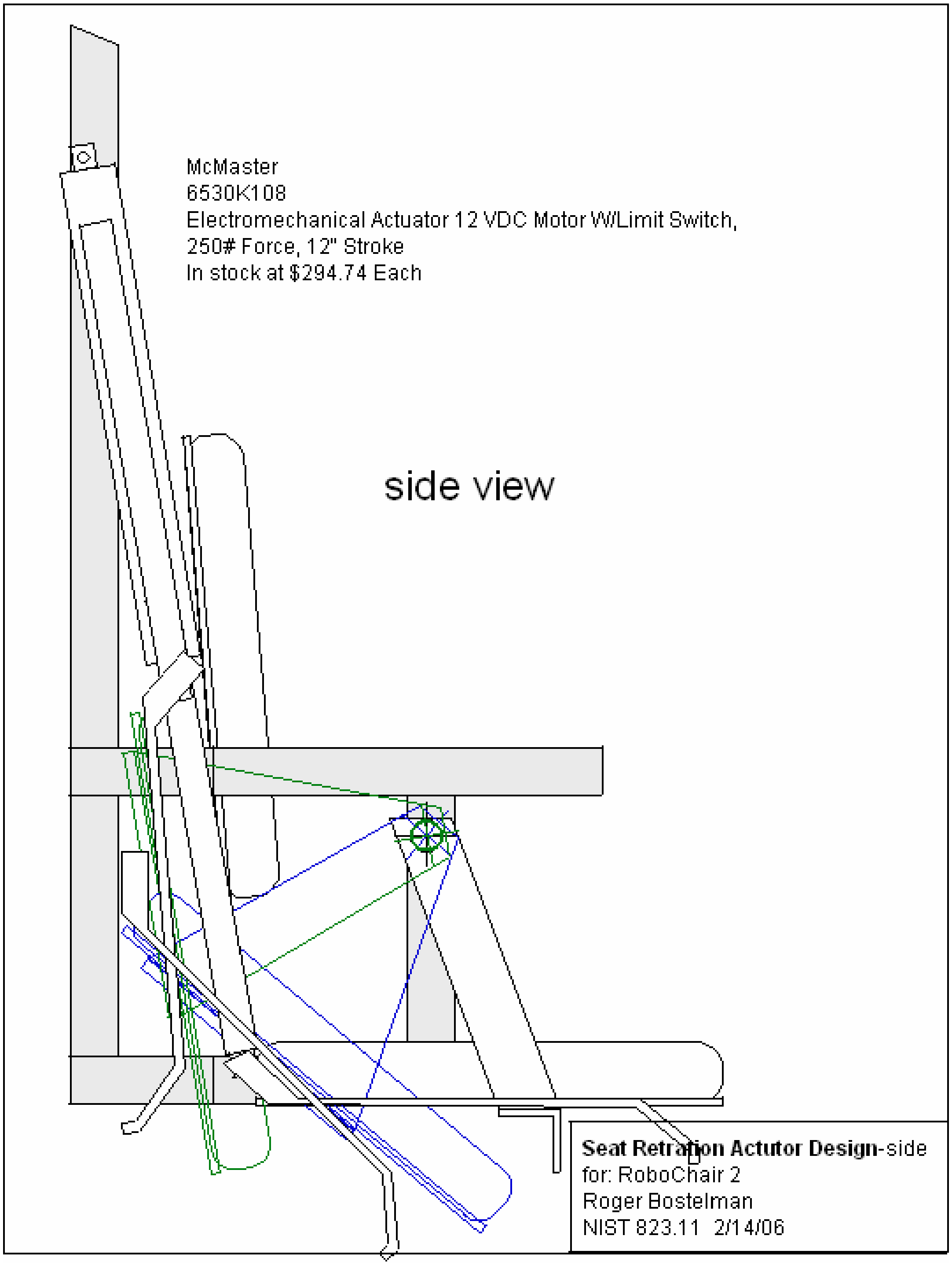

37" x 8" x 1/8"
6061 alum. sht
#50537
1-1/2"
1/2" rad.
seat support
18-1/2"
8"
top view
7-1/4"
side view
front view
29-1/4"
7-1/4"
notch

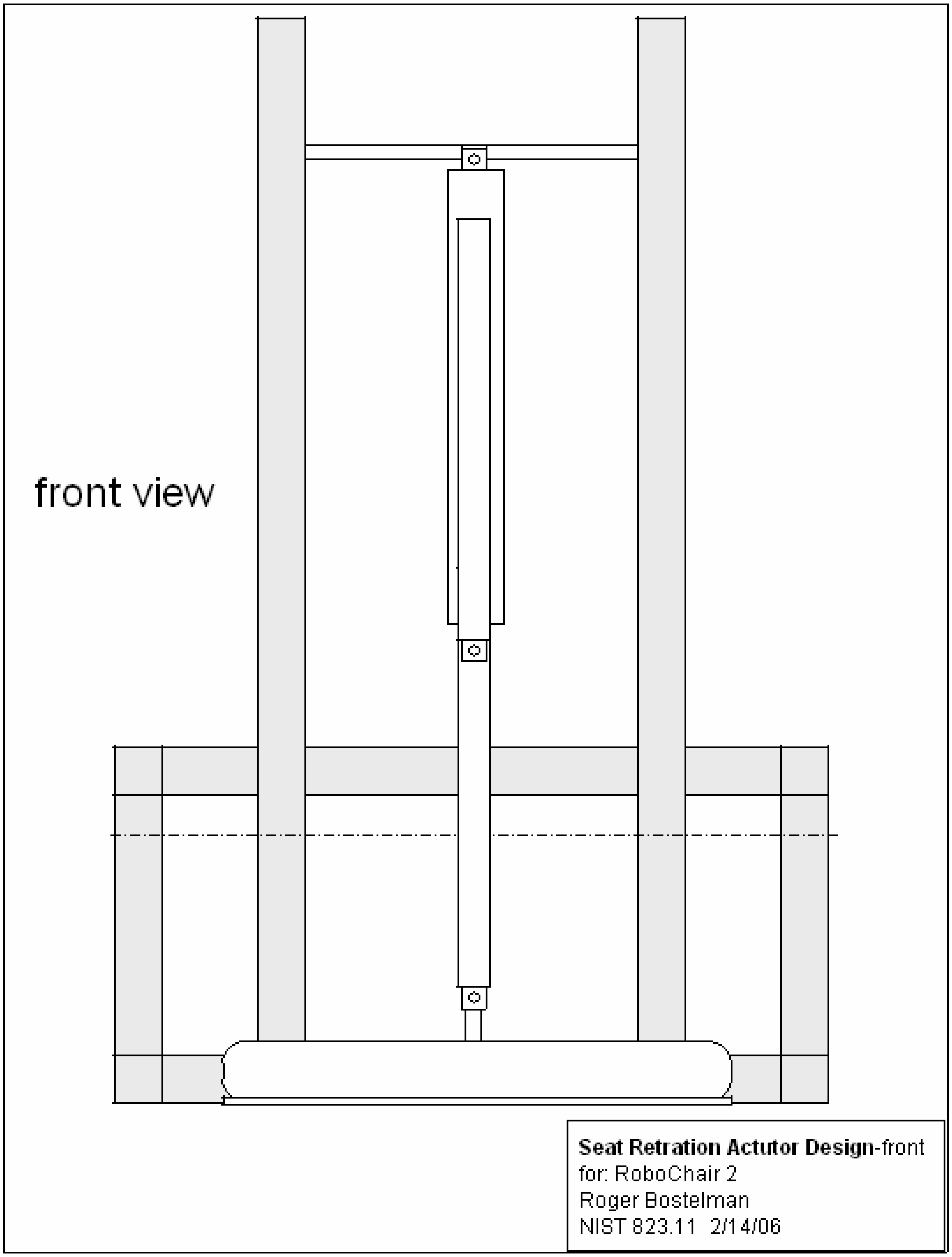

16"
2 x 1" 8020 covered with
foam cushion on top
and front surfaces
8-5/8"
3/4"
13/16"
Torso Lift Design
for: RoboChair 2
Roger Bostelman
NIST 823.11 4/24/06

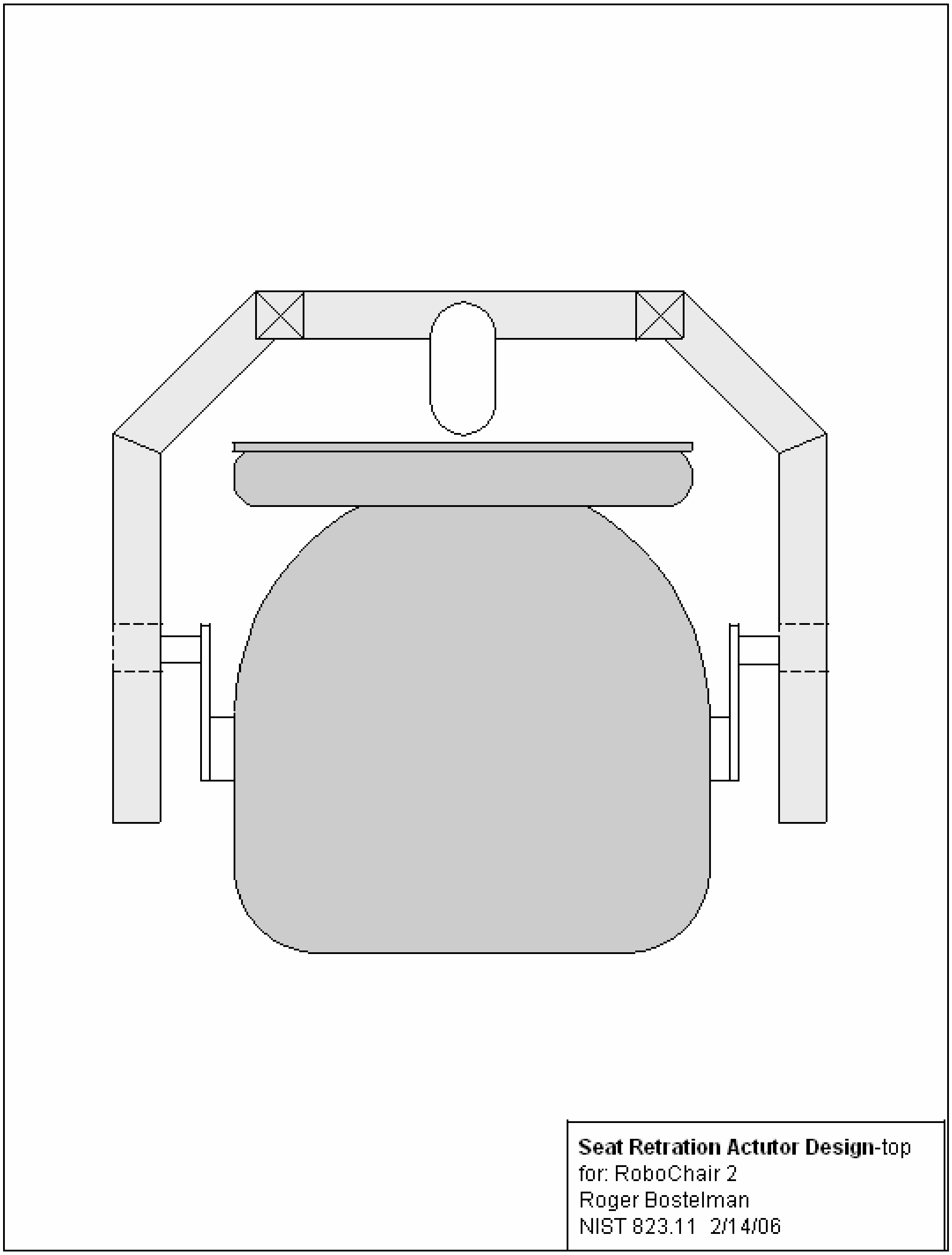

foot pivot support bracket
Make 2
2-23/32"
1-25/32"
3/8" dia.
14.5°
9/16"
7/32"
1-13/32"
1/4" dia.
3-5/8"
7/16"
15/32"

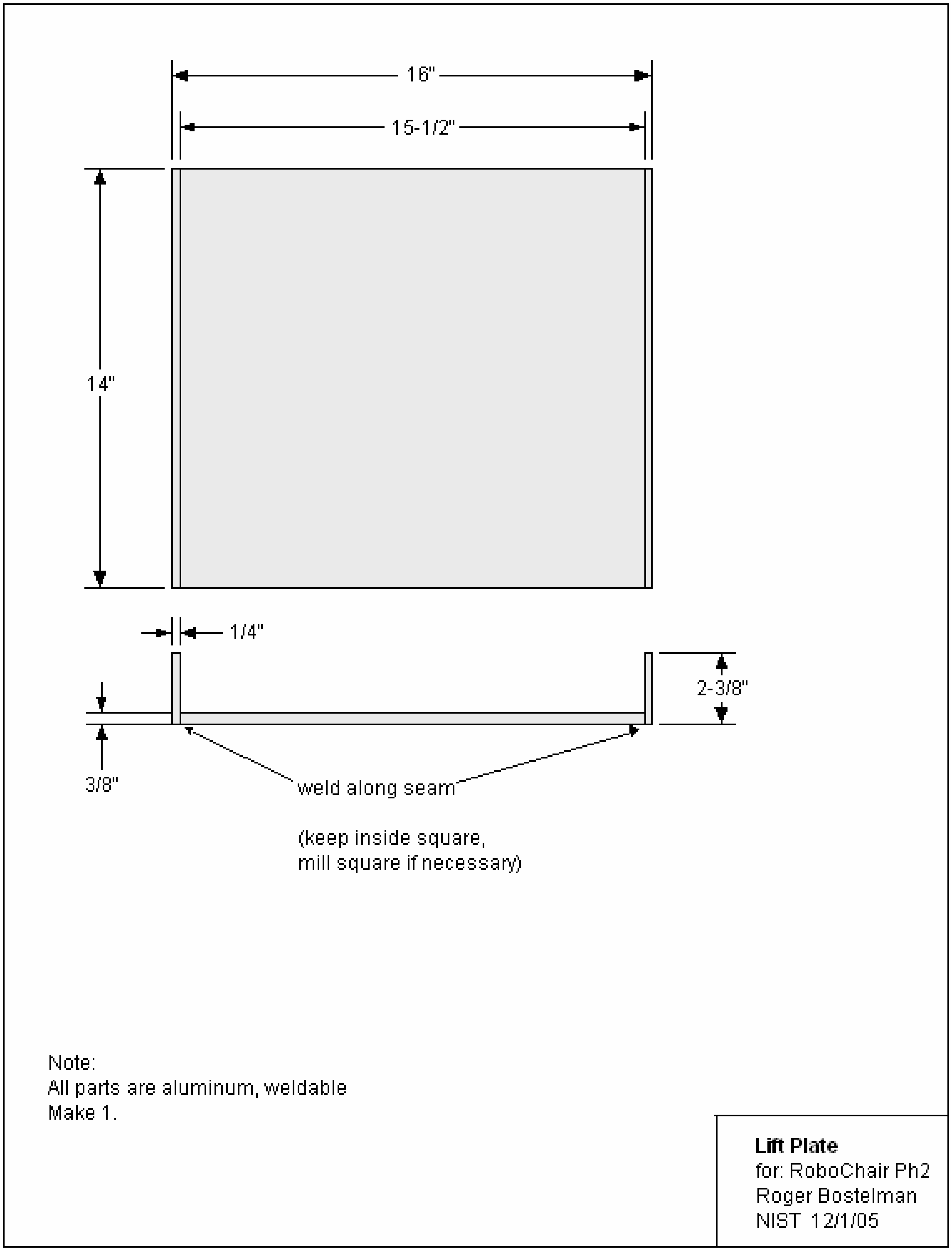

actuator support bracket
Make 1
2"
1-35/64"
7/16"
1/4"
1/4" dia.
2"

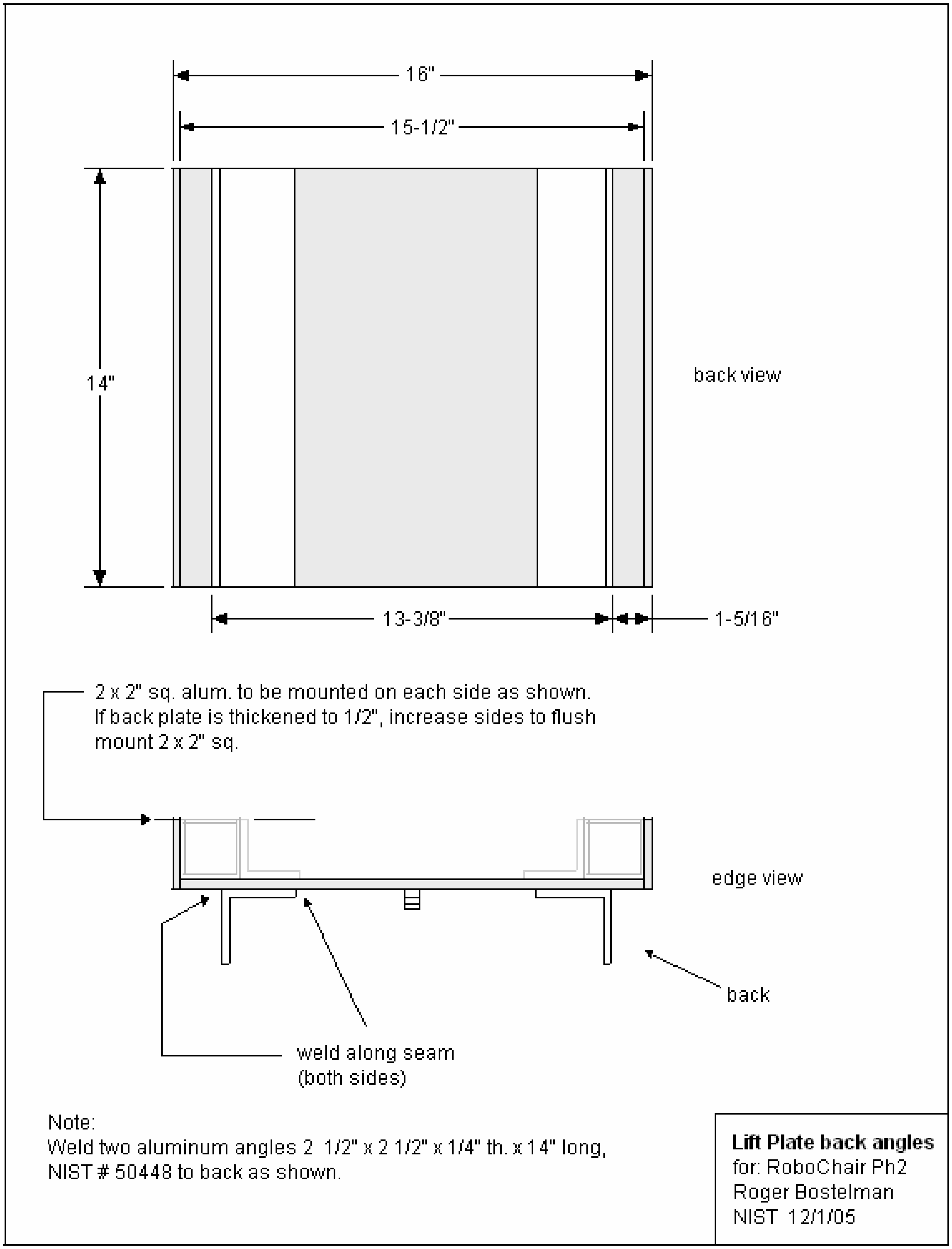

foot rest
Make 2
9"
1-1/16"
1-1/16"
4-5/8"

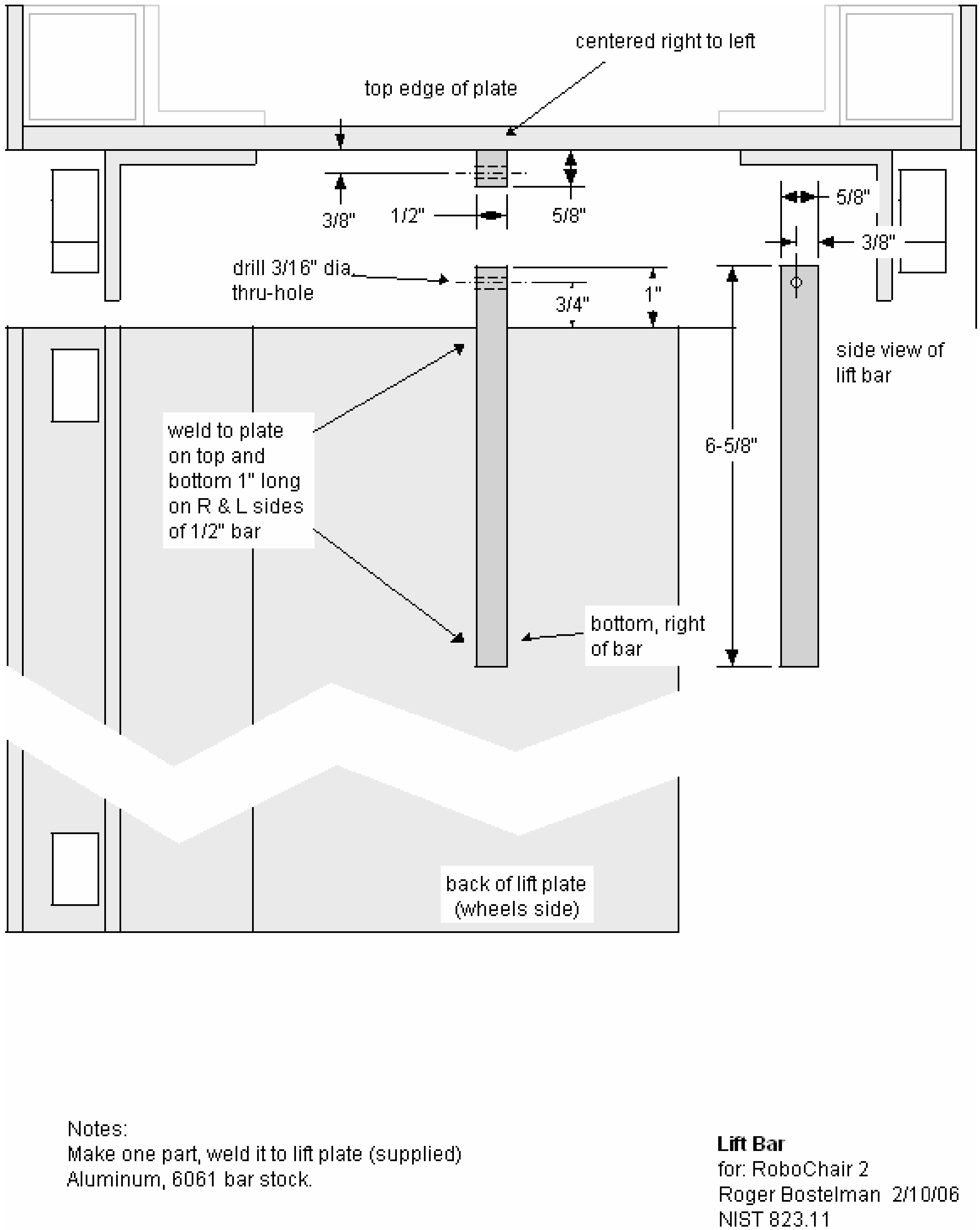

McMaster
6530K108
Electromechanical Actuator 12 VDC Motor W/Limit Switch,
250# Force, 12" Stroke
In stock at $294.74 Each
side view
Seat Retration Actutor Design-side
for: RoboChair 2
Roger Bostelman
NIST 823.11 2/14/06

