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  - Johannes Pellenz (Germany)
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Dozens of people have contributed to the development and validation of these test methods. They include FEMA urban search and rescue task force teams, firefighters, law enforcement, collaborating test facilities, other civilian and military organizations, and commercial manufacturers.

Disclaimer

Commercial equipment shown in this document are for illustrative purposes only. This does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products identified are necessarily the best available for the purpose.
NOTICE

The International System of Units (SI) is used throughout this document. Conversions from SI units to U.S. Customary units are made where possible but approximate equivalents are used to specify materials which are readily available in the domestic market or to avoid excessive fabrication costs of test apparatuses while maintaining repeatability and reproducibility of the test method results.

Any issues please contact:

Ann Marie Virts
ann.virts@nist.gov

Project Leader
Mobility Performance of Robotic Systems

Associate Project Leader
Emergency Response Robots Program

Intelligent Systems Division
Engineering Laboratory
National Institute of Standards and Technology
Existing arena from Mahidol to be used in 2022 RoboCup

(MAN 1) Center Between Objects

(MAN 2) Align Ground Contacts

(MAN 3) Traverse Incline

(MAN 4) Negotiate Leaning Objects

(OBS 2) Hurdles

(OBS 3) Stair with Optional Debris

(TER 1) Sand/Gravel

(DEX 5) Shoring

(DEX 6) Door Opening:
(In-person finals only)

All task boards, omni, parallel and valve should be used.
New Build for 2022 RoboCup

**MAN 5**
Pallet Terrain

**OBS 1**
Variable Height Rails

**TER 2**
K-Rails on Crossover Slope

**TER 3**
Pinwheel Ramps on Crossover Slope

**TER 4**
Crate Terrain for Legged Robots
Note: We will be using most of the existing arena from Mahidol (Listed in green).

We will not have stepfields in this years design.

(MAN 1) Center Between Objects
(MAN 2) Align Ground Contacts
(MAN 3) Traverse Incline
(MAN 4) Negotiate Leaning Objects
(MAN 5) Pallet Terrain

(OBS 1) Variable Height Rails
(OBS 2) Hurdles
(OBS 3) Stair with Optional Debris
(TER 1) Sand/Gravel
(TER 2) K-Rails on Crossover Slope
(TER 3) Pinwheel Ramps on Crossover Slope
(TER 4) Crate Terrain for Legged Robots

(DEX 1) Directed Inspection
(DEX 2) Touch/Insert
(DEX 3) Extract/Place
(DEX 4) Strength Tasks in the Work Volume:
(DEX 5) Shoring
(DEX 6) Door Opening: (In-person finals only)
Operator Booth (12)

PURCHASE LIST:
- [39] 48 x 96 x 1/2 in. OSB
- [48] 2 x 4 x 96 in. post

CUT LIST:
- [12] 48 x 96 x 1/2 in. - Wall Panel (A)
- [24] 2 x 4 x 96 in. – Post (B)
- [12] 24 x 48 x 1/2 in.- Shelf (C)
- [12] 2 x 4 x 47 in. - Brace (D)
- [24] 2 x 4 x 47 in. - Shelf Support Post (E)
- [24] 2 x 4 x 21 in. - Shelf Support Post (F)

Fabrication
- Attach OSB panels A shown in Figure A.
- Attach brace D as shown in Figure A.
- Lay out two shelf support post (E) 21 in. from each other such that post are on edge. Attach Shelf support (F) to (E) as shown in Figure B. Attach OSB panel (C) to frame.
- Install shelf unit into operator station. Shelf height is standing height for operator from floor as shown in Figure C.
**Ramps - 220**

**PURCHASE LIST:**
- [62] 48 x 96 in. OSB
- [46] 4 x 4 x 96 in. post

**CUT LIST:**
- [220] 22 x 22 5/8 x 5/8 in. OSB (top) (A)
- [220] 5 3/4 x 22 x 7/16 in. OSB (back) (B)
- [440] 5 3/4 x 22 x 21 3/8 x 7/16 in. OSB triangle (sides) (C)
- [440] 4 x 4 x 5 3/4 in. Post 15º Mitre cut sq. to long point (back legs) (D)
- [440] 4 x 4 x 2 3/4 in. Post 15º Mitre cut sq. to long point (front legs) (E)

### Ramp Fabrication

- Place triangles (C) flatly on the floor. Attach one top post (E) to support triangle (C) and repeat for additional side as shown in Figure A. Note: Posts will be flush with the top of support triangle (C).
- Attach Front Leg (E) as shown in Figure A.
- Attach ramp surface (A) to support triangles (C). Note: Use rougher side up as the ramp surface if there is a difference in surface texture.
- Attach back plate (B) to high side of ramp as shown in Figure A.
Maze Wood

PURCHASE LIST:
- [80] 48 x 96 x 1/2 in. OSB
- [100] 2 x 4 x 96 in. post

Ramps are fabricated on page: 9
Will be built in place. Similar design.
Search Rails for Maze

**PURCHASE LIST:**
- [10] 2 x 4 x 96 in. post
- [3] 4 x 4 x 96 in. post

**CUT LIST:**
- [20] 2 x 4 x 48 in. post (A)
- [20] 4 x 4 x 12 in. post (B) cut on a 45°
- [100] 2 ID in x 2 in. - Pipe (C)
- [100] 2 in. – Caps (D)
Victim Fidcials (40 halves)

**PURCHASE LIST:**
- [20] 48 x 96 in. post
- [20] 24 ID x 48 in. Concrete Form

**CUT LIST:**
- [80] 2 x 4 x 24 in. Post (A)
- [20] 24 ID x 48 in. Concrete Form (B)

**FABRICATION INSTRUCTIONS – Barrels**
- Cut concrete form in half lengthwise

**FABRICATION INSTRUCTIONS – Barrel Braces**
- Drill 1/4 in thru hole centered in barrel braces as shown in Figure A. Repeat for additional 39.

**FABRICATION INSTRUCTIONS – Barrel halves**
- Attach braces as shown in Figure B. Repeat for additional 39 halves.
Pallet Terrain

**PURCHASE LIST:**
- [16] ~48 x ~48 in. pallets
- [3] 2 x 4 x 96 in. post
- [1] 48 x 96 x 1/2 in. OSB

**CUT LIST:**
- [12] 2 x 4 x 24 in. – Post (A)
- [3] 12 x 96 x 1/2 in. OSB Panel (B)
- [2] 12 x 60 x 1/2 in. OSB Panel (C)

- Attach Post A to Post A shown in Figure A.
- Layout pallets as show in Figure B.
- Attach Posts and panels as shown in Figure B.
### Variable Height Rails

#### PURCHASE LIST:
- [6] 48 x 96 x 1/2 in. OSB
- [5] 4 x 4 x 96 in. Post
- [10] 2 x 4 x 96 in. Post

#### CUT LIST:
- [4] 48 x 96 x 1/2 in. OSB (A)
- [3] 48 x 48 x 1/2 in. OSB (B)
- [2] 24 x 56 x 1/2 in. OSB (C)
- [4] 4 x 4 x ~65 in. Post (NOTE: 45° Mitre cut) (D)
- [2] 4 x 4 x 12 in. Post (E)
- [2] 2 x 4 x 56 in. Post (F)
- [4] 2 x 4 x 48 in. Post (G)
- [4] 2 x 4 x 47 in. Post (H)
- [4] 2 x 4 x 46 in. Post (I)
- [6] 2 x 4 x 24 in. Post (J)

#### Instructions:
- Attach Post E to panels A and B as shown in Figure A. Repeat for additional panel.
- Attach posts G, H and I to Panels A and B as shown in Figure B. Note there is a 1 in. gap between H and I.
- Attach Post F and J to Panel C. Repeat for additional panel. Note: There are double post J on opposite corners.
- Cut post to length shown in Figure D. This should be cut to fit.
K-Rails on Crossover Slope

PURCHASE LIST:
- [8] 48 x 96 x 5/8 in. OSB
- [5] 48 x 96 x 1/2 in. OSB
- [40] 2 x 4 x 96 in. Post
- [15] 4 x 4 x 96 in. Post

CUT LIST:
Terrain
- [4] 48 x 96 x 5/8 in. OSB (A)
- [8] 2 x 4 x 96 in. Post (B)
- [8] 2 x 4 x 45 in. Post (C)
- [8] 2 x 4 x 12 in. Post (D)
- [8] 4 x 4 x 63 5/8 in. (NOTE: cut to fit) arrow head on both ends. Post (E)

Frame
- [6] 12 x 90 x 5/8 in. OSB (F)
- [6] 12 x 23 3/8 x 5/8 in. OSB (G)
- [6] 12 x 10 15/16 x 5/8 in. OSB (H)
- [12] 2 x 4 x 90 in. Post (I)
- [12] 2 x 4 x 80 in. Post (J)
- [12] 4 x 4 x 23 3/8 in. (15° cut) Post (K)
- [12] 4 x 4 x 10 15/16 in. (15° cut) Post (L)

Terrain Fabrication
- Attach Posts B and C to OSB panel A as shown in **Figure A**.
- Attach Post D centered as shown in **Figure A**.
- Cut to fit Post E and insert into frame. **Repeat for additional 3 terrain panels**.