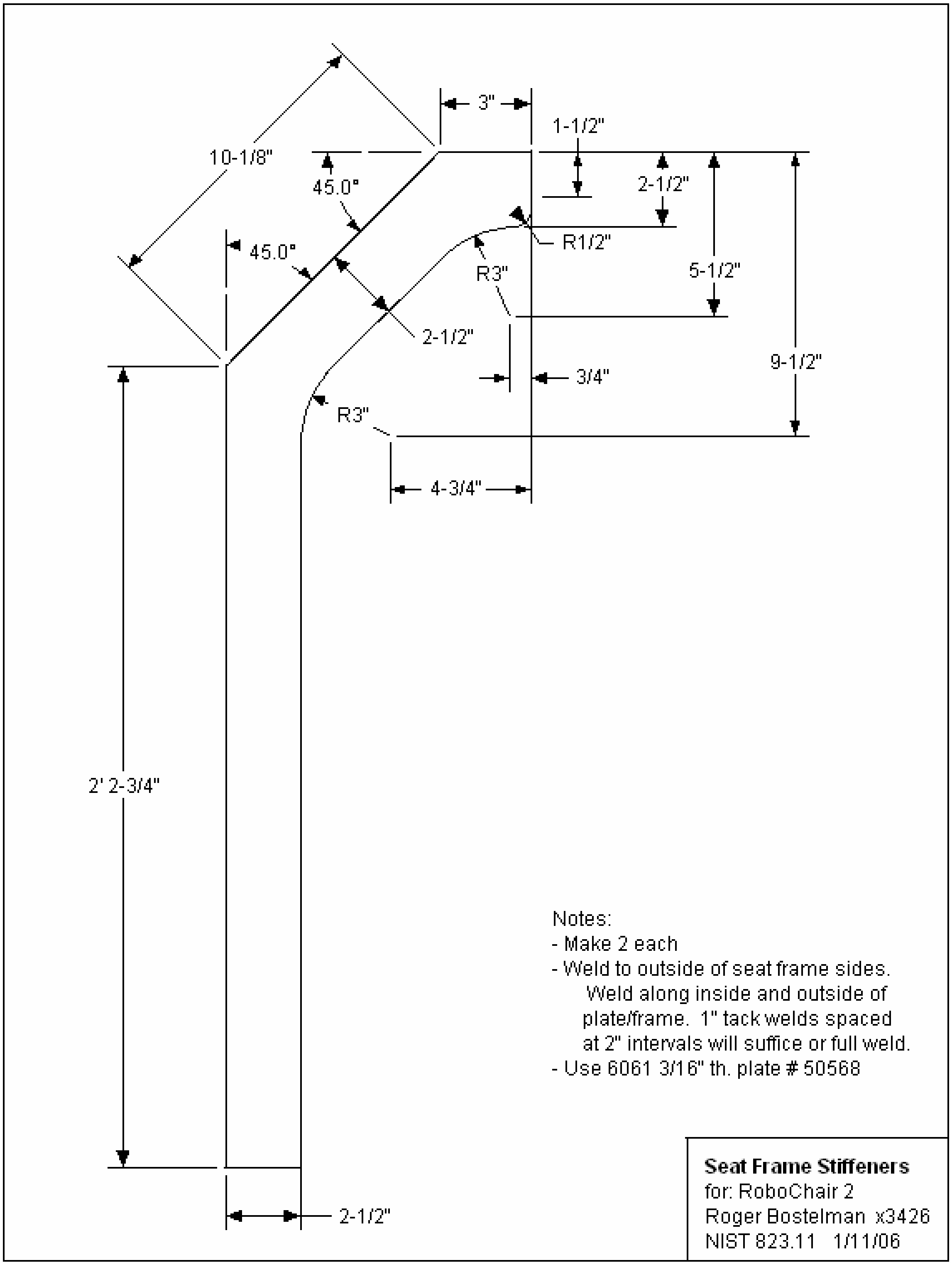

front view
Seat Retration Actutor Design-front
for: RoboChair 2
Roger Bostelman
NIST 823.11 2/14/06

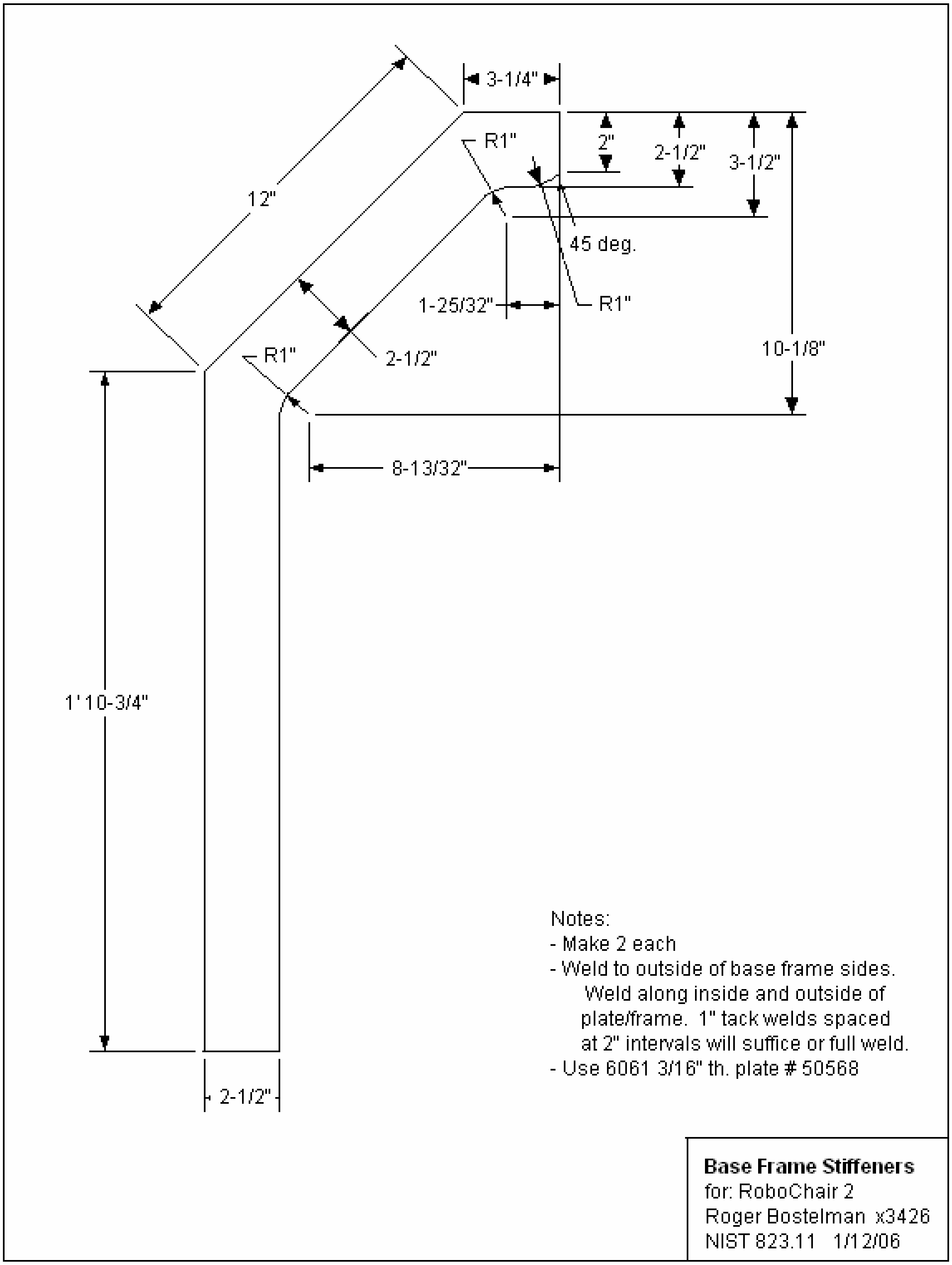

Seat Retration Actutor Design-top
for: RoboChair 2
Roger Bostelman
NIST 823.11   2/14/06

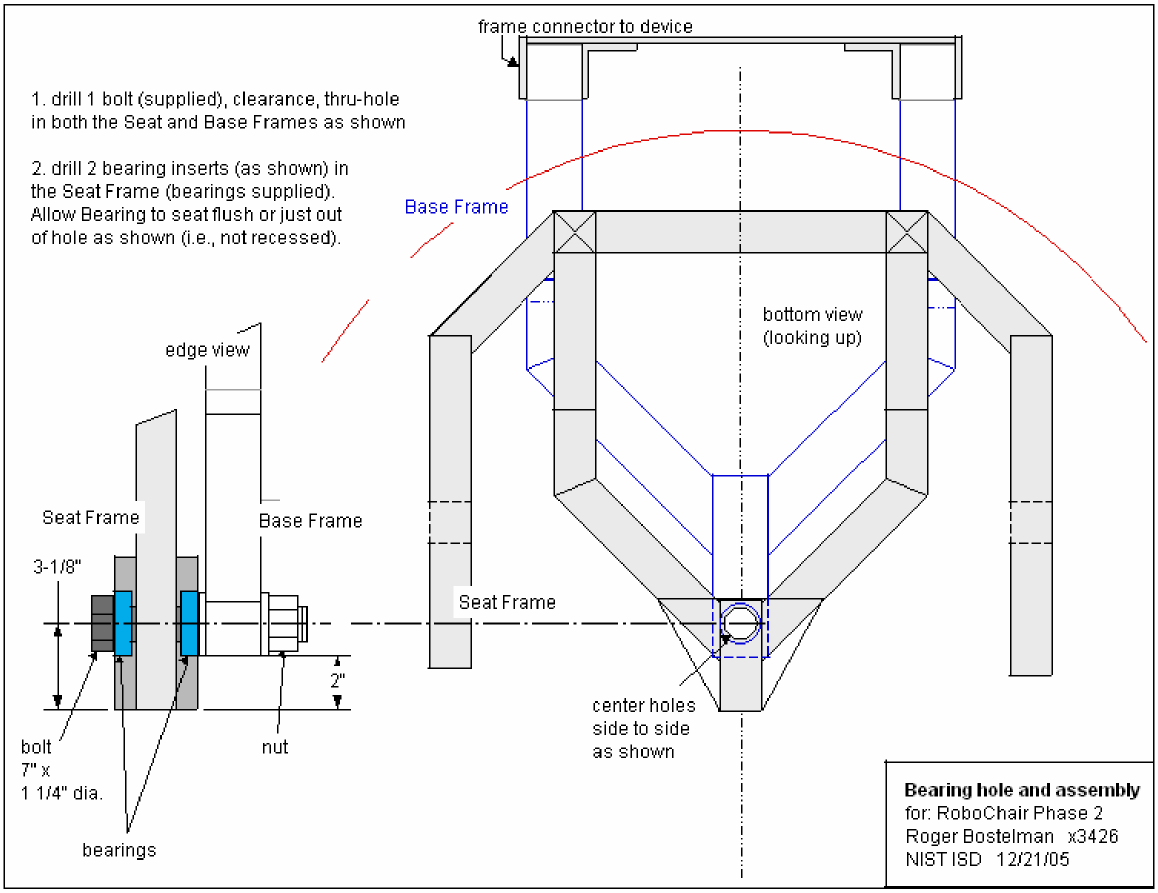

16"
15-1/2"
14"
1/4"
2-3/8"
3/8"
weld along seam
(keep inside square,
mill square if necessary)
Note:
All parts are aluminum, weldable
Make 1.
Lift Plate
for: RoboChair Ph2
Roger Bostelman
NIST 12/1/05

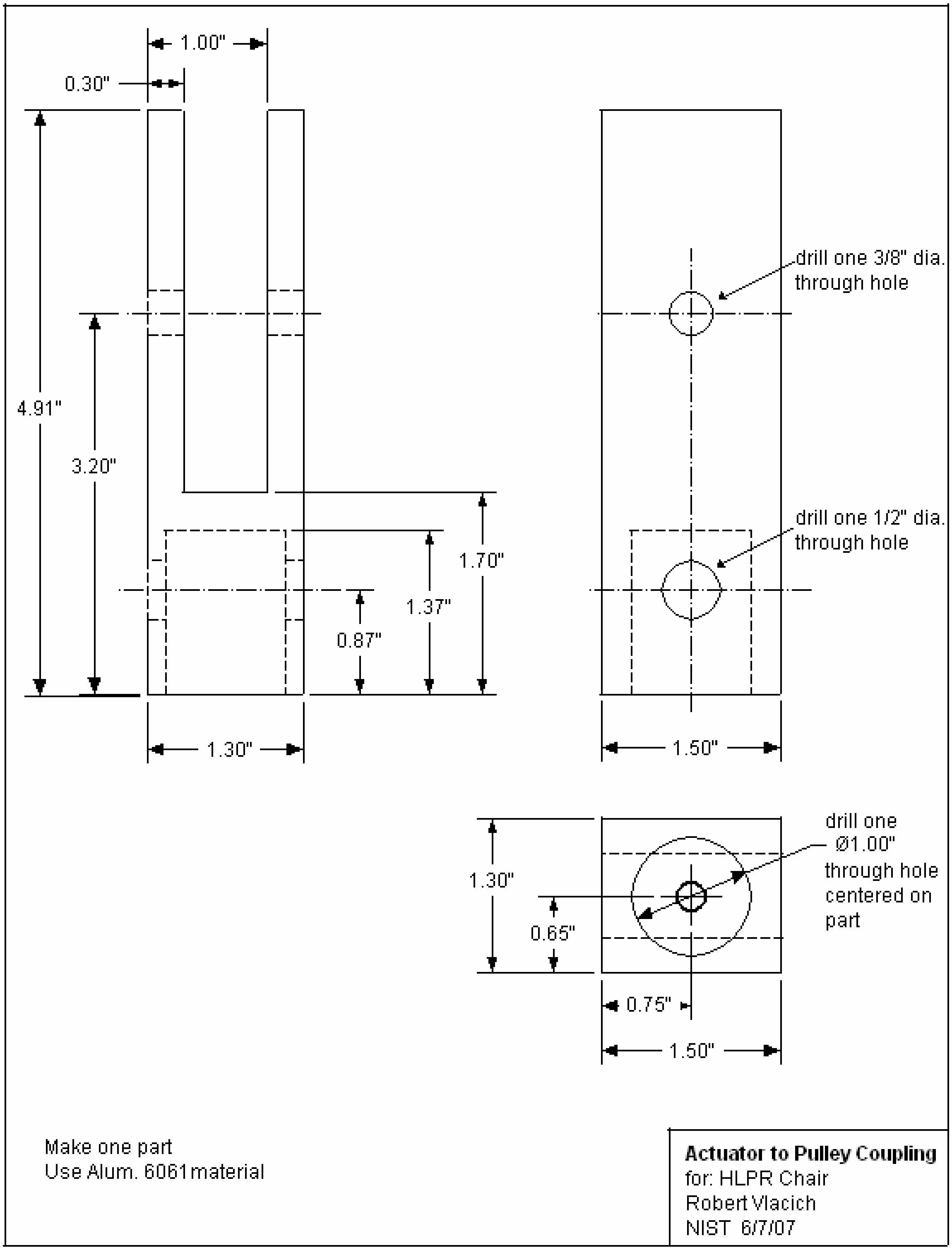

16"
15-1/2"
14"
back view
13-3/8"
1-5/16"
2 x 2" sq. alum. to be mounted on each side as shown.
If back plate is thickened to 1/2", increase sides to flush
mount 2 x 2" sq.
edge view
back
weld along seam
(both sides)
Note:
Weld two aluminum angles 2 1/2" x 2 1/2" x 1/4" th. x 14" long,
NIST # 50448 to back as shown.
Lift Plate back angles
for: RoboChair Ph2
Roger Bostelman
NIST 12/1/05


centered right to left
top edge of plate
3/8"
1/2"
5/8"
5/8"
3/8"
drill 3/16" dia.
thru-hole
3/4"
1"
side view of
lift bar
weld to plate
on top and
bottom 1" long
on R & L sides
of 1/2" bar
6-5/8"
bottom, right
of bar
back of lift plate
(wheels side)
Notes:
Make one part, weld it to lift plate (supplied)
Aluminum, 6061 bar stock.
Lift Bar
for: RoboChair 2
Roger Bostelman 2/10/06
NIST 823.11

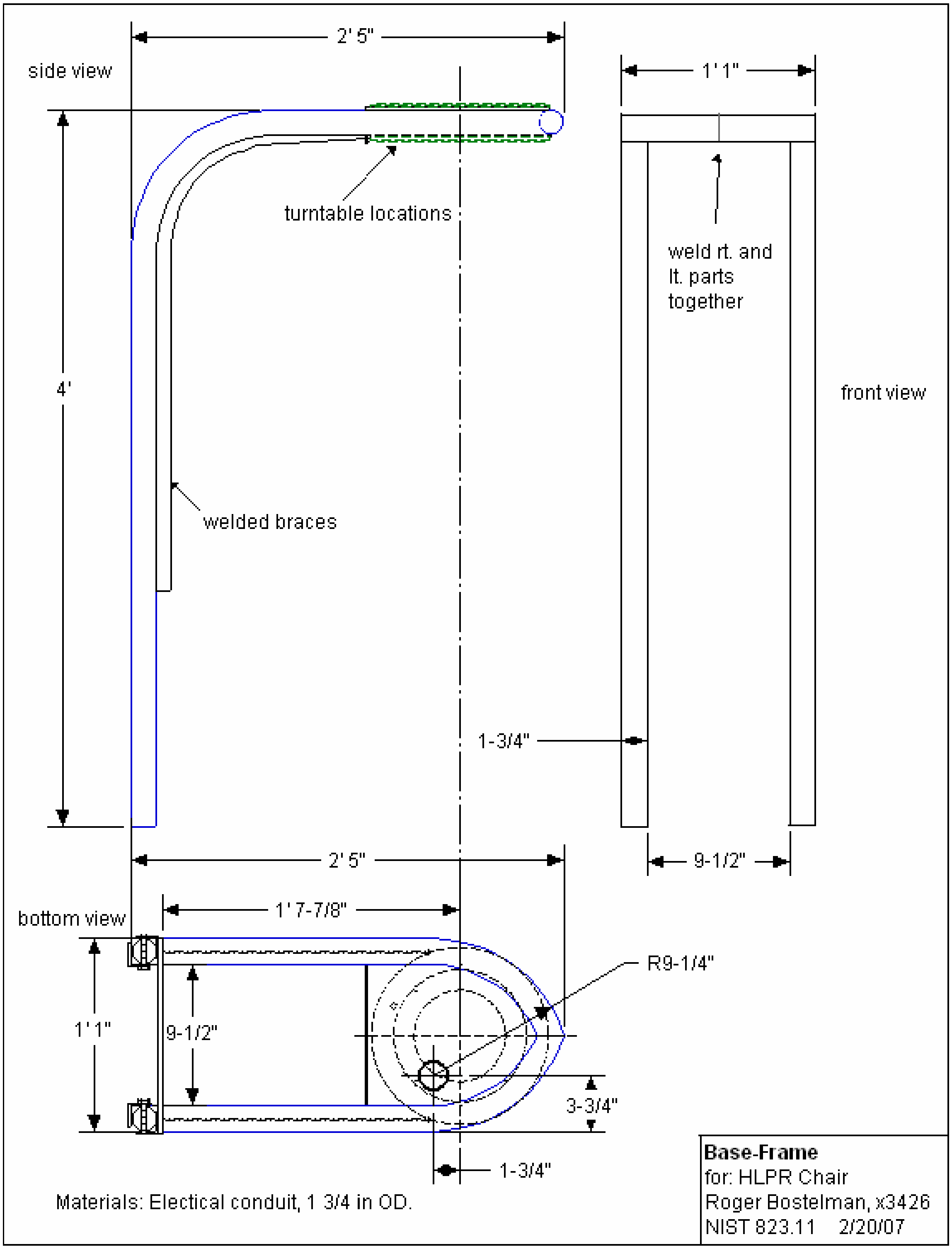

10-1/8"
3"
1-1/2"
45.0°
2-1/2"
45.0°
R1/2"
R3"
5-1/2"
2-1/2"
9-1/2"
3/4"
R3"
4-3/4"
2' 2-3/4"
Notes:
- Make 2 each
- Weld to outside of seat frame sides. Weld along inside and outside of plate/frame. 1" tack welds spaced at 2" intervals will suffice or full weld.
- Use 6061 3/16" th. plate # 50568
2-1/2"
Seat Frame Stiffeners
for: RoboChair 2
Roger Bostelman x3426
NIST 823.11 1/11/06

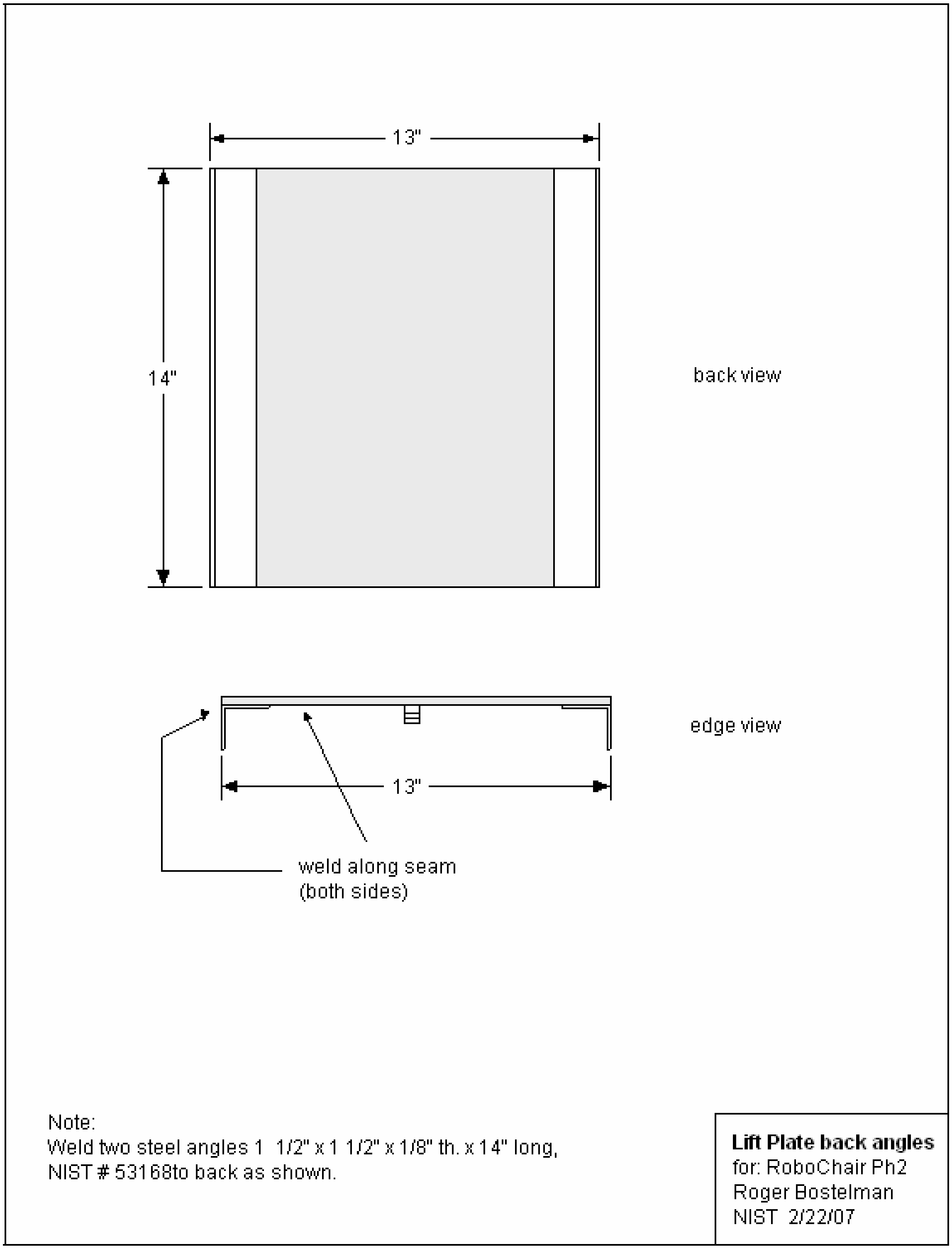

3-1/4"
12"
R1"
2"
2-1/2"
3-1/2"
45 deg.
1-25/32"
R1"
R1"
2-1/2"
10-1/8"
8-13/32"
1' 10-3/4"
2-1/2"
Notes:
- Make 2 each
- Weld to outside of base frame sides.
Weld along inside and outside of
plate/frame. 1" tack welds spaced
at 2" intervals will suffice or full weld.
- Use 6061 3/16" th. plate # 50568
Base Frame Stiffeners
for: RoboChair 2
Roger Bostelman x3426
NIST 823.11 1/12/06

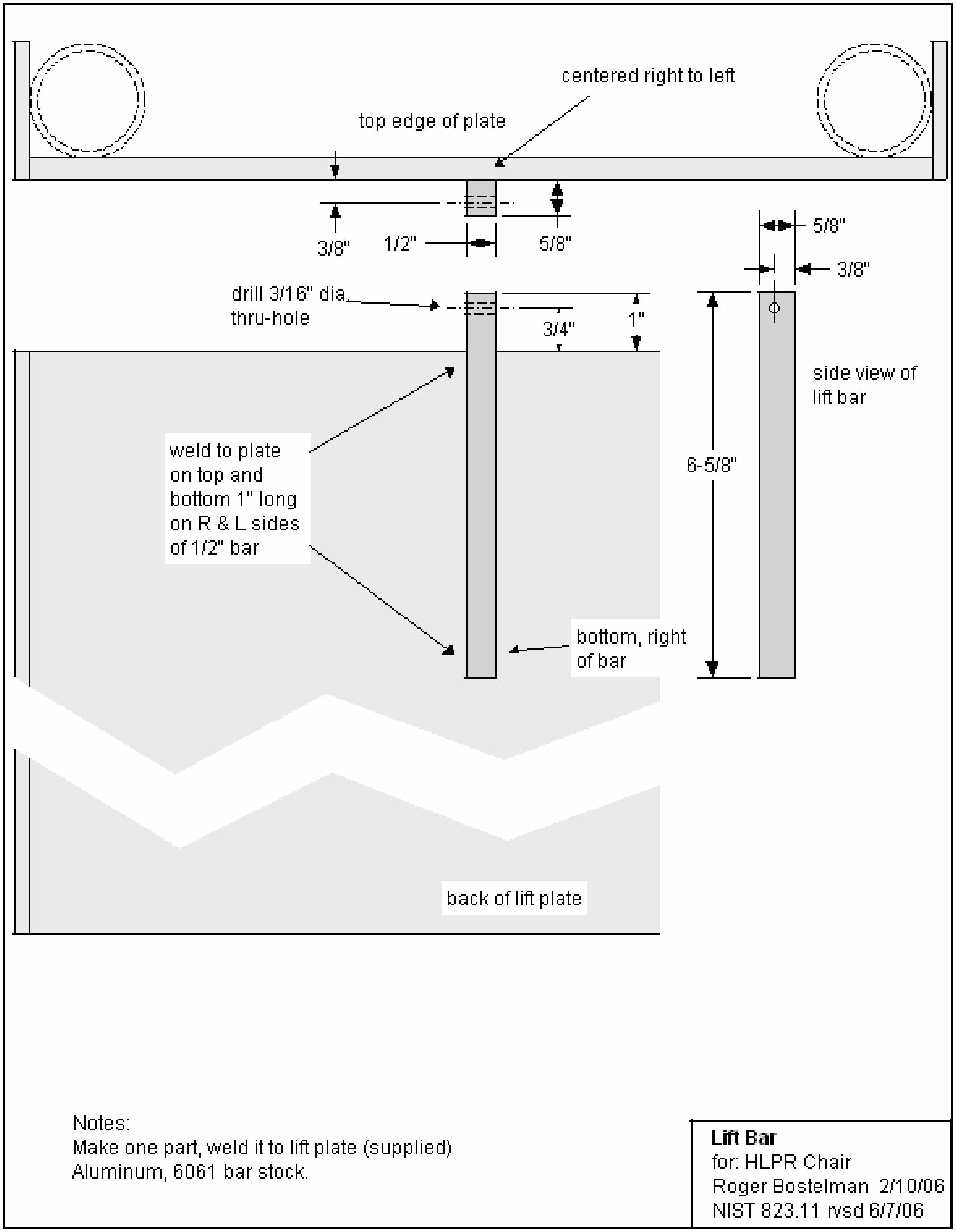

frame connector to device
1. drill 1 bolt (supplied), clearance, thru-hole in both the Seat and Base Frames as shown
2. drill 2 bearing inserts (as shown) in the Seat Frame (bearings supplied). Allow Bearing to seat flush or just out of hole as shown (i.e., not recessed).
Base Frame
bottom view (looking up)
edge view
Seat Frame
Base Frame
3-1/8"
Seat Frame
2"
center holes side to side as shown
bolt
7" x
1 1/4" dia.
nut
bearings
Bearing hole and assembly
for: RoboChair Phase 2
Roger Bostelman x3426
NIST ISD 12/21/05

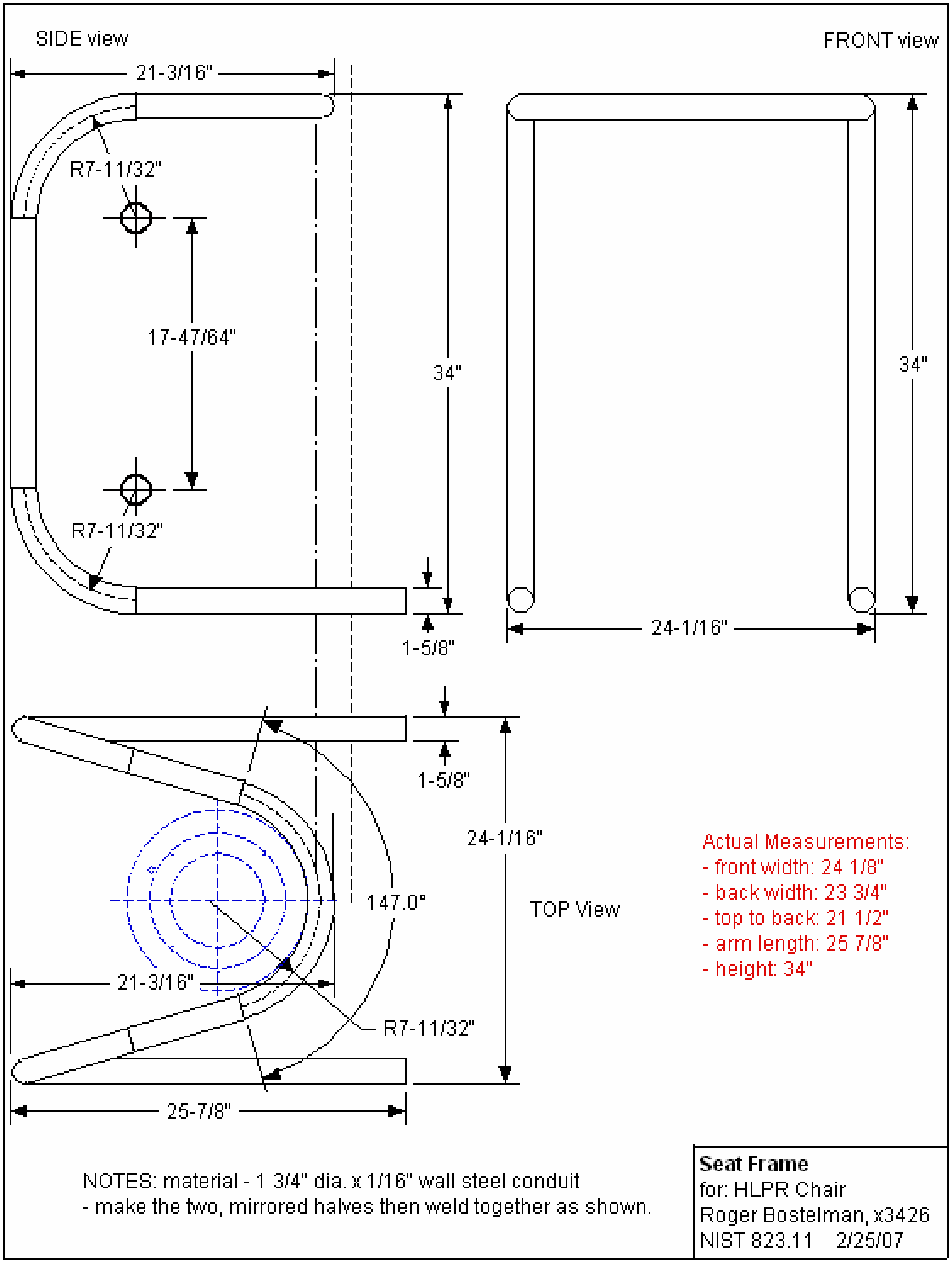

1.00"
0.30"
4.91"
3.20"
1.70"
1.37"
0.87"
1.30"
drill one 3/8" dia. through hole
drill one 1/2" dia. through hole
1.50"
1.30"
0.65"
drill one Ø1.00" through hole centered on part
0.75"
1.50"
Make one part
Use Alum. 6061material
Actuator to Pulley Coupling
for: HLPR Chair
Robert Vlacich
NIST 6/7/07

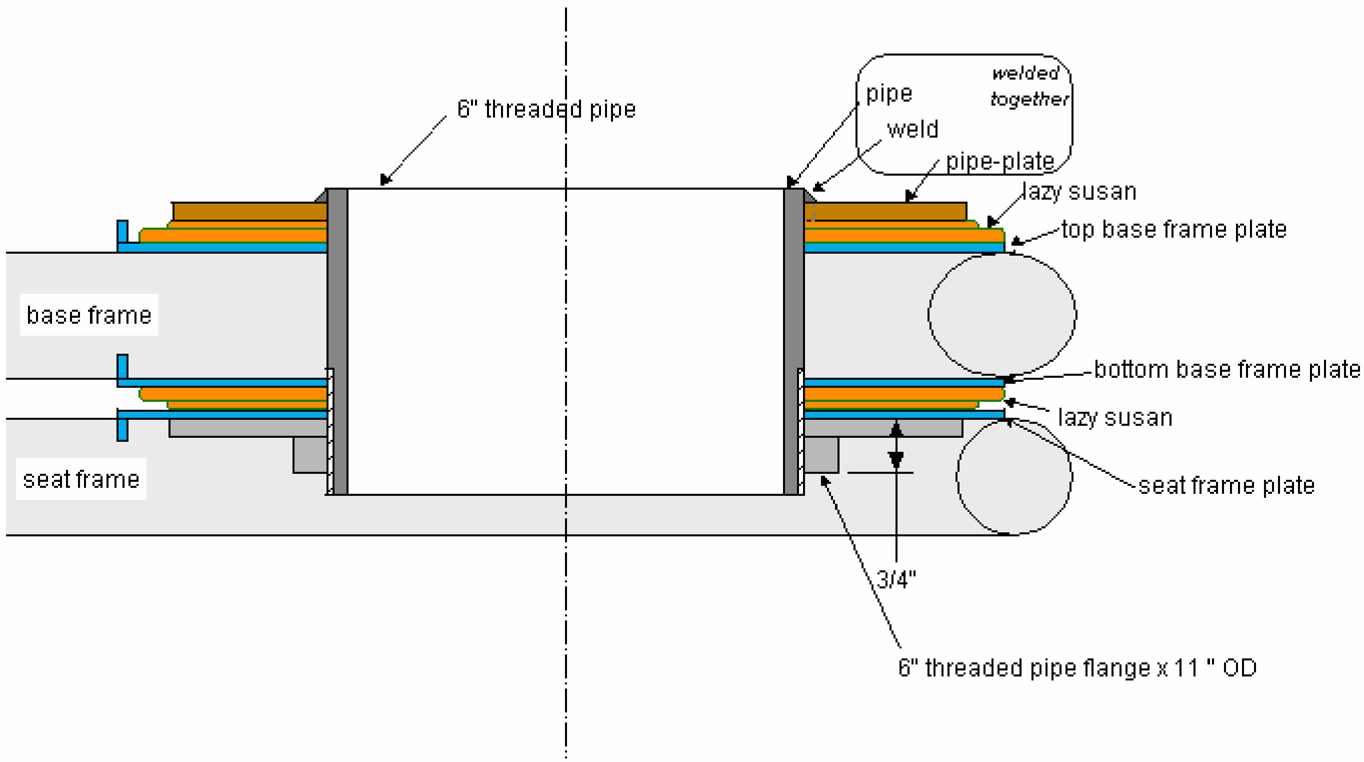
Modifications to Original Designs




13"
14"
back view
edge view
13"
weld along seam
(both sides)
Note:
Weld two steel angles 1 1/2" x 1 1/2" x 1/8" th. x 14" long,
NIST # 53168to back as shown.
Lift Plate back angles
for: RoboChair Ph2
Roger Bostelman
NIST 2/22/07

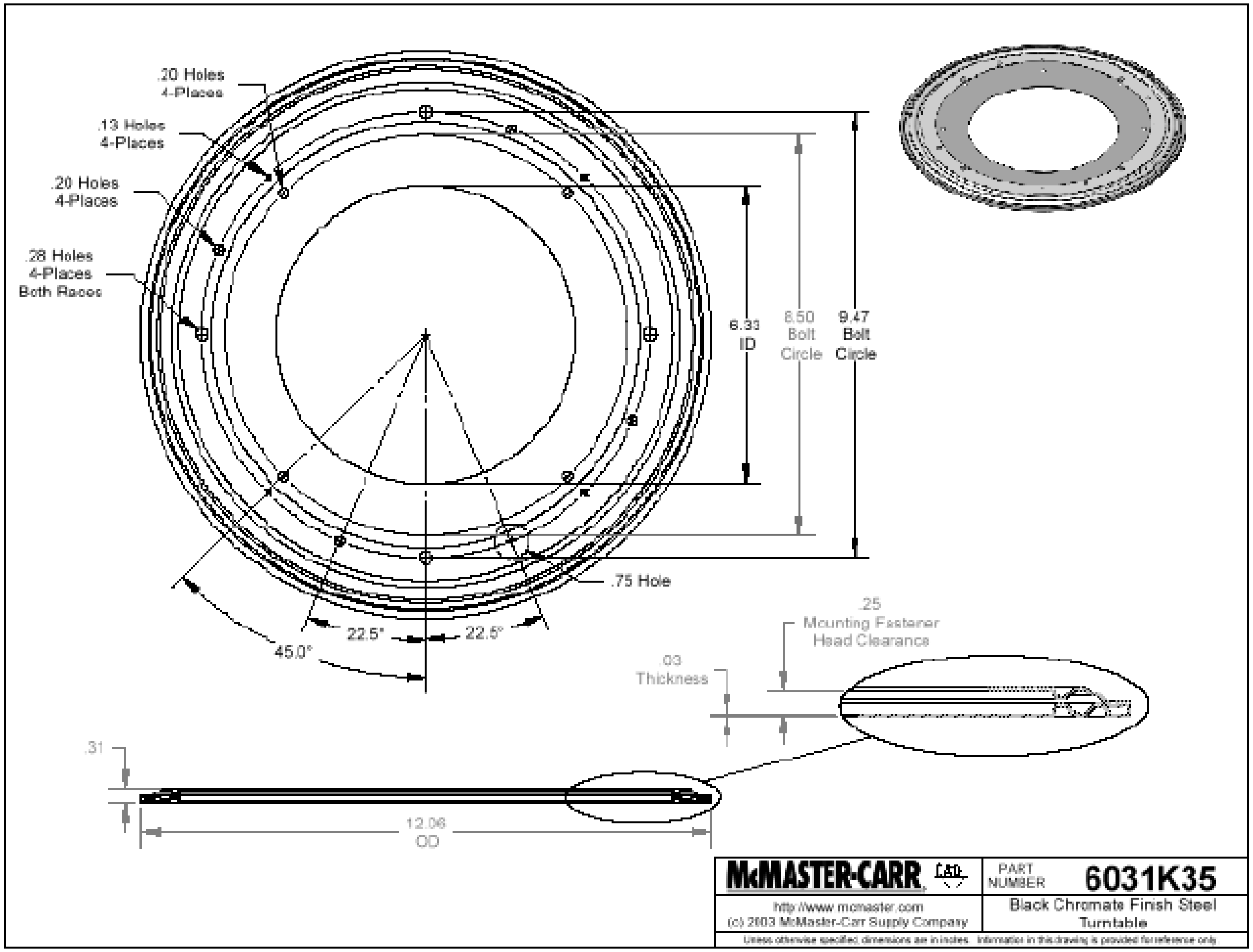

centered right to left
top edge of plate
3/8"
1/2"
5/8"
5/8"
3/8"
drill 3/16" dia thru-hole
3/4"
1"
6-5/8"
side view of lift bar
weld to plate on top and bottom 1" long on R & L sides of 1/2" bar
bottom, right of bar
back of lift plate
Notes:
Make one part, weld it to lift plate (supplied)
Aluminum, 6061 bar stock.
Lift Bar
for: HLPR Chair
Roger Bostelman 2/10/06
NIST 823.11 rvsd 6/7/06


SIDE view
FRONT view
21-3/16"
R7-11/32"
17-47/64"
34"
R7-11/32"
1-5/8"
34"
24-1/16"
1-5/8"
24-1/16"
147.0"
TOP View
21-3/16"
R7-11/32"
25-7/8"
Actual Measurements:
- front width: 24 1/8"
- back width: 23 3/4"
- top to back: 21 1/2"
- arm length: 25 7/8"
- height: 34"
NOTES: material - 1 3/4" dia. x 1/16" wall steel conduit
- make the two, mirrored halves then weld together as shown.
Seat Frame
for: HLPR Chair
Roger Bostelman, x3426
NIST 823.11 2/25/07

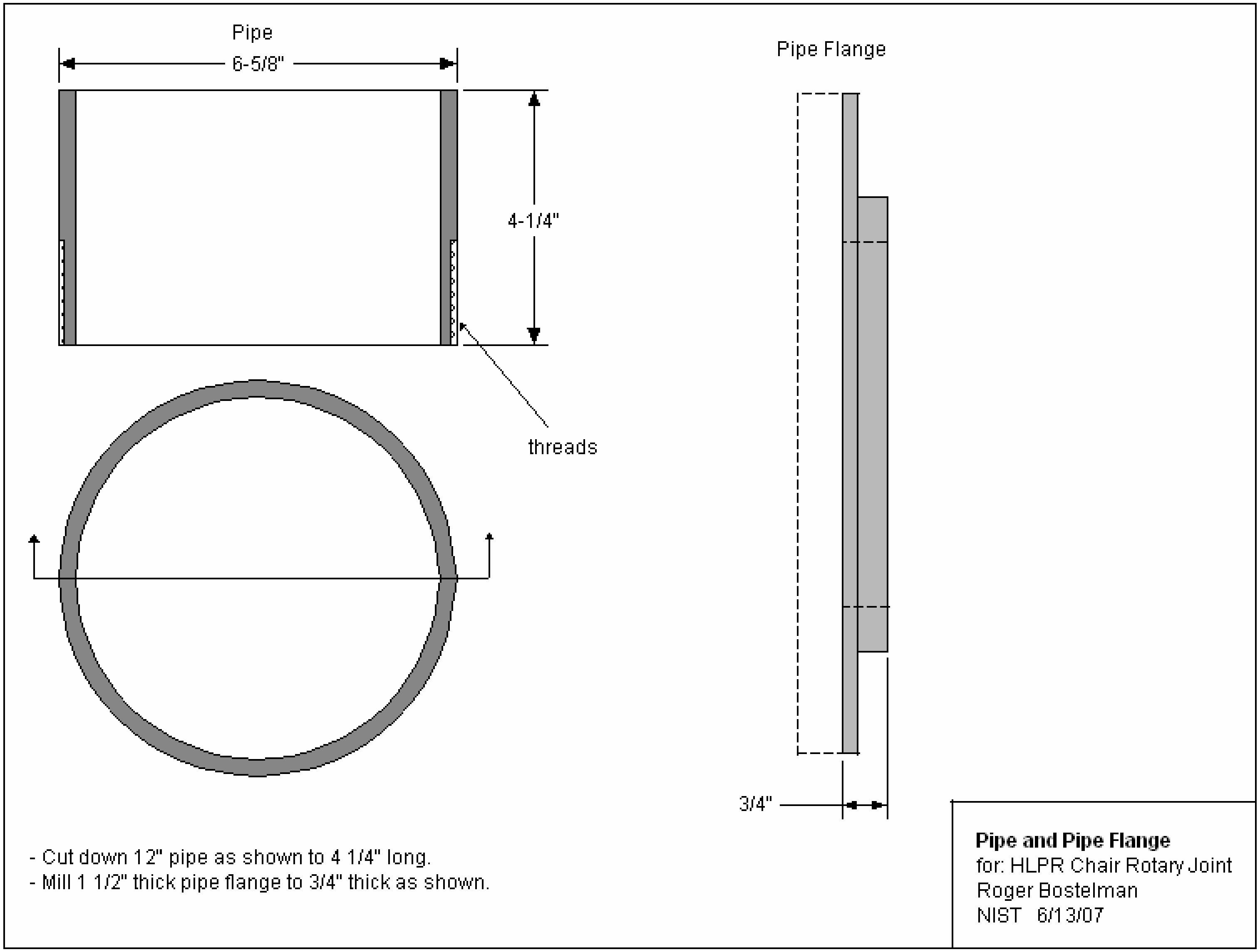


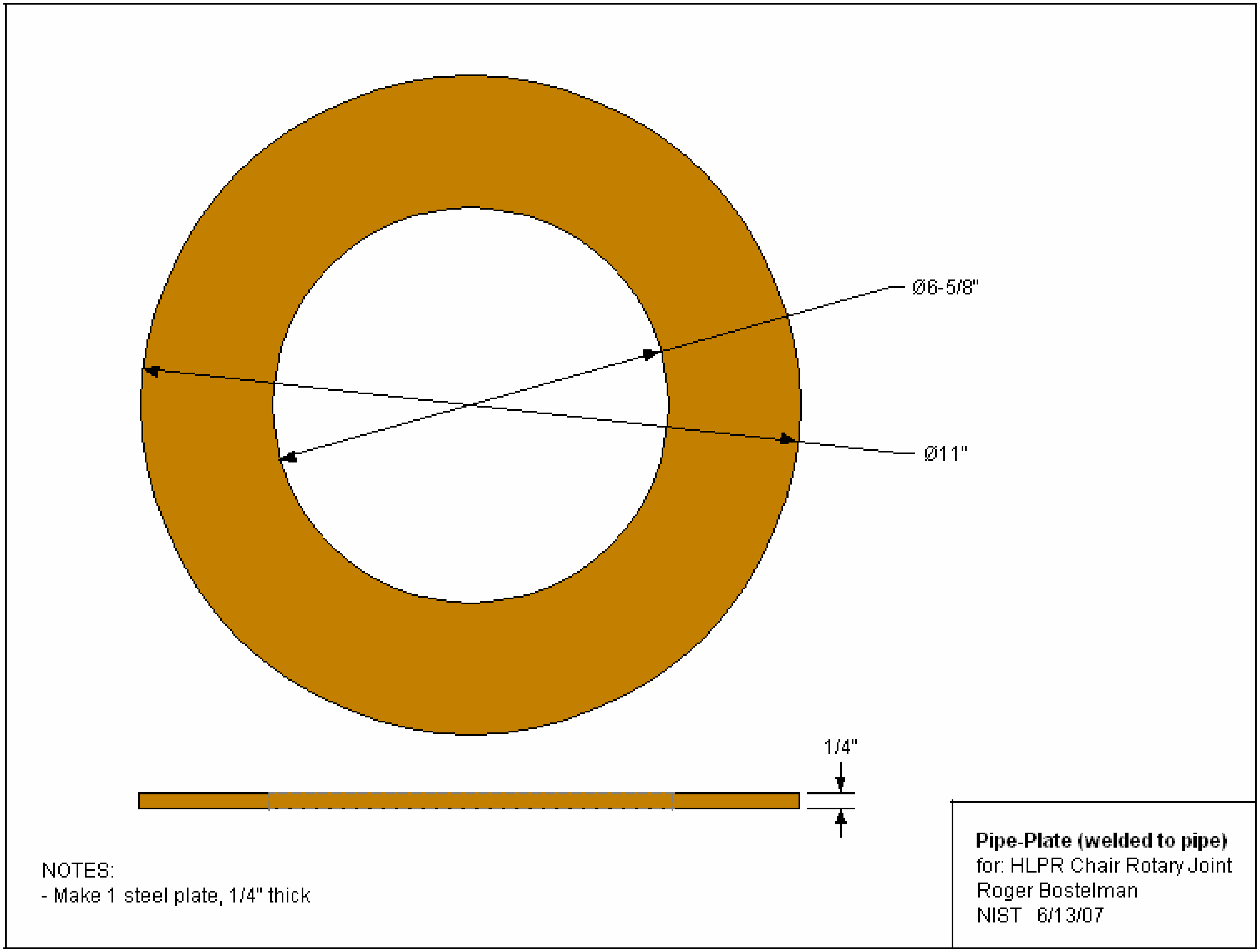
NOTES:
- pipe flange screws on pipe threads to compress:
  - seat frame with welded seat plate against:
  - bottom lazy susan against:
  - bottom plate (welded to bottom of base frame) against:
  - top plate (welded to top of base frame) against:
  - top lazy susan against:
  - pipe-plate (welded to pipe top).
- allowing seat frame to rotate with respect to base frame.

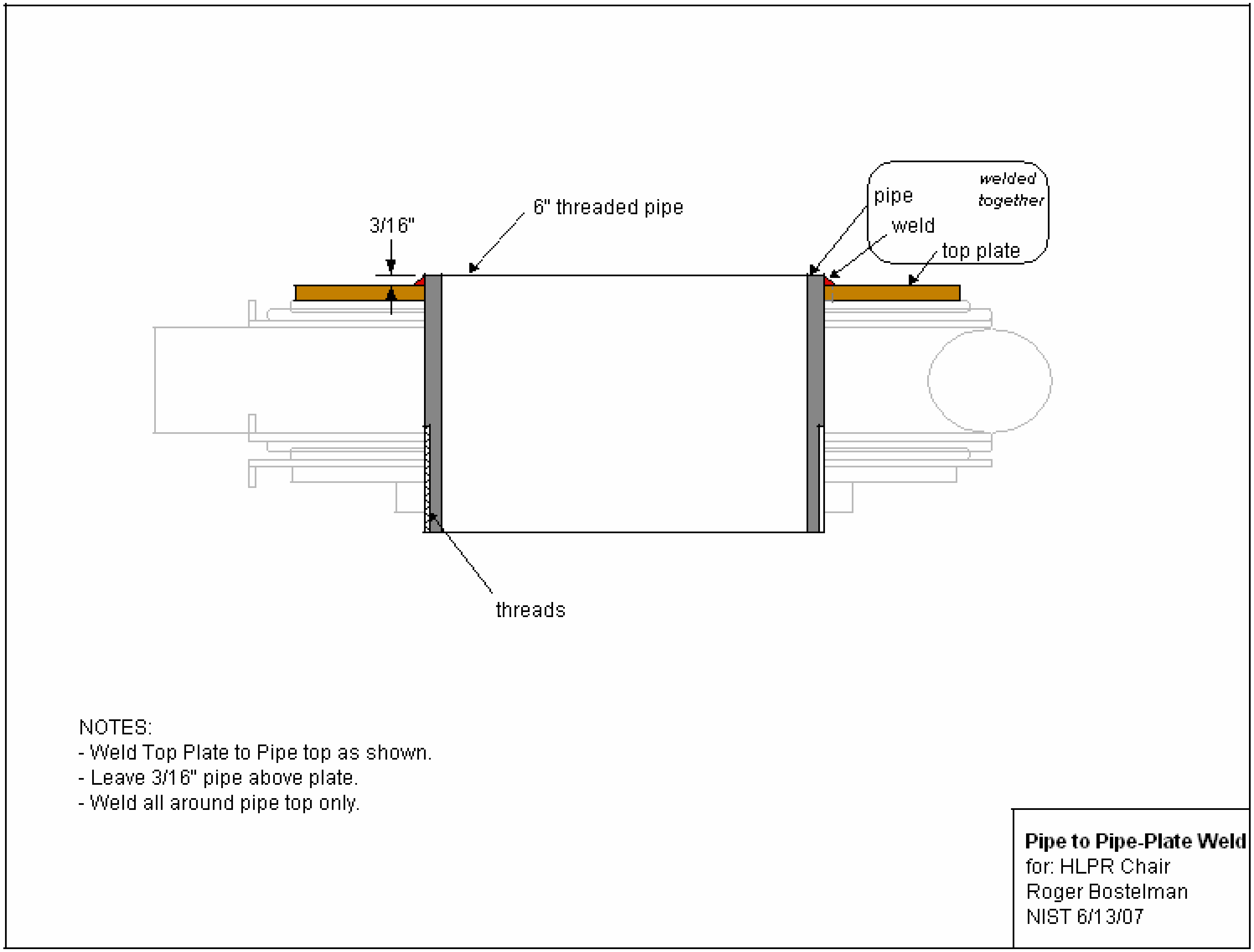
Rotary Joint Design
for: HLPR Chair
Roger Bostelman
NIST 6/7/07

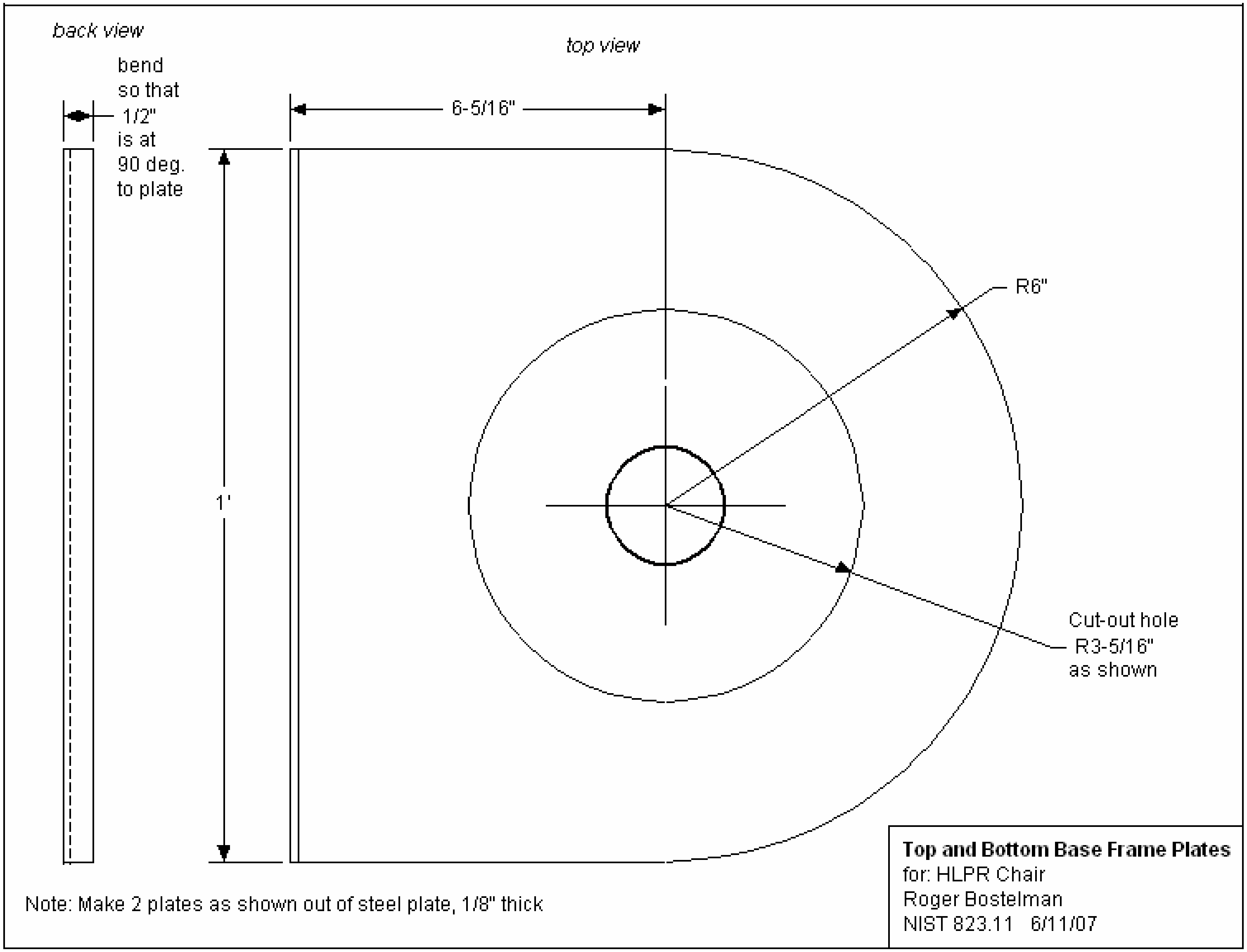


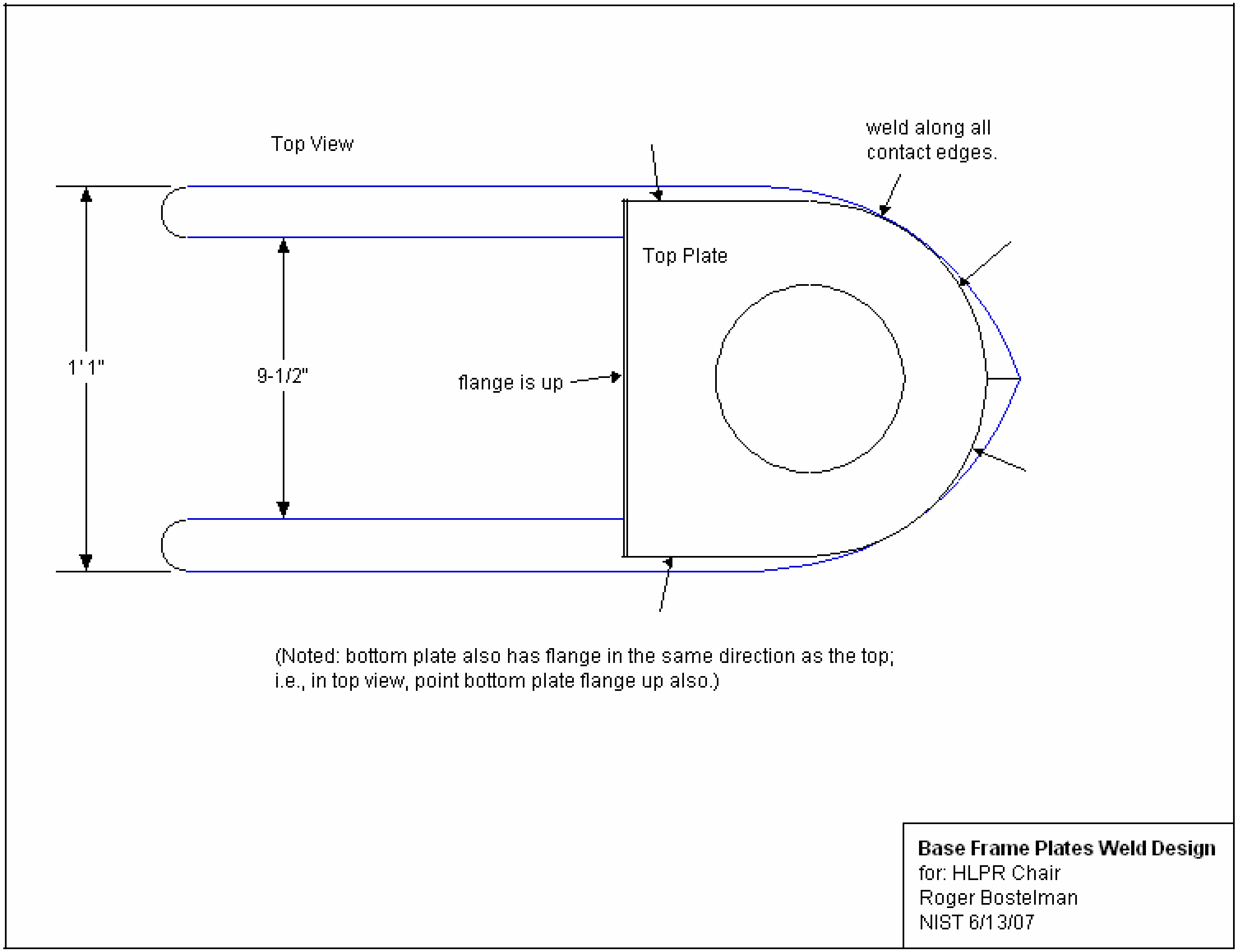
This drawing provided courtesy of McMaster-Carr. Other manufactured turntables could also be used.

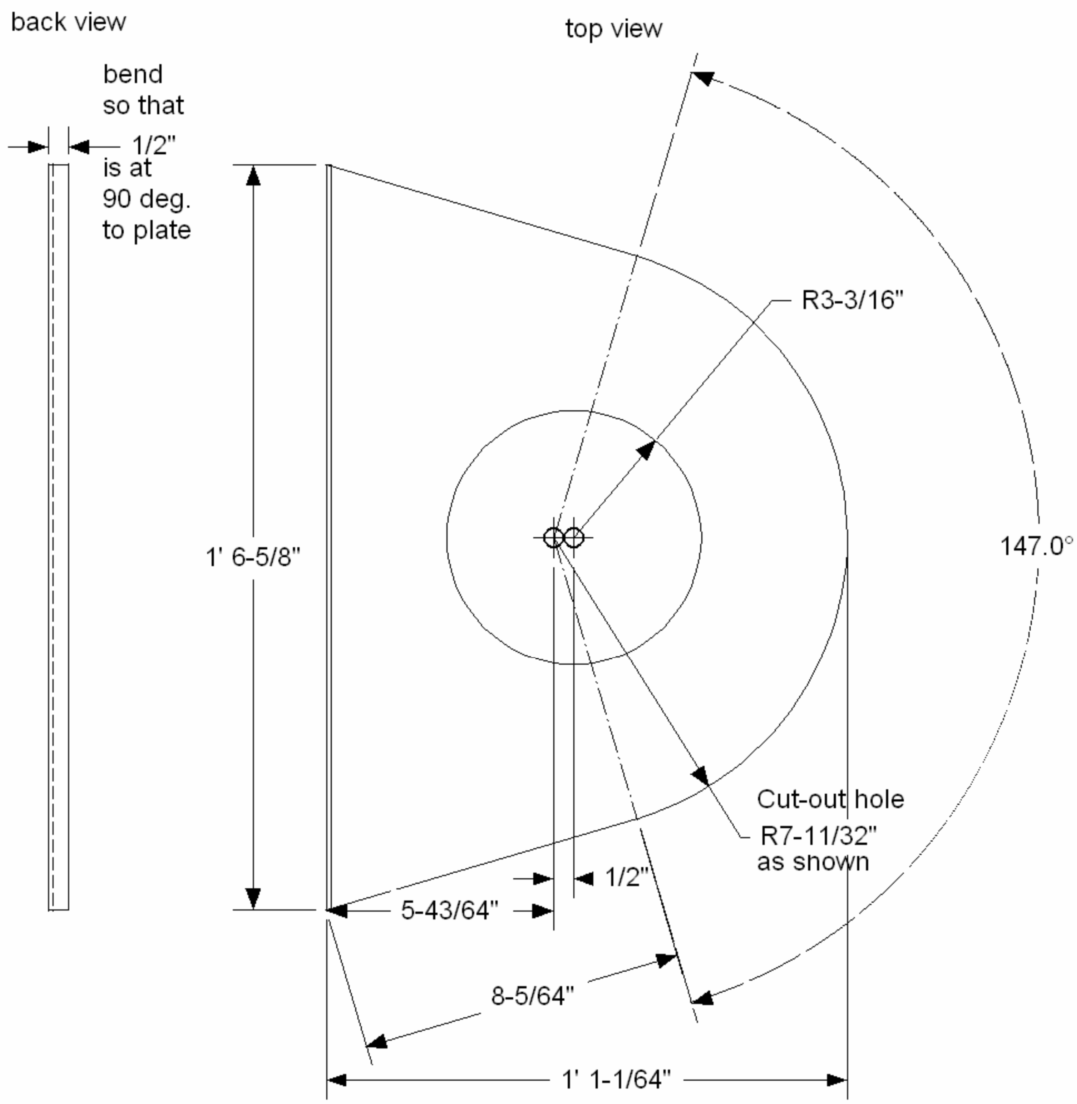

Pipe
6-5/8"
4-1/4"
threads
Pipe Flange
3/4"
- Cut down 12" pipe as shown to 4 1/4" long.
- Mill 1 1/2" thick pipe flange to 3/4" thick as shown.
Pipe and Pipe Flange
for: HLPR Chair Rotary Joint
Roger Bostelman
NIST 6/13/07


Ø6-5/8"
Ø11"
1/4"
NOTES:
- Make 1 steel plate, 1/4" thick
Pipe-Plate (welded to pipe)
for: HLPR Chair Rotary Joint
Roger Bostelman
NIST 6/13/07


6" threaded pipe
3/16"
pipe
weld
welded together
top plate
threads
NOTES:
- Weld Top Plate to Pipe top as shown.
- Leave 3/16" pipe above plate.
- Weld all around pipe top only.
Pipe to Pipe-Plate Weld
for: HLPR Chair
Roger Bostelman
NIST 6/13/07

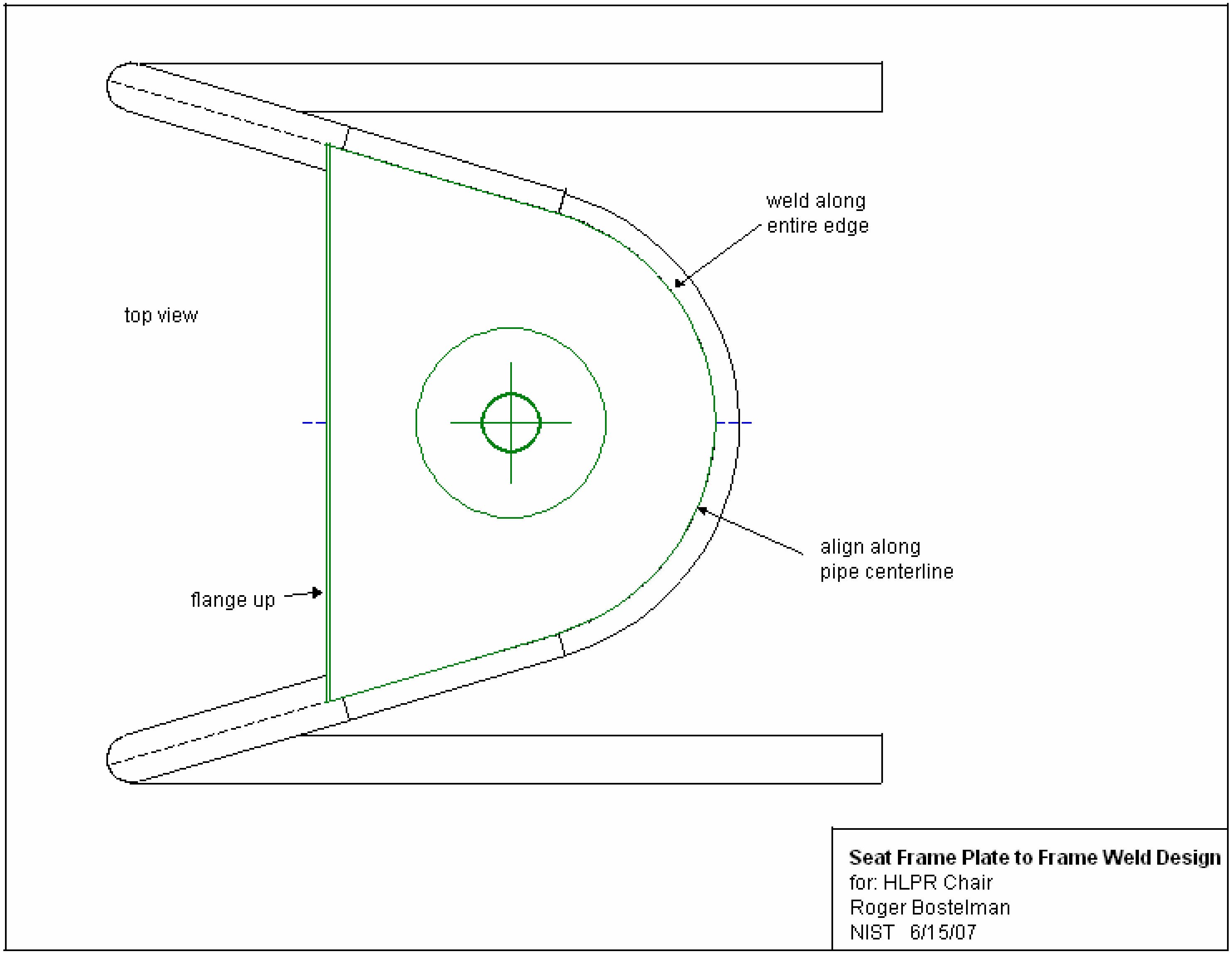

back view
bend
so that
1/2"
is at
90 deg.
to plate
top view
6-5/16"
1'
R6"
Cut-out hole
R3-5/16"
as shown
Note: Make 2 plates as shown out of steel plate, 1/8" thick
Top and Bottom Base Frame Plates
for: HLPR Chair
Roger Bostelman
NIST 823.11 6/11/07

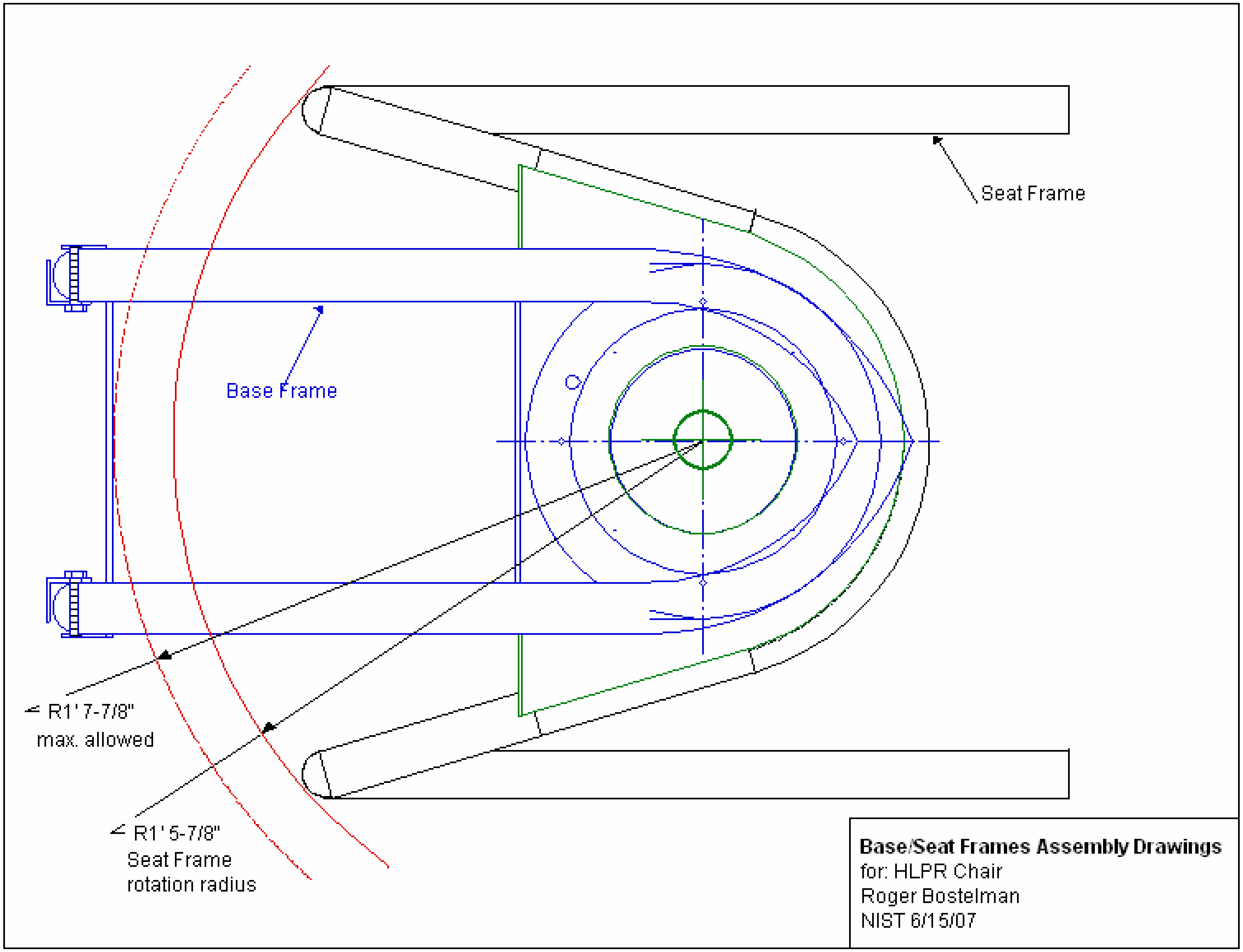

Top View
weld along all
contact edges.
Top Plate
1' 1"
9-1/2"
flange is up
(Noted: bottom plate also has flange in the same direction as the top;
i.e., in top view, point bottom plate flange up also.)
Base Frame Plates Weld Design
for: HLPR Chair
Roger Bostelman
NIST 6/13/07

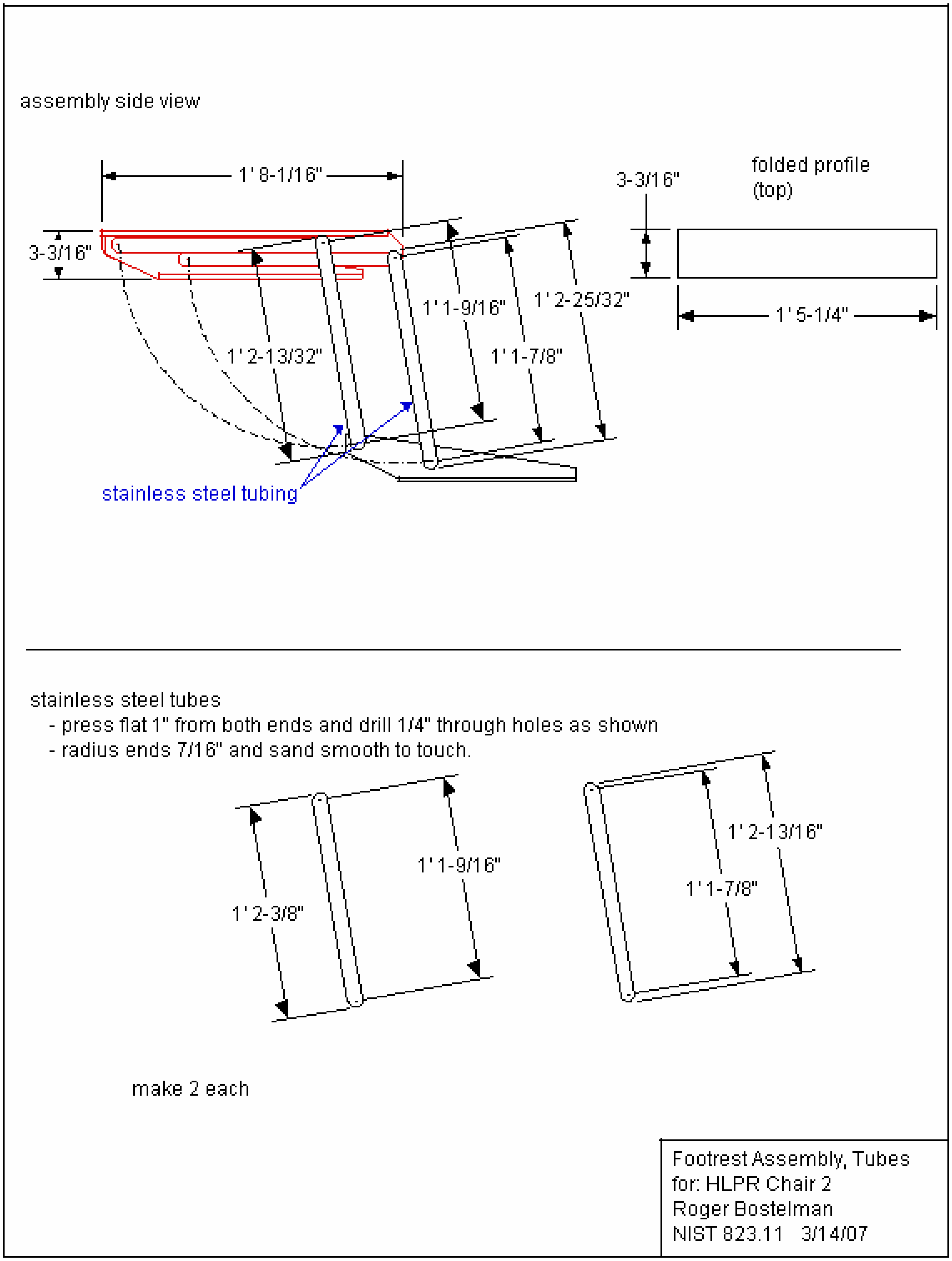


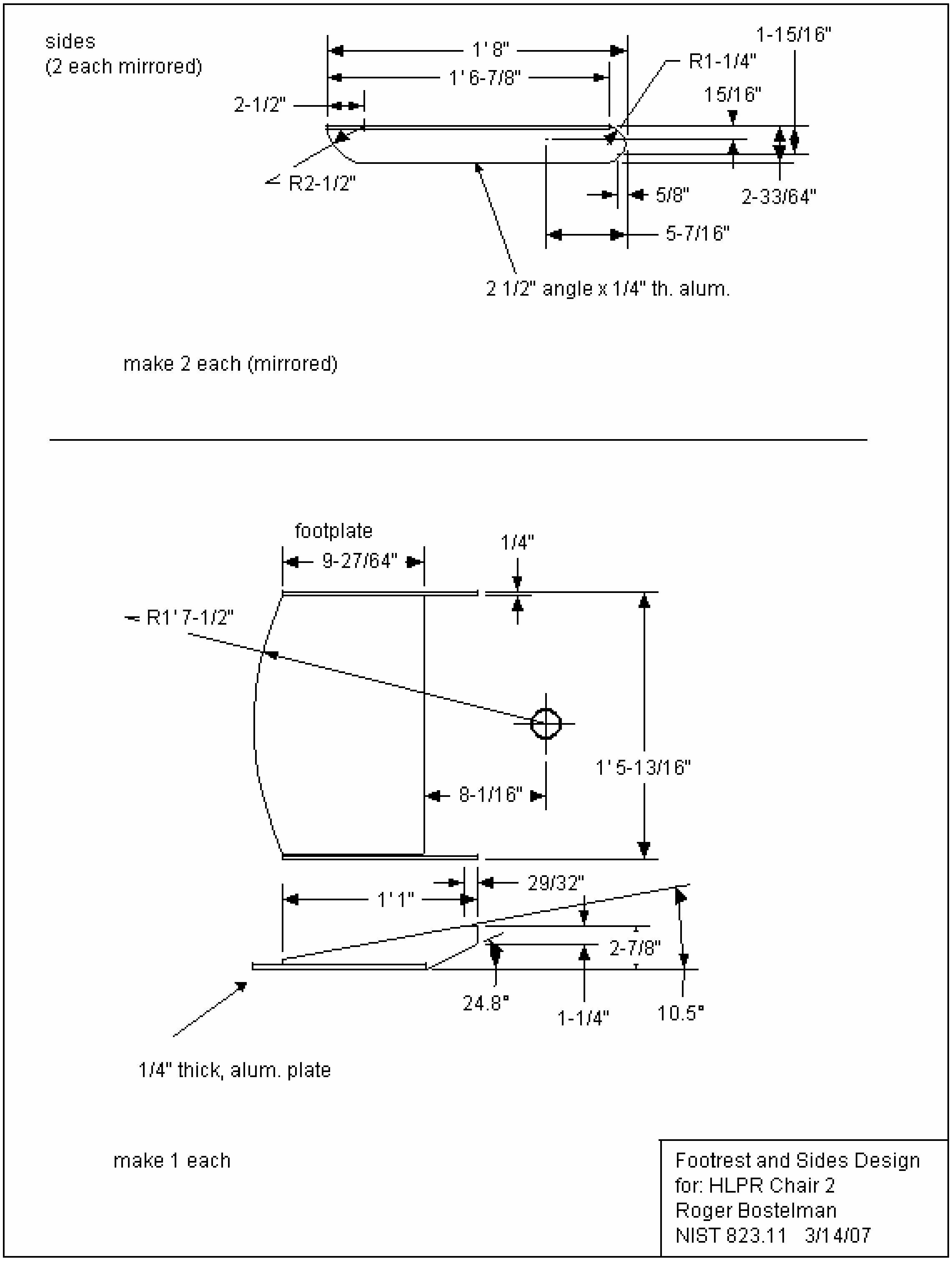
Note: Make 1 plate as shown out of steel plate, 1/8" thick

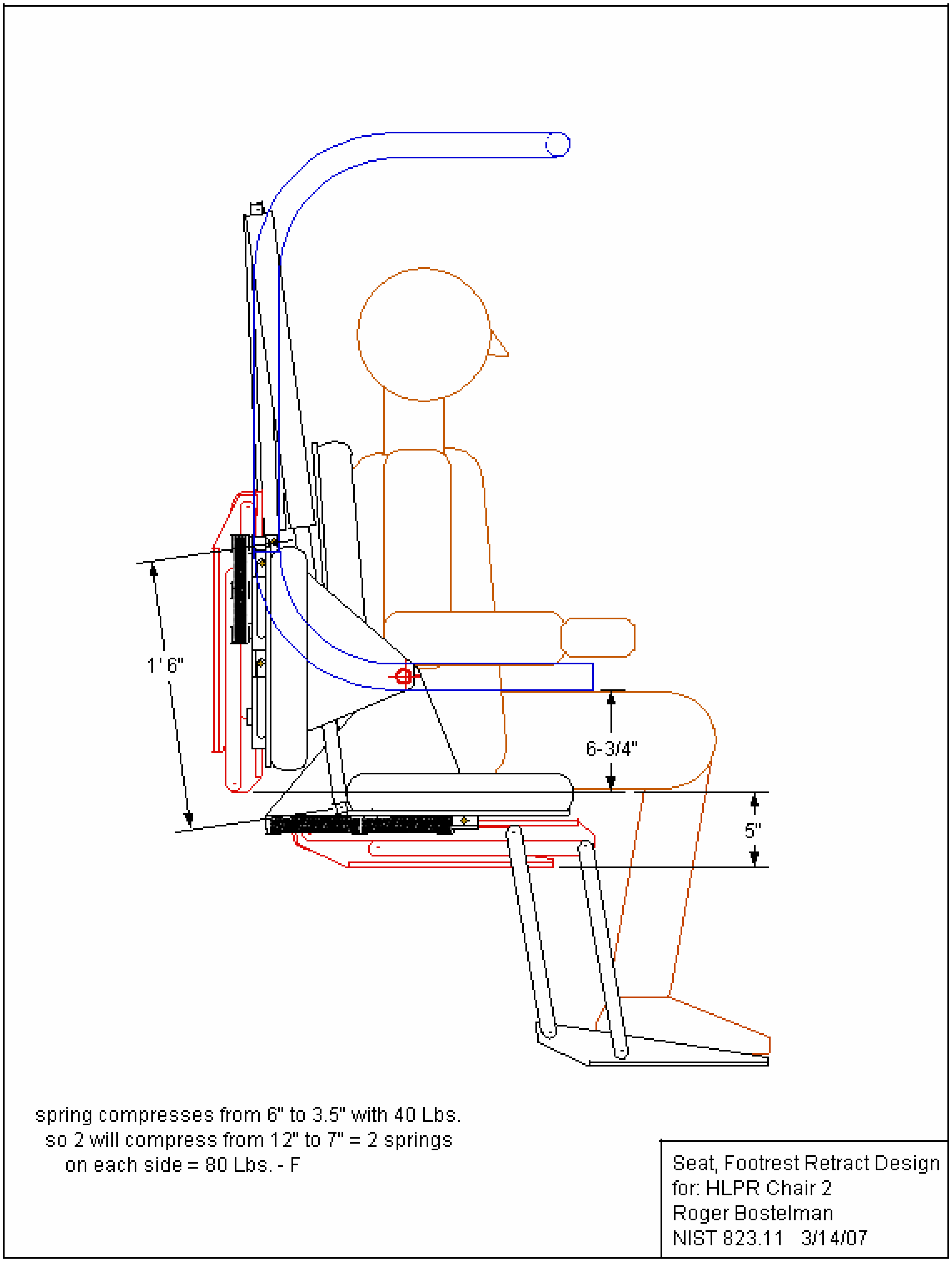
Seat Frame Plate
for: HLPR Chair
Roger Bostelman
NIST 823.11 6/11/07

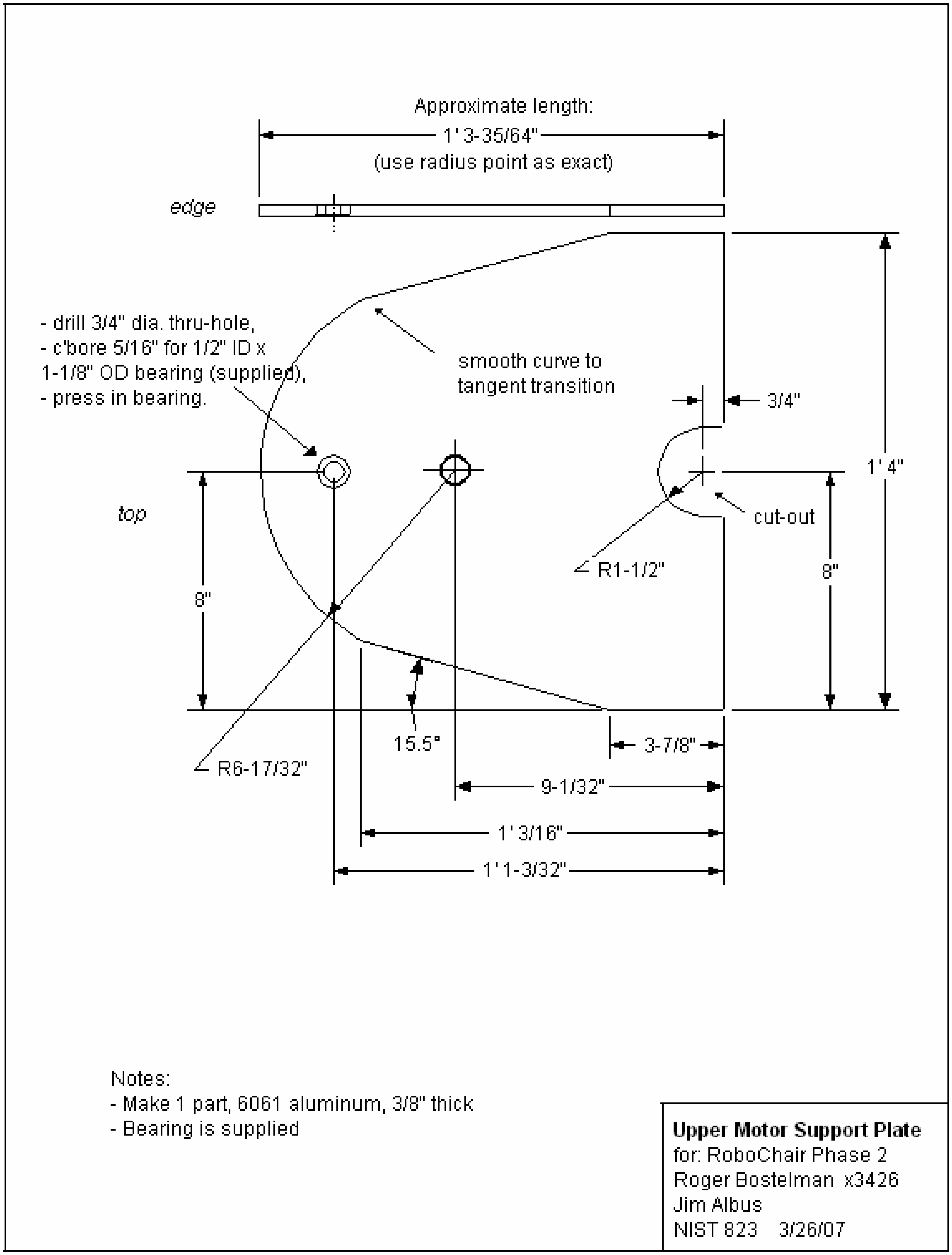

weld along
entire edge
top view
align along
pipe centerline
flange up
Seat Frame Plate to Frame Weld Design
for: HLPR Chair
Roger Bostelman
NIST 6/15/07

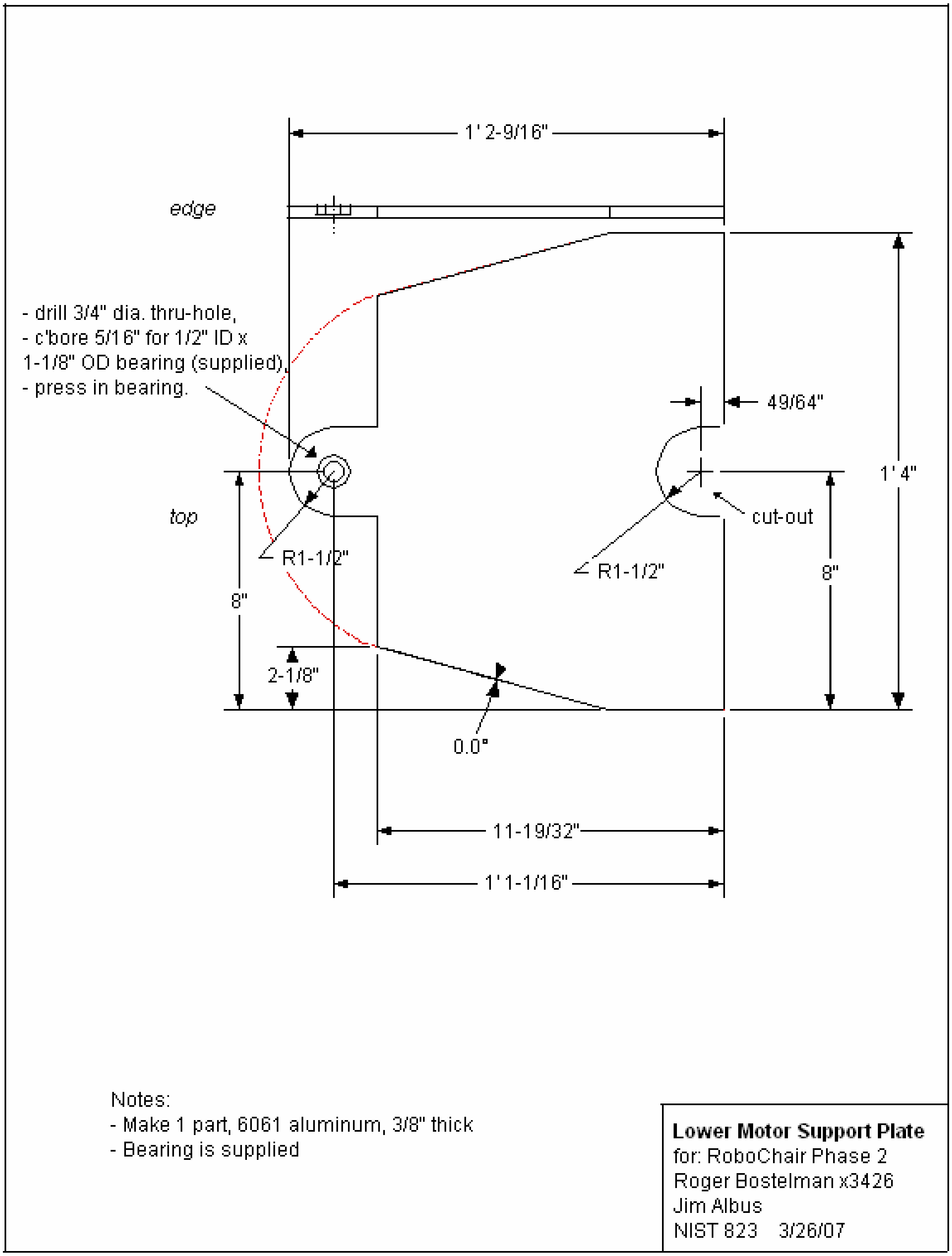

Seat Frame
Base Frame
R1' 7-7/8"
max. allowed
R1' 5-7/8"
Seat Frame
rotation radius
Base/Seat Frames Assembly Drawings
for: HLPR Chair
Roger Bostelman
NIST 6/15/07


assembly side view
1' 8-1/16"
3-3/16"
3-3/16"
folded profile
(top)
1' 5-1/4"
1' 1-9/16"
1' 2-25/32"
1' 2-13/32"
1' 1-7/8"
stainless steel tubing
stainless steel tubes
- press flat 1" from both ends and drill 1/4" through holes as shown
- radius ends 7/16" and sand smooth to touch.
1' 1-9/16"
1' 2-3/8"
1' 2-13/16"
1' 1-7/8"
make 2 each
Footrest Assembly, Tubes
for: HLPR Chair 2
Roger Bostelman
NIST 823.11 3/14/07

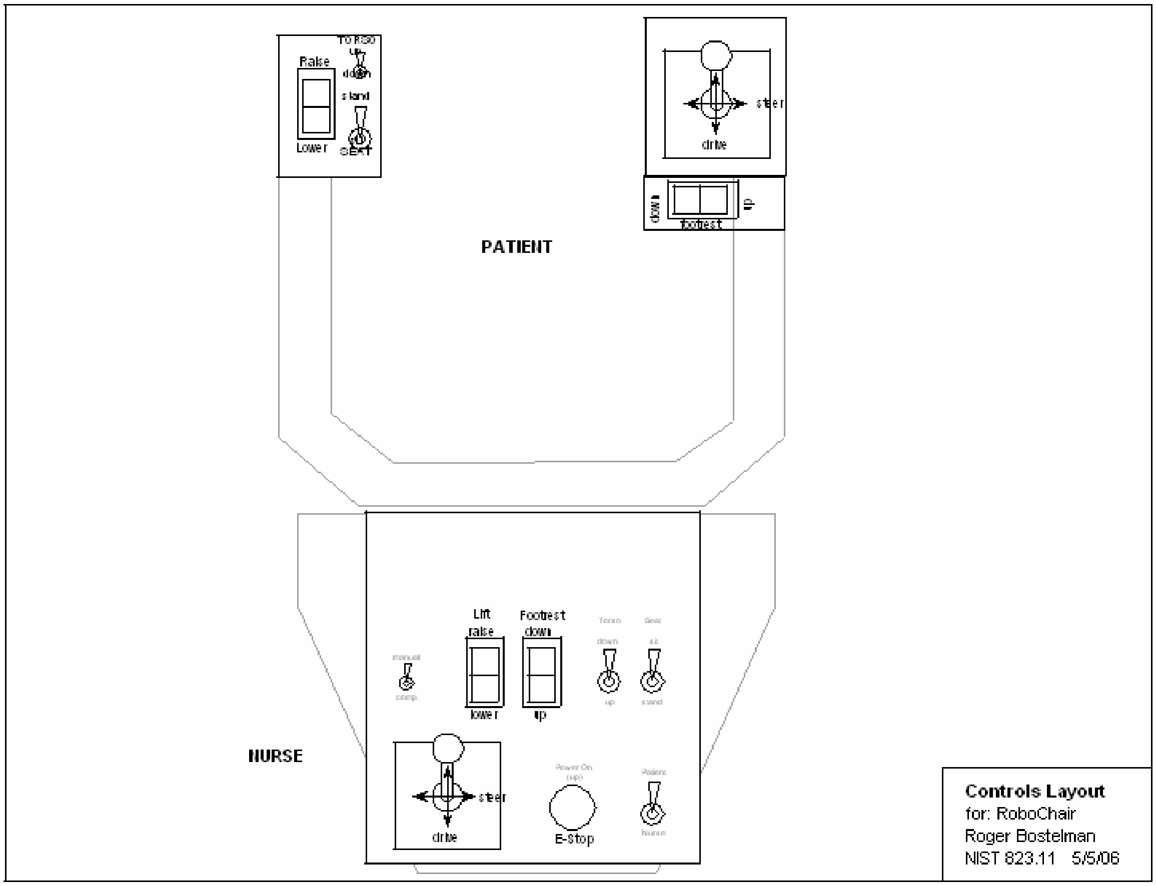

sides
(2 each mirrored)
1' 8"
1' 6-7/8"
2-1/2"
R1-1/4"
1-15/16"
15/16"
R2-1/2"
5/8"
2-33/64"
5-7/16"
2 1/2" angle x 1/4" th. alum.
make 2 each (mirrored)
footplate
9-27/64"
1/4"
R1' 7-1/2"
1' 5-13/16"
8-1/16"
29/32"
1' 1"
2-7/8"
24.8°
1-1/4"
10.5°
1/4" thick, alum. plate
make 1 each
Footrest and Sides Design
for: HLPR Chair 2
Roger Bostelman
NIST 823.11 3/14/07

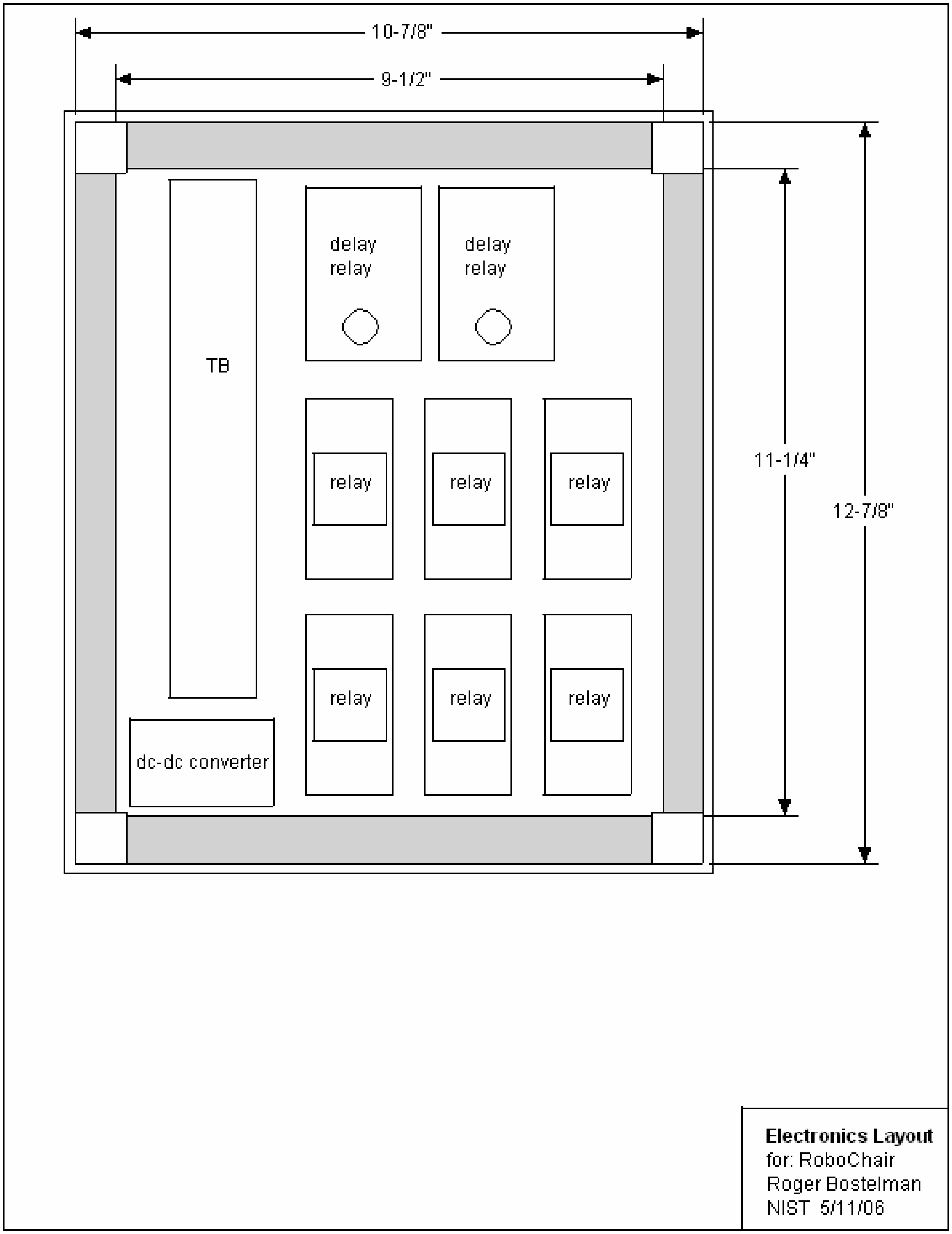

1' 6"
6-3/4"
5"
spring compresses from 6" to 3.5" with 40 Lbs.
so 2 will compress from 12" to 7" = 2 springs
on each side = 80 Lbs. - F
Seat, Footrest Retract Design
for: HLPR Chair 2
Roger Bostelman
NIST 823.11 3/14/07

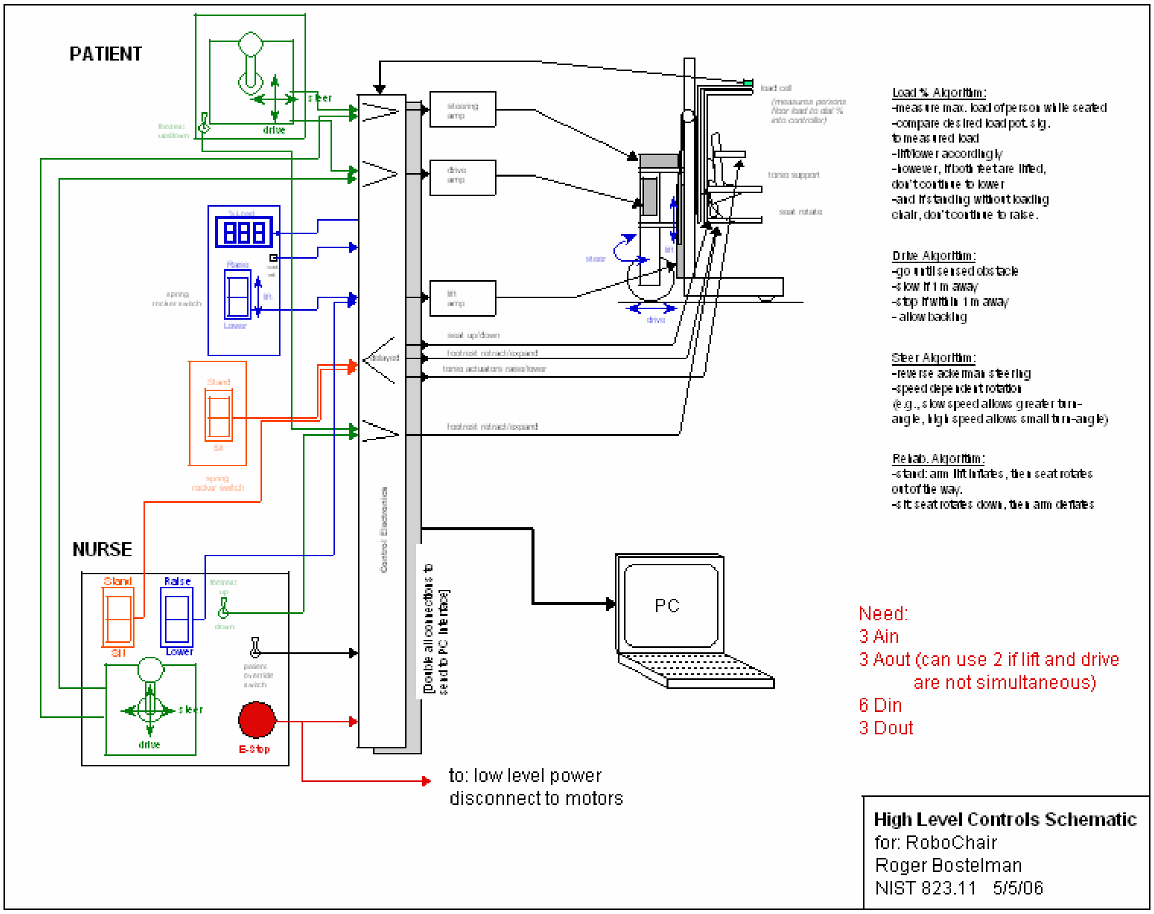

Approximate length:
1' 3-35/64"
(use radius point as exact)
edge
- drill 3/4" dia. thru-hole,
- c'bore 5/16" for 1/2" ID x
1-1/8" OD bearing (supplied),
- press in bearing.
smooth curve to
tangent transition
3/4"
1' 4"
top
cut-out
R1-1/2"
8"
8"
15.5°
3-7/8"
R6-17/32"
9-1/32"
1' 3/16"
1' 1-3/32"
Notes:
- Make 1 part, 6061 aluminum, 3/8" thick
- Bearing is supplied
Upper Motor Support Plate
for: RoboChair Phase 2
Roger Bostelman x3426
Jim Albus
NIST 823 3/26/07

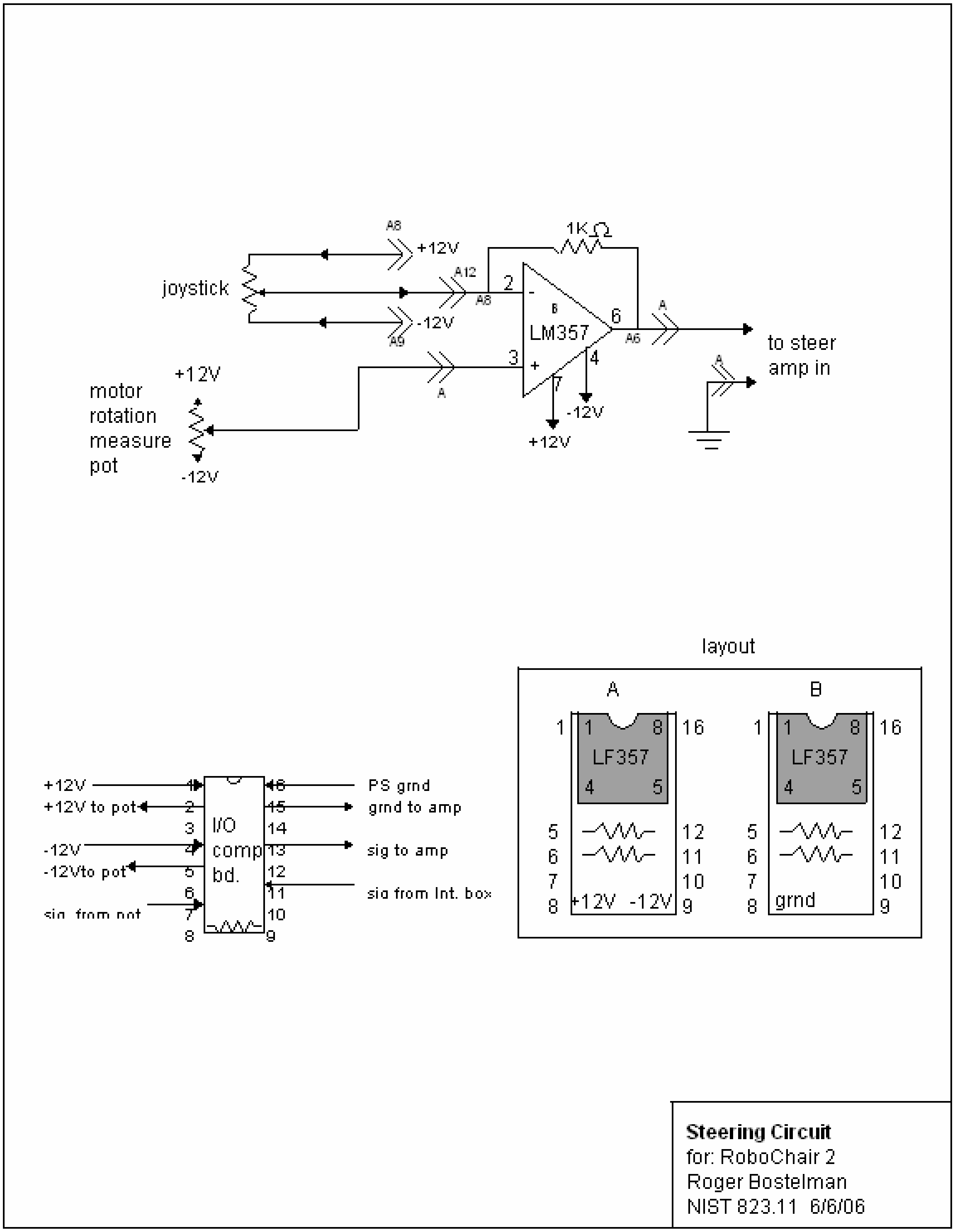

1' 2-9/16"
edge
- drill 3/4" dia. thru-hole,
- c'bore 5/16" for 1/2" ID x
1-1/8" OD bearing (supplied),
- press in bearing.
49/64"
1' 4"
top
cut-out
R1-1/2"
R1-1/2"
8"
8"
2-1/8"
0.0°
11-19/32"
1' 1-1/16"
Notes:
- Make 1 part, 6061 aluminum, 3/8" thick
- Bearing is supplied
Lower Motor Support Plate
for: RoboChair Phase 2
Roger Bostelman x3426
Jim Albus
NIST 823 3/26/07

Electrical Design

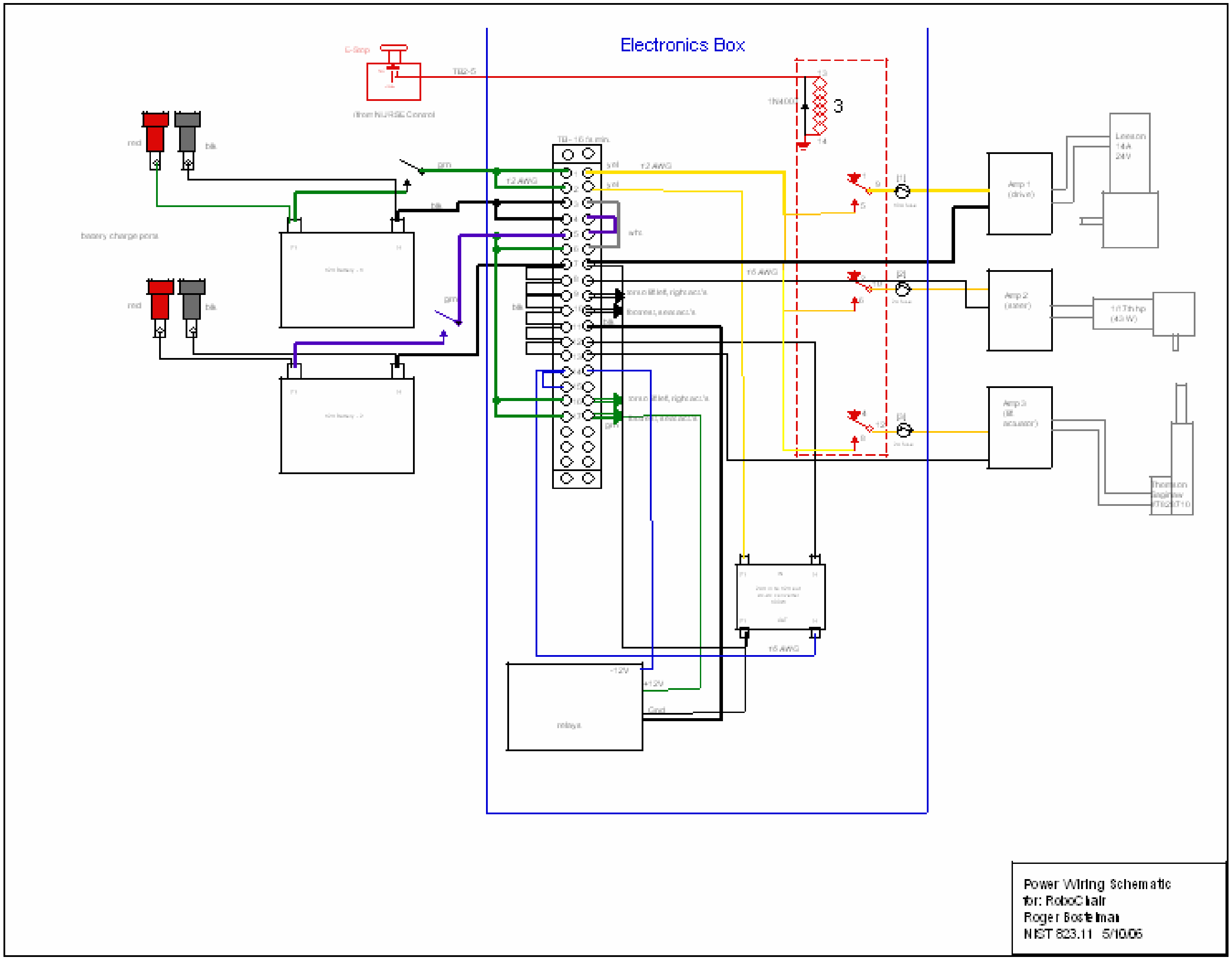


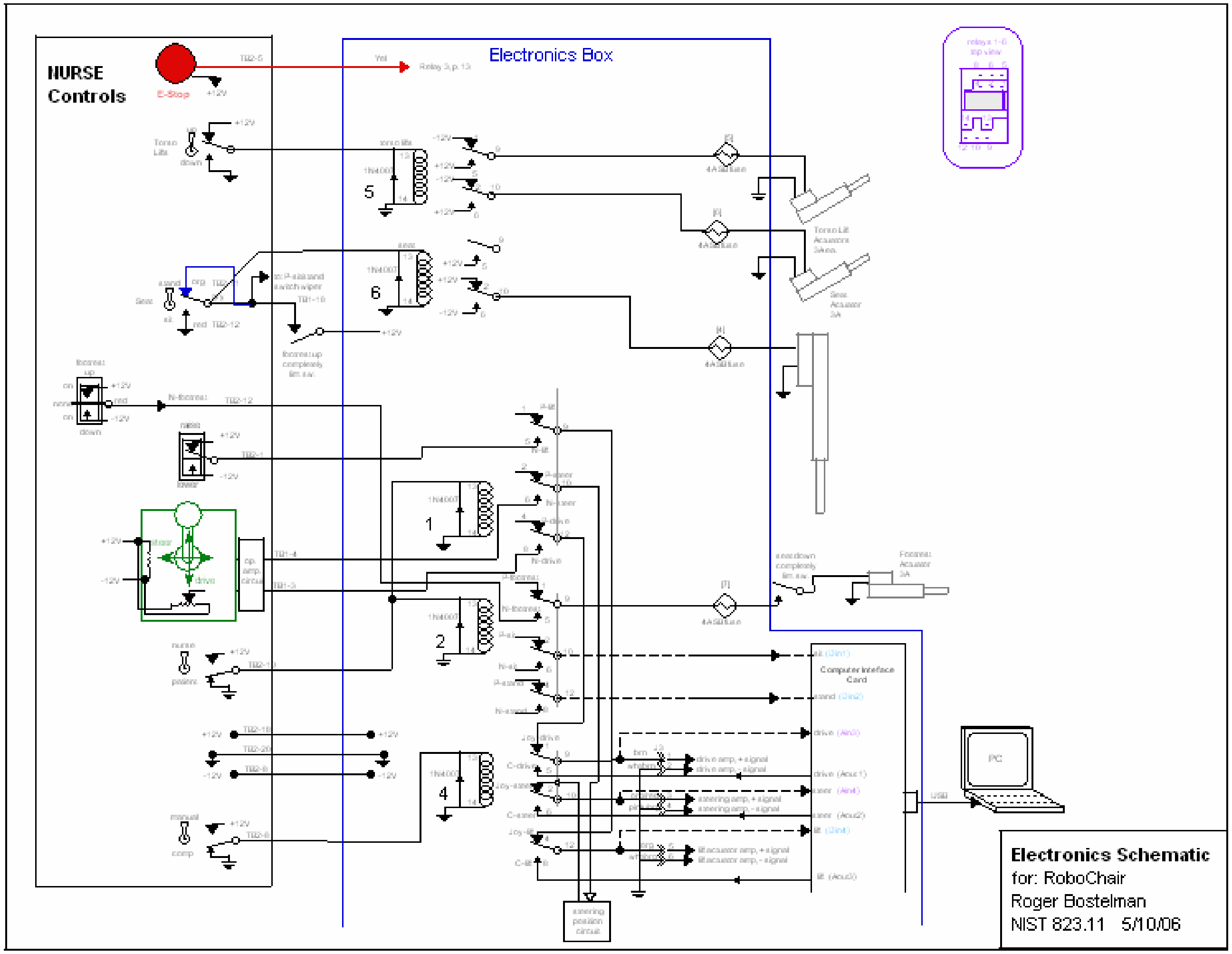

10-7/8"
9-1/2"
delay relay
delay relay
TB
relay
relay
relay
relay
relay
relay
dc-dc converter
11-1/4"
12-7/8"
Electronics Layout
for: RoboChair
Roger Bostelman
NIST 5/11/06

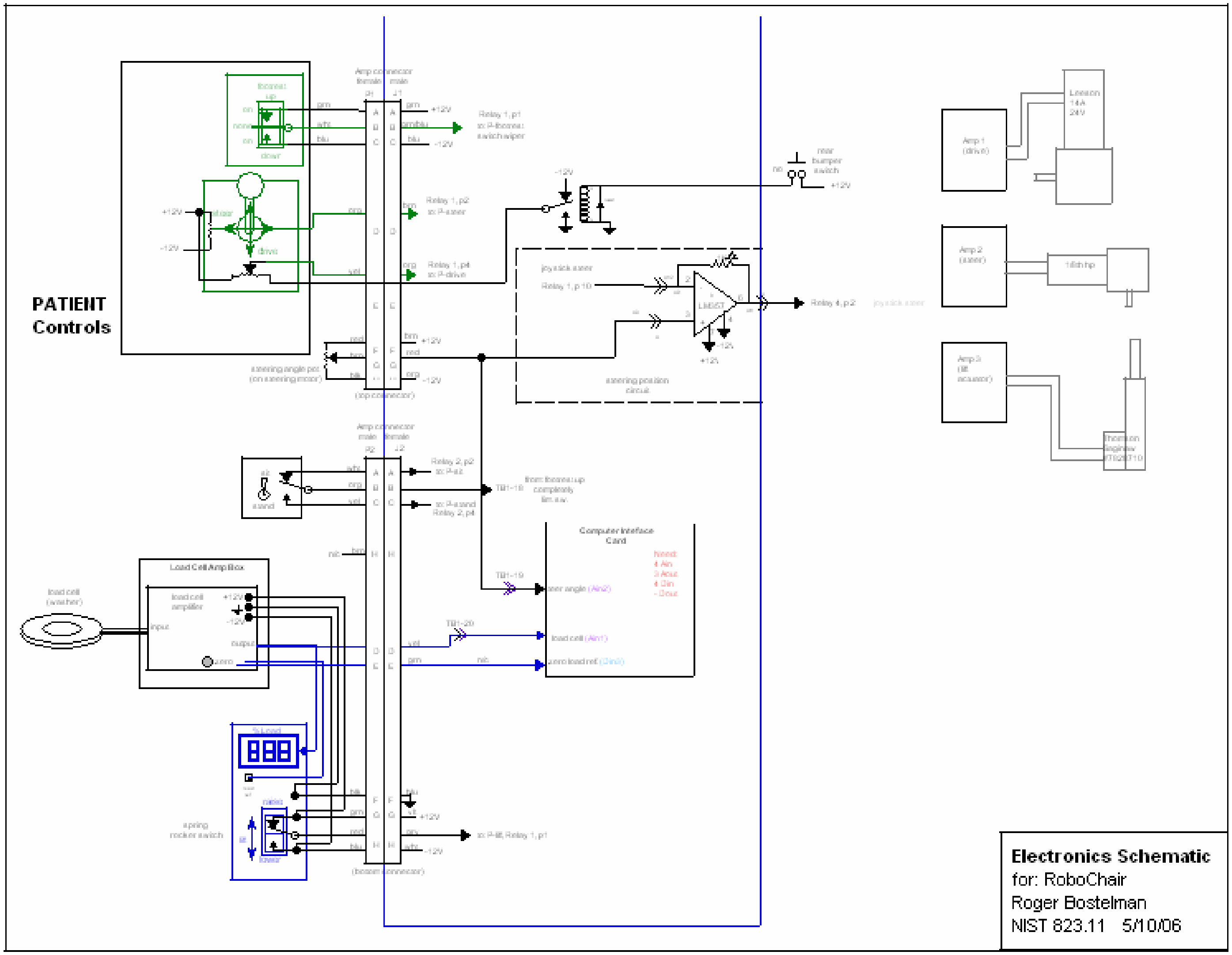

PATIENT
steer
drive
NURSE
Stand
Sit
Raise
Lower
steer
drive
E-Stop
Control Electronics
[Double all connections to send to PC interface]
steering amp
drive amp
lift amp
seat up/down
footrest retract/expand
torso actuators raise/lower
footrest retract/expand
steer
drive
lift
PC
Load % Algorithm:
-measure max. load of person while seated
-compare desired load pot. sig.
to measured load
-lift/lower accordingly
-however, if both feet are lifted,
don't continue to lower
-and if standing without loading
chair, don't continue to raise.
Drive Algorithm:
-go until sensed obstacle
-slow if 1 m away
-stop if within 1 m away
- allow backing
Steer Algorithm:
-reverse ackerman steering
-speed dependent rotation
(e.g., slow speed allows greater turn-
angle, high speed allows small turn-angle)
Rehab. Algorithm:
-stand: arm lift inflates, then seat rotates
out of the way.
-sit: seat rotates down, then arm deflates
Need:
3 Ain
3 Aout (can use 2 if lift and drive
are not simultaneous)
6 Din
3 Dout
to: low level power
disconnect to motors
High Level Controls Schematic
for: RoboChair
Roger Bostelman
NIST 823.11 5/5/06

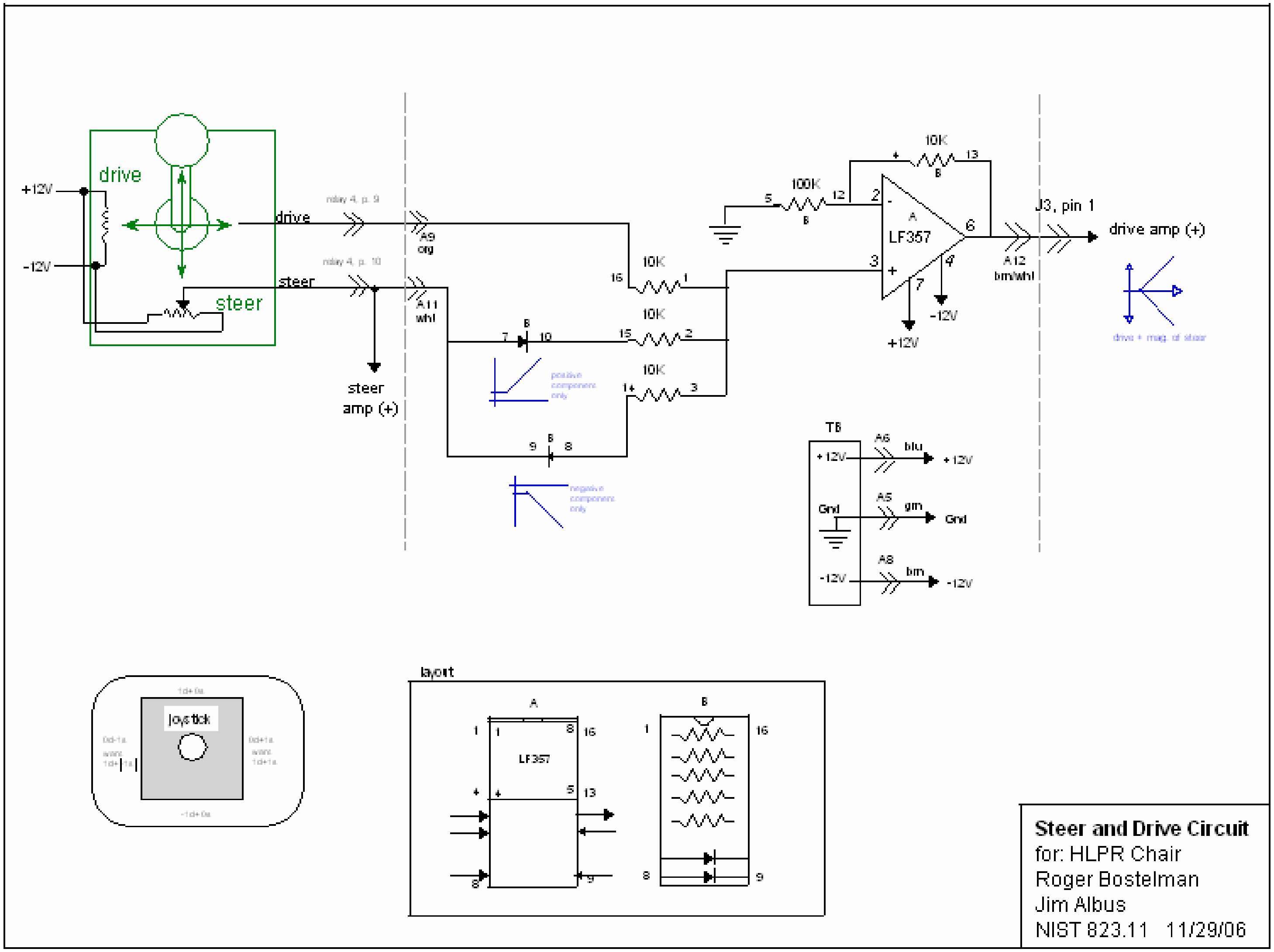


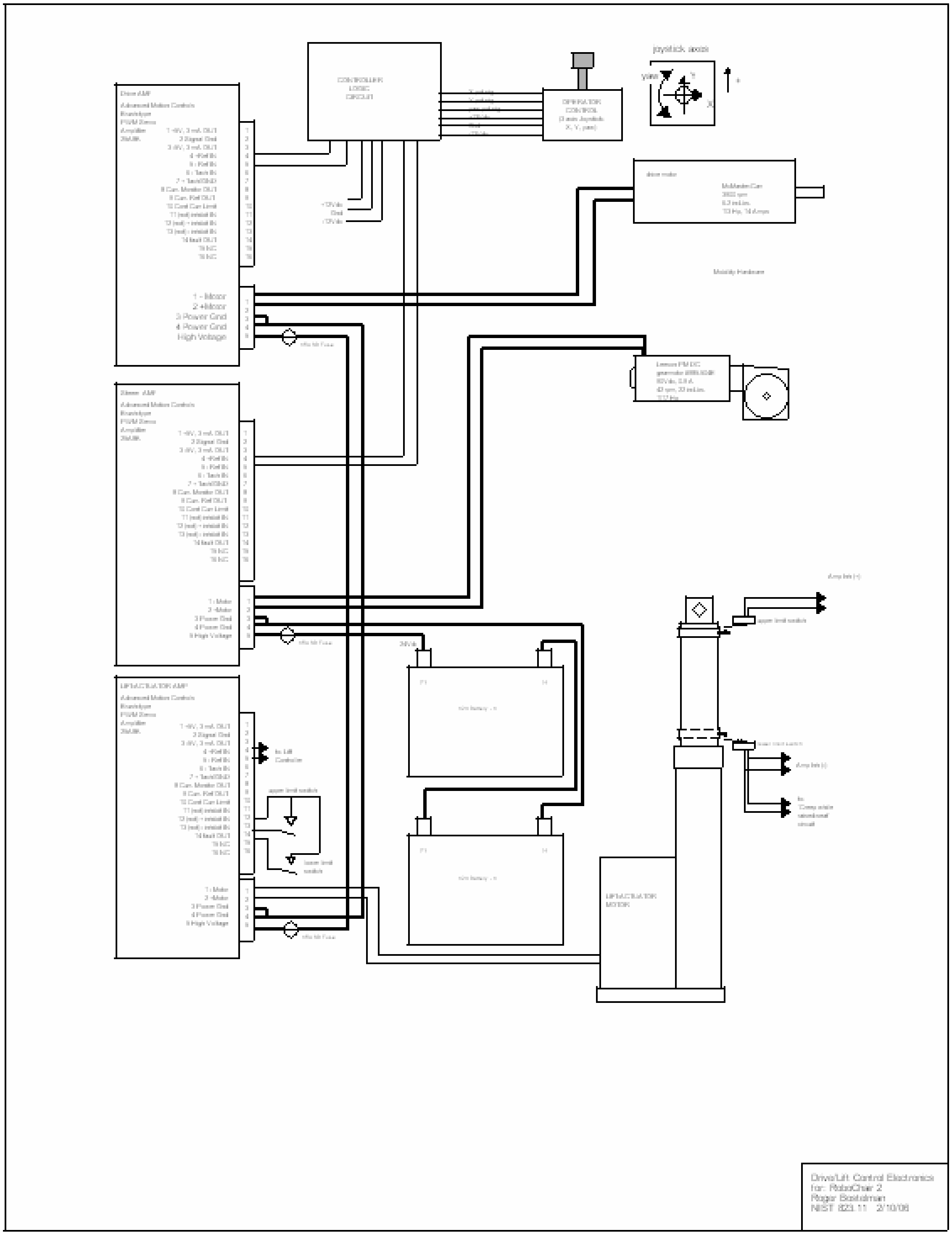
joystick
+12V
-12V
1KΩ
LM357
to steer
amp in
motor
rotation
measure
pot
layout
A
B
LF357
+12V -12V
grnd
PS grnd
grnd to amp
sig to amp
sig from Int. box
+12V to pot
-12Vto pot
sig from pot
I/O
comp
bd.
Steering Circuit
for: RoboChair 2
Roger Bostelman
NIST 823.11 6/6/06

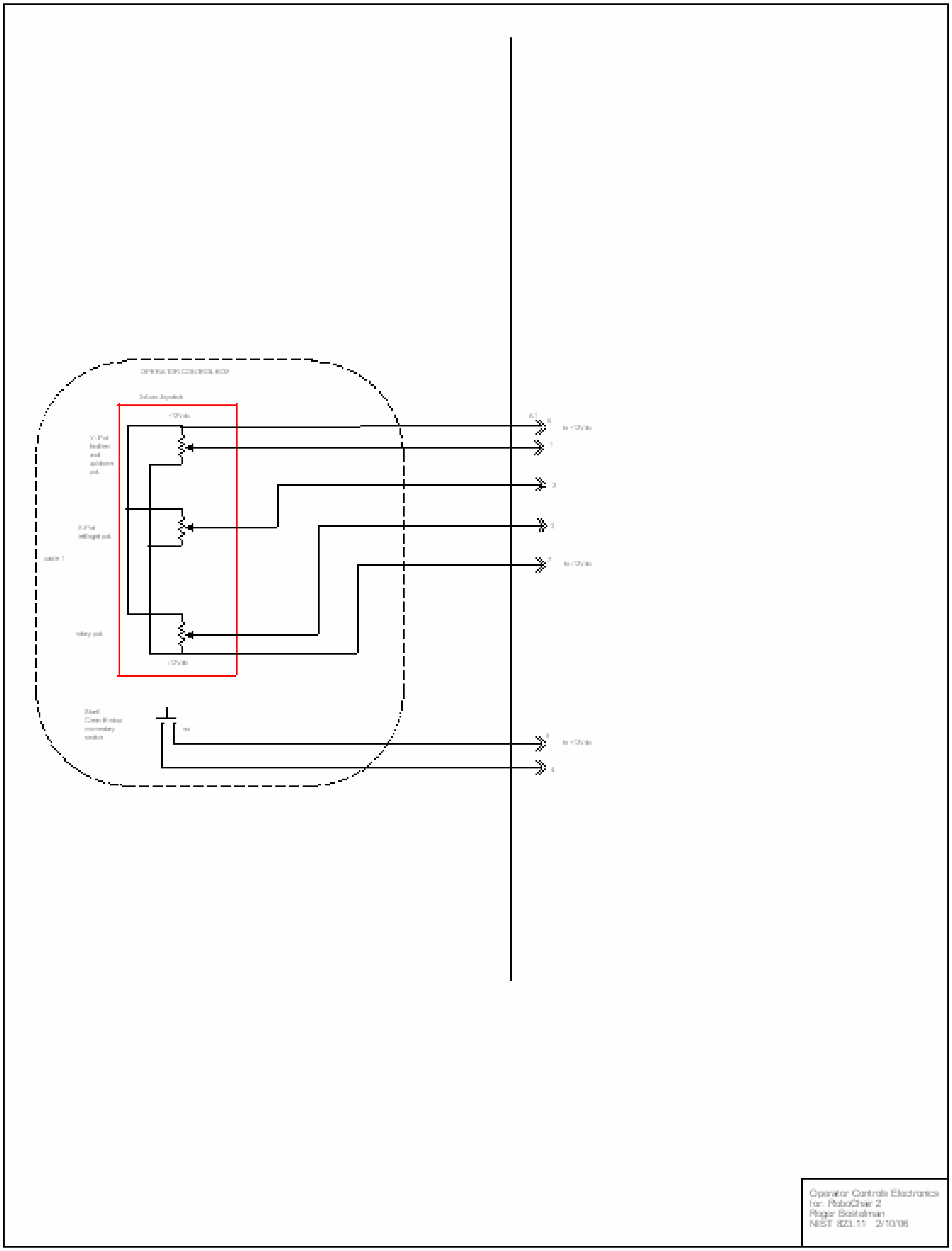

Electronics Box
red
blk
red
blk
3
Power Wiring Schematic
for: RoboChair
Roger Bostelman
NIST 823.11 5/10/06

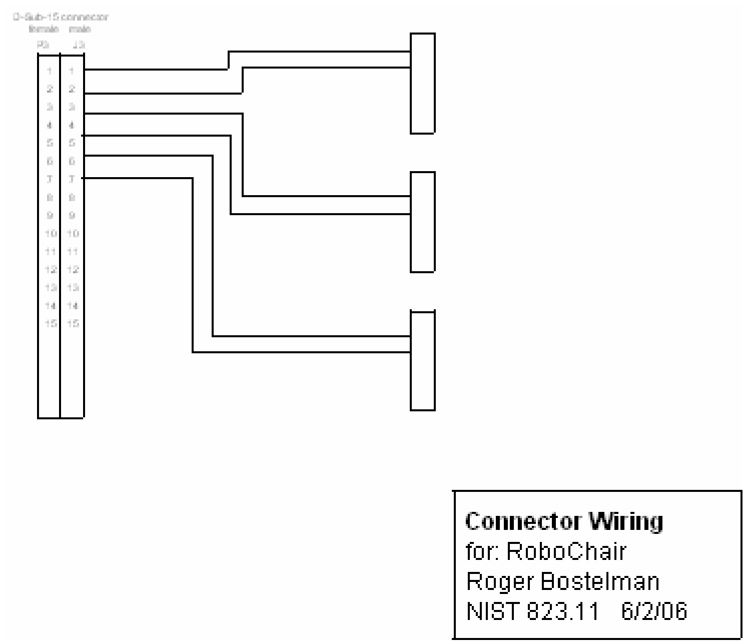

NURSE
Controls
E-Stop
Electronics Box
Electronics Schematic
for: RoboChair
Roger Bostelman
NIST 823.11 5/10/06


PATIENT
Controls
Electronics Schematic
for: RoboChair
Roger Bostelman
NIST 823.11 5/10/06


drive
+12V
-12V
steer
drive
steer
steer amp (+)
A9 org
A11 whl
10K
100K
LF357
6
J3, pin 1
drive amp (+)
A12 brn/whl
+12V
-12V
TB
+12V
Gnd
-12V
A6
blu
A5
grn
A8
brn
layout
A
B
LF357
joystick
Steer and Drive Circuit
for: HLPR Chair
Roger Bostelman
Jim Albus
NIST 823.11 11/29/06

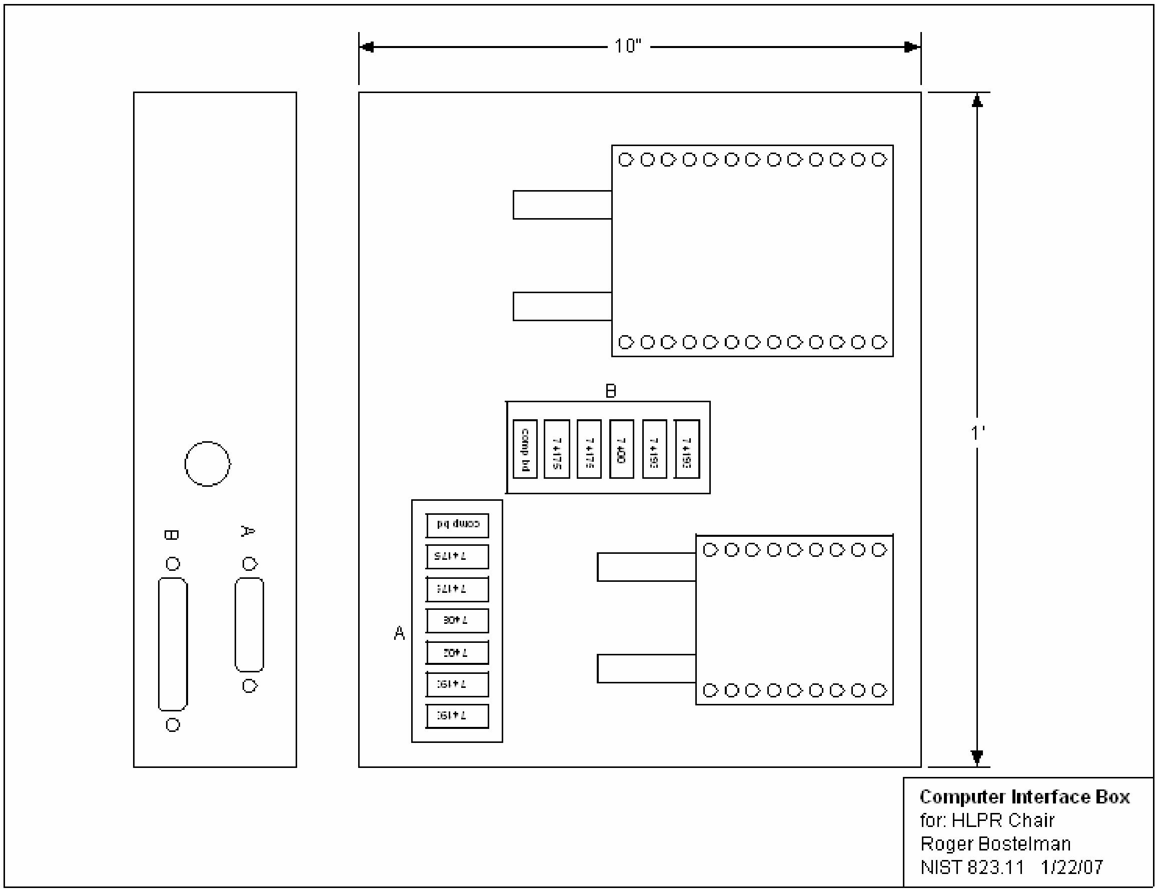

Drive/Lift Control Electronics
for: RoboChair 2
Roger Bostelman
NIST 823.11 2/10/08

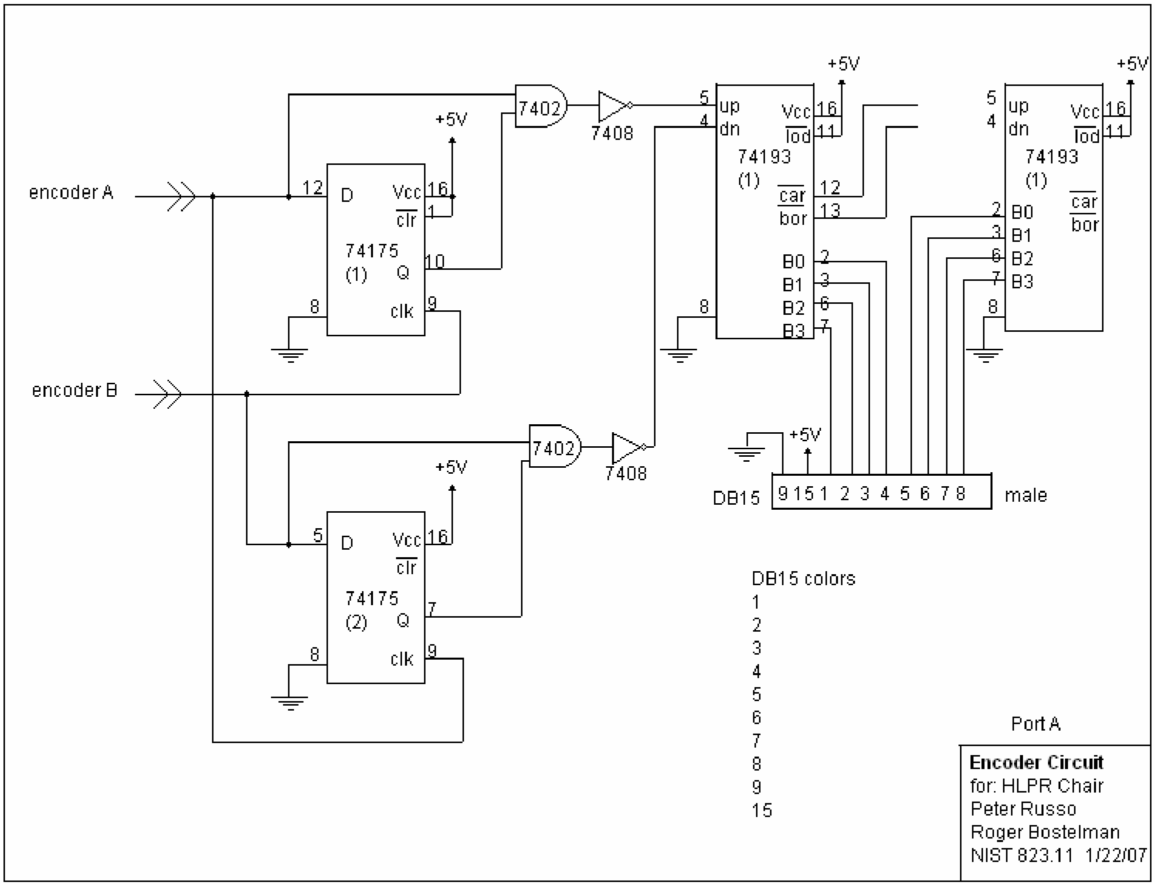

OPERATOR CONTROL BOX
Operator Controls Electronics
for: RoboChair 2
Roger Bostelman
NIST 823.11 2/10/06

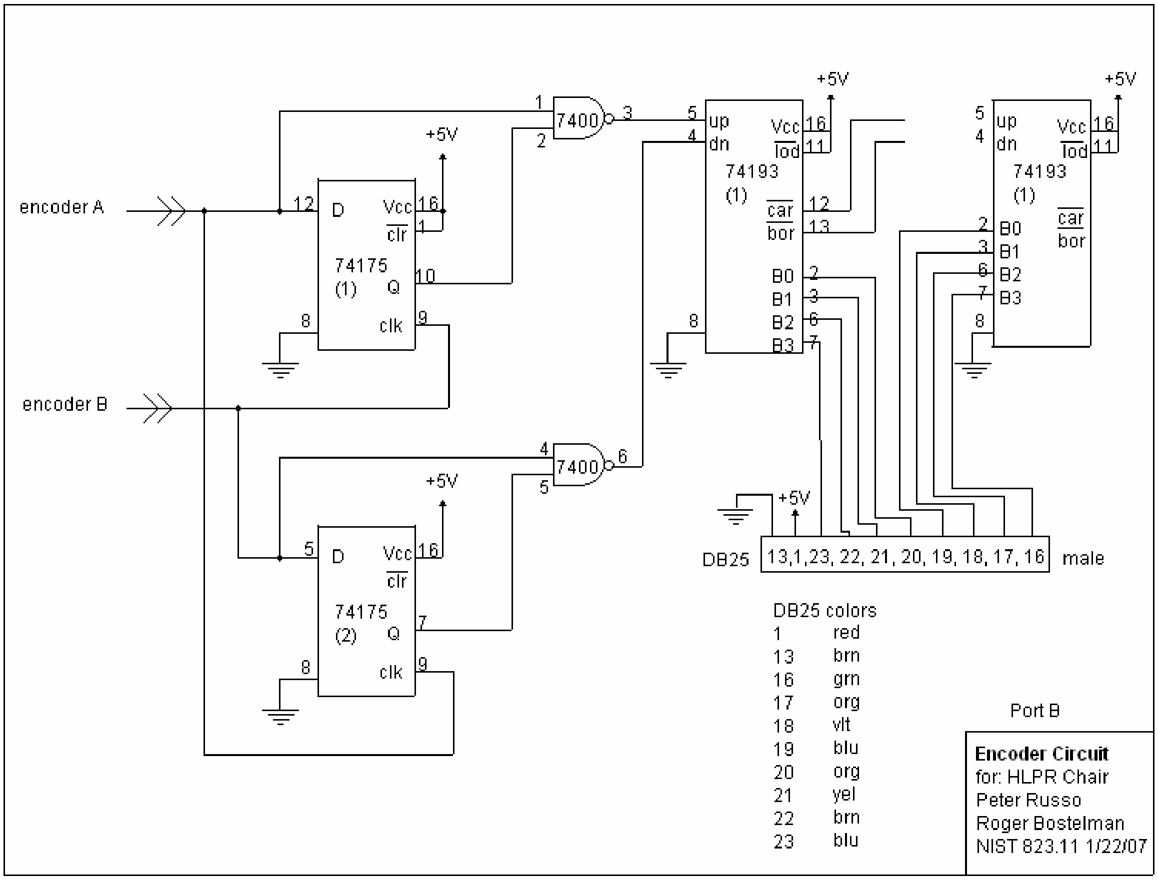

D-Sub-15 connector
female male
P3 J3
Connector Wiring
for: RoboChair
Roger Bostelman
NIST 823.11 6/2/06

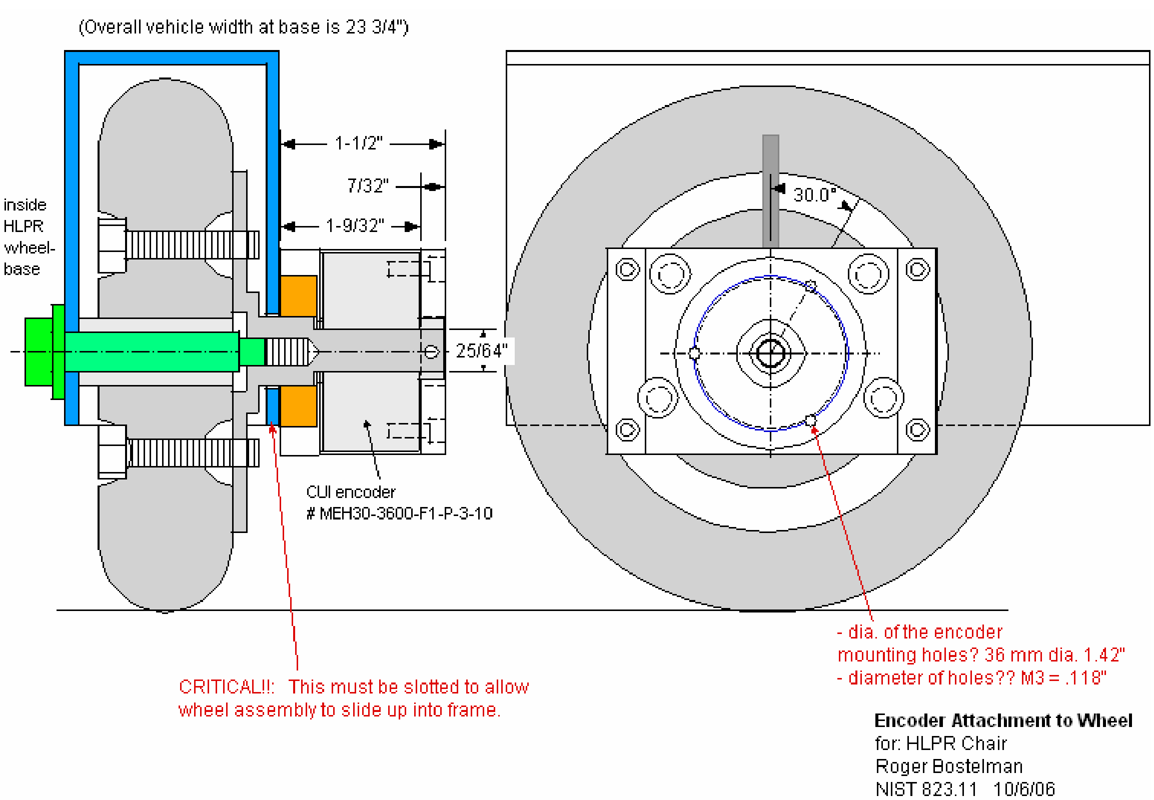
Towards Autonomous Control

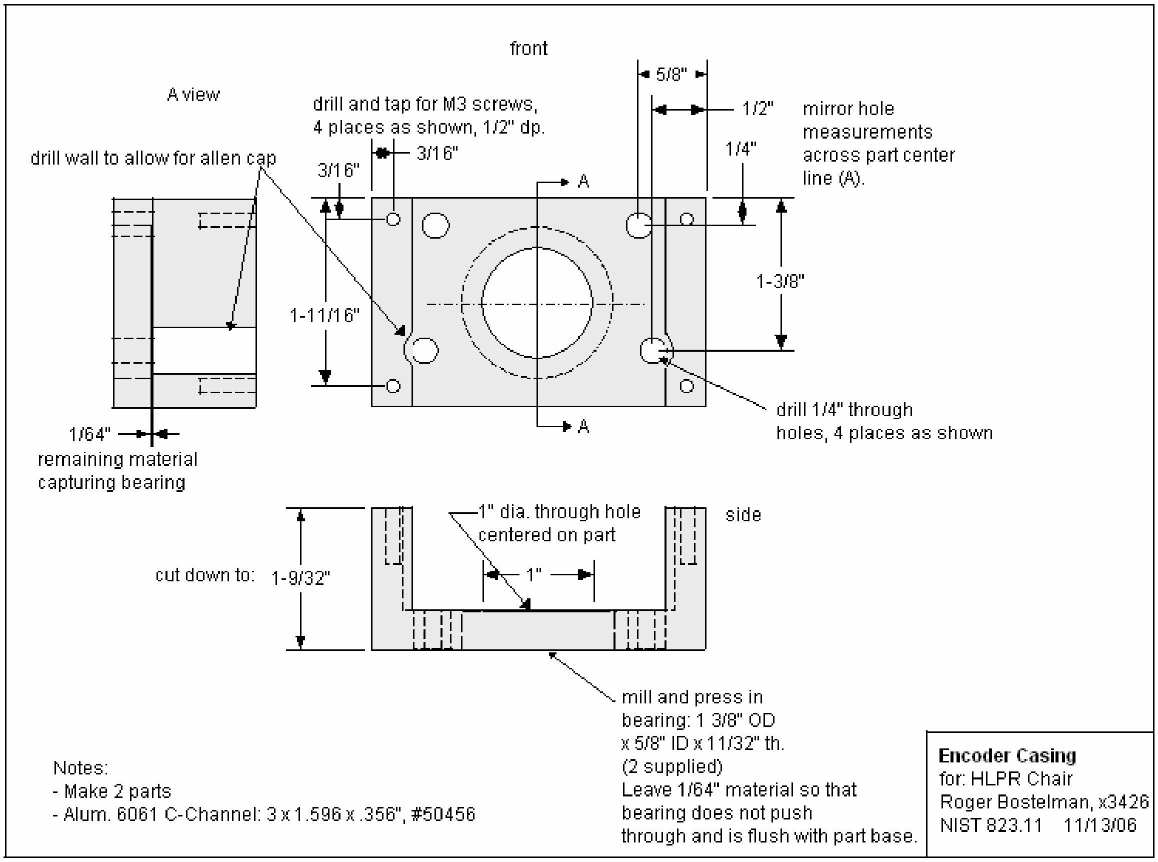
Refer to Photograph 8 for the following design drawings in this section.

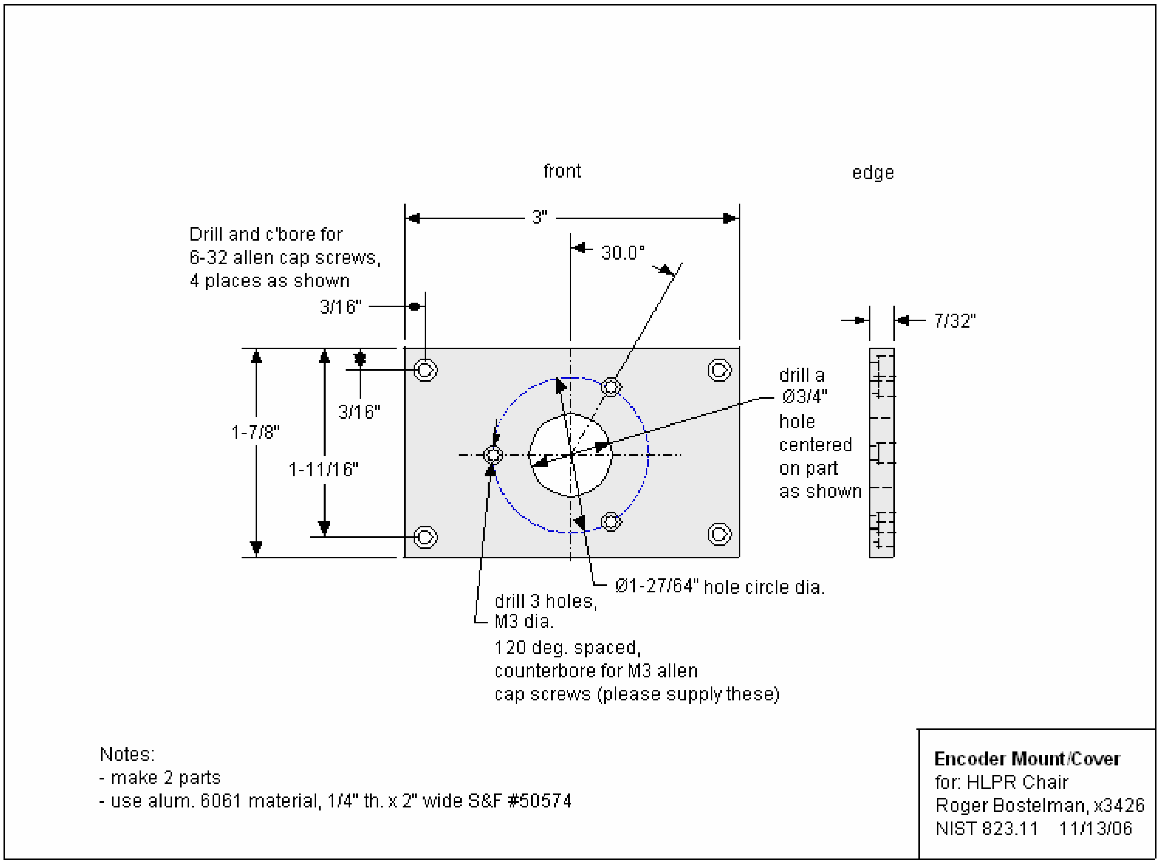



encoder A
encoder B
74175
(1)
74175
(2)
D
Vcc
clr
Q
clk
+5V
7402
7408
74193
(1)
up
dn
lod
car
bor
B0
B1
B2
B3
DB15
9 15 1 2 3 4 5 6 7 8
male
DB15 colors
1
2
3
4
5
6
7
8
9
15
Port A
Encoder Circuit
for: HLPR Chair
Peter Russo
Roger Bostelman
NIST 823.11 1/22/07

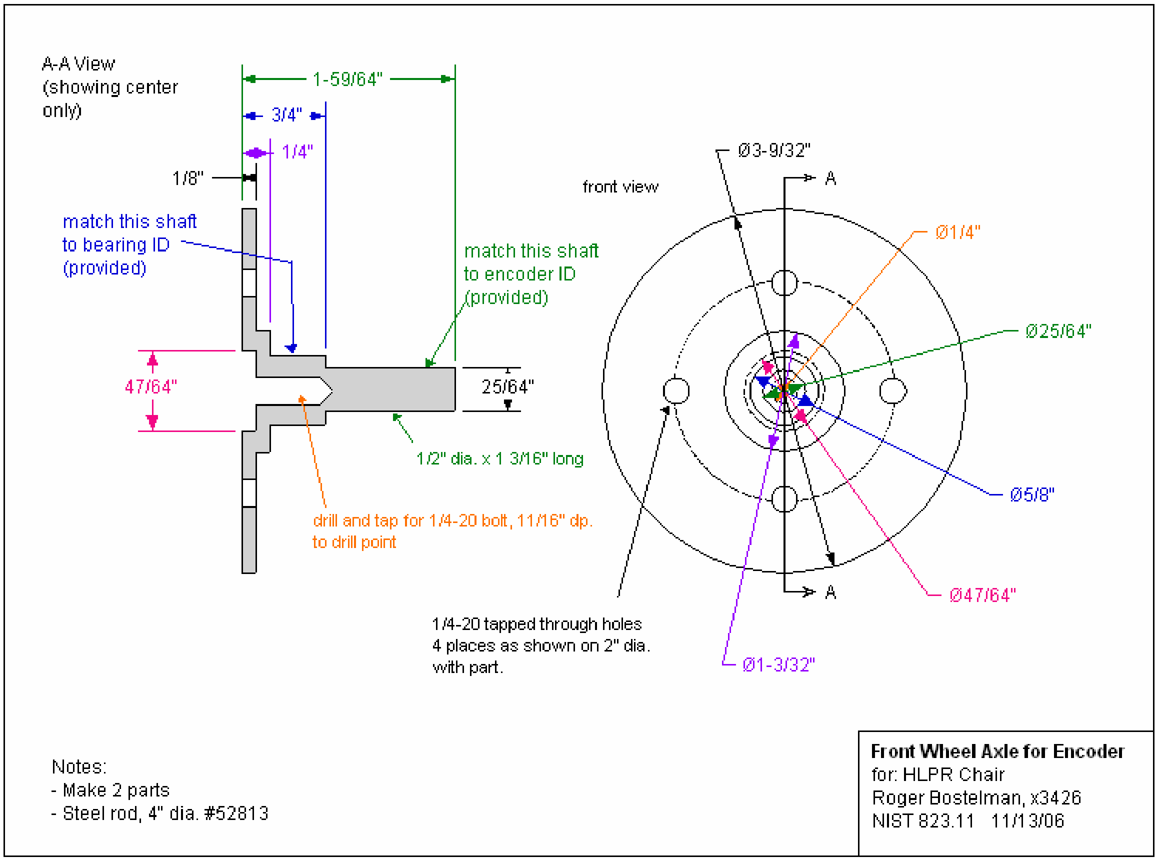

encoder A
encoder B
74175
(1)
74175
(2)
D
Vcc
clr
Q
clk
7400
74193
(1)
up
dn
lod
car
bor
B0
B1
B2
B3
+5V
DB25
13,1,23, 22, 21, 20, 19, 18, 17, 16
male
DB25 colors
1 red
13 brn
16 grn
17 org
18 vlt
19 blu
20 org
21 yel
22 brn
23 blu
Port B
Encoder Circuit
for: HLPR Chair
Peter Russo
Roger Bostelman
NIST 823.11 1/22/07


(Overall vehicle width at base is 23 3/4")
inside HLPR wheel-base
1-1/2"
7/32"
1-9/32"
25/64"
30.0°
CUI encoder
MEH30-3600-F1-P-3-10
CRITICAL!!: This must be slotted to allow wheel assembly to slide up into frame.
- dia. of the encoder mounting holes? 36 mm dia. 1.42"
- diameter of holes?? M3 = .118"
Encoder Attachment to Wheel
for: HLPR Chair
Roger Bostelman
NIST 823.11 10/6/06

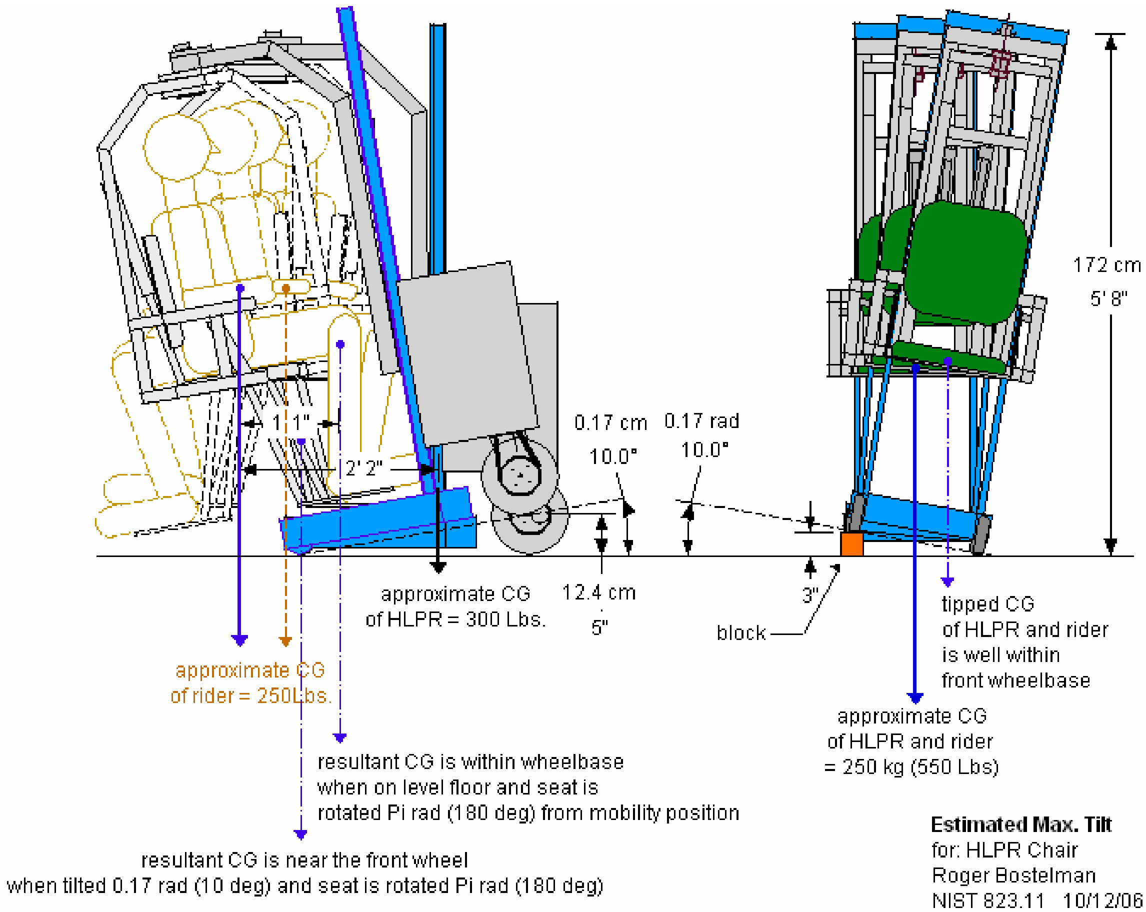

front
A view
drill and tap for M3 screws,
4 places as shown, 1/2" dp.
5/8"
1/2"
mirror hole
measurements
across part center
line (A).
1/4"
drill wall to allow for allen cap
3/16"
3/16"
A
1-3/8"
1-11/16"
drill 1/4" through
holes, 4 places as shown
A
1/64"
remaining material
capturing bearing
1" dia. through hole
centered on part
side
cut down to:
1-9/32"
1"
mill and press in
bearing: 1 3/8" OD
x 5/8" ID x 11/32" th.
(2 supplied)
Leave 1/64" material so that
bearing does not push
through and is flush with part base.
Notes:
- Make 2 parts
- Alum. 6061 C-Channel: 3 x 1.596 x .356", #50456
Encoder Casing
for: HLPR Chair
Roger Bostelman, x3426
NIST 823.11 11/13/06



front
edge
3"
30.0°
Drill and c'bore for
6-32 allen cap screws,
4 places as shown
3/16"
7/32"
3/16"
1-7/8"
1-11/16"
drill a
Ø3/4"
hole
centered
on part
as shown
Ø1-27/64" hole circle dia.
drill 3 holes,
M3 dia.
120 deg. spaced,
counterbore for M3 allen
cap screws (please supply these)
Notes:
- make 2 parts
- use alum. 6061 material, 1/4" th. x 2" wide S&F #50574
Encoder Mount/Cover
for: HLPR Chair
Roger Bostelman, x3426
NIST 823.11 11/13/06


A-A View
(showing center
only)
1-59/64"
3/4"
1/4"
1/8"
match this shaft
to bearing ID
(provided)
match this shaft
to encoder ID
(provided)
47/64"
25/64"
1/2" dia. x 1 3/16" long
drill and tap for 1/4-20 bolt, 11/16" dp.
to drill point
front view
Ø3-9/32"
A
Ø1/4"
Ø25/64"
Ø5/8"
Ø47/64"
A
Ø1-3/32"
1/4-20 tapped through holes
4 places as shown on 2" dia.
with part.
Notes:
- Make 2 parts
- Steel rod, 4" dia. #52813
Front Wheel Axle for Encoder
for: HLPR Chair
Roger Bostelman, x3426
NIST 823.11 11/13/06

Stability Testing



Prototype Cost Estimate

Item	*Manufacturer/Vendor*	*no. each*	*unit cost*	*cost*
Lift Actuator		1	286.00	286.00
Drive motor, 14A, PM	Leeson	1	155.26	155.26
Steering motor, 1/8 hp	Leeson	1	285.00	285.00
Amplifiers	Servo Systems	3	295.00	885.00
Gear Reducers, couplings	McMaster Carr	2	321.60	643.20
Lubricant	McMaster Carr	1	27.70	27.70
Seat Actuator, 12"	McMaster Carr	1	294.74	294.74
Footrest Actuator, 3"	Firgelli	1	80.00	80.00
Torso Lift Actuator, 3"	Firgelli	2	80.00	160.00
Arm pads - foam, vinyl	JoAnn Fabrics	1	20.00	20.00
Seat, Backrest		1	50.00	50.00
Wheel, tire	McMaster Carr	1	33.00	33.00
chain (unit = per foot)	McMaster Carr	3	3.47	10.41
Sprockets, 1.67, 5.06"	McMaster Carr	1	38.33	38.33
Electrical boxes	Lowes	3	13.00	39.00
Wire		1	100.00	100.00
Switches		4	40.00	160.00
Circuit Breakers		5	40.00	200.00
Joystick		2	300.00	600.00
Misc. Elect. Parts		1	100.00	100.00
Fork Lift frame		1	500.00	500.00
Seatbelt		2	119.99	239.98
Batteries, 12V, PC925	Odyssey	2	100.00	200.00
Battery, 12V, 10Ah		1	25.35	25.35
Shops work**	NIST	1	5,000.00	5,000.00
Misc. Parts - bolts, etc.		1	200.00	200.00
		total:		**$ 10,332.97**

** Shop work for this prototype was dramatically reduced incorporating a redesigned seat and base frame through the use of bent tubing (see Modifications to Original Design section). The base frame was made from 5 cm (2 in) OD steel electrical conduit with a welded support bead and the seat frame was designed at NIST and procured from a pipe bending manufacturer. A 30 cm (12 in) diameter turntable bearing ring was used as the rotation device. The total for these components was approximately $400.00 verses $5,000.00.