Incline Fabrication
- Attach Posts K to OSB panel G as shown in **Figure B**.
- Attach Posts L to OSB panel H as shown in **Figure C**.
- Attach Post I and J as shown in **Figure D**.
- Attach panel F as shown in **Figure D. Repeat steps 1-3 for 5 additional inclines**
K-Rails on Crossover Slope

Frame Fabrication

- Cut out triangle as shown in Figure A. Repeat for additional triangle.
- Install terrain panels and incline as shown in Figure B.
- Install containment panels around terrain as shown in Figure C.
- Place operator booth as shown.

Frame

- [3] 24 x 96 x 1/2 in. OSB (M)
- [4] 24 x 48 x 1/2 in. OSB (N)
- [4] 48 x 48 x 1/2 in. OSB (O)
- [2] 24 x 48 x 48 x 1/2 in OSB (P)
- [2] 2 x 4 x 96 in. Post (Q)
- [5] 4 x 4 x 12 in. Post (R)

Figure A

Figure B

Figure C

Figure D
Pinwheel Ramps on Crossover Slope

PURCHASE LIST:
- [8] 48 X 96 X 5/8 in. OSB
- [5] 48 X 96 X 1/2 in. OSB
- [40] 2 X 4 X 96 in. Post
- [7] 4 x 4 x 96 in. Post

CUT LIST:
- Incline
  - [6] 12 x 90 x 5/8 in. OSB (F)
  - [6] 12 x 23 3/8 x 5/8 in. OSB (G)
  - [6] 12 x 10 15/16 x 5/8 in. OSB (H)
  - [12] 2 x 4 x 90 in. Post (I)
  - [12] 2 x 4 x 80 in. Post (J)
  - [12] 4 x 4 x 23 3/8 in. (15° cut) Post (K)
  - [12] 4 x 4 x 10 15/16 in. (15° cut) Post (L)
- Terrain Tray
  - [4] 48 x 96 x 5/8 in. OSB (A)
  - [8] 2 x 4 x 96 in. Post (B)
  - [8] 2 x 4 x 45 in. Post (C)
- Frame
  - [3] 24 x 96 x 1/2 in. OSB (M)
  - [4] 24 x 48 x 1/2 in. OSB (N)
  - [4] 48 x 48 x 1/2 in. OSB (O)
  - [2] 24 x 48 x 48 x 1/2 in OSB (P)
  - [2] 2 x 4 x 96 in. Post (Q)
  - [5] 4 x 4 x 12 in. Post (R)

Ramps are fabricated on page: 9

Terrain Tray Fabrication
- Attach Posts B and C to OSB panel A as shown in Figure A. Repeat for additional 3 terrain panels.

Incline Fabrication
- Attach Posts K to OSB panel G as shown in Figure B
- Attach Posts L to OSB panel H as shown in Figure C.
- Attach Post I and J as shown in Figure D.
- Attach panel F as shown in Figure D. Repeat steps 1-3 for 5 additional inclines
**Pinwheel Ramps on Crossover Slope**

### Frame Fabrication

- Cut out triangle as shown in Figure A. Repeat for additional triangle.
- Install ramps and incline as shown in Figure B.
- Install containment panels around terrain as shown in Figure C.
- Place operator booth as shown.

### Frame

- [3] 24 x 96 x 1/2 in. OSB (M)
- [4] 24 x 48 x 1/2 in. OSB (N)
- [4] 48 x 48 x 1/2 in. OSB (O)
- [2] 24 x 48 x 48 x 1/2 in OSB (P)
- [2] 2 x 4 x 96 in. Post (Q)
- [5] 4 x 4 x 12 in. Post (R)

---

**FIGURE A**

24 in.  
48 in.  
48 in.

**FIGURE B**

**FIGURE C**

**FIGURE D**
Crate Terrain for Legged Robots

PURCHASE LIST:
- [3] 48 x 96 x 1/2 in. OSB
- [18] 2 x 4 x 96 in. Post
- [110] 12 x 12 x 10 1/2 in. crate
  (https://www.uline.com/Product/ProductDetailRootItem?modelnumber=S-16317)
- [250] 12 in. cable ties.

CUT LIST:
- [2] 48 x 96 x 1/2 in. OSB (A)
- [2] 48 x 52 x 1/2 in. OSB (B)
- [6] 2 x 4 x 96 in. Post (C)
- [6] 2 x 4 x 52 in. Post (D)
- [2] 2 x 4 x 48 in. Post (E)
- [8] 2 x 4 x 45 in. Post (F)
- [2] 2 x 4 x 44 in. Post (G)

Wall Fabrication
- Attach OSB panel and Posts as A shown in Figure A. Repeat for additional panel.
- Attach OSB panel and Posts as A shown in Figure B. Repeat for additional panel.
- Attach walls together as shown in Figure C.

Crate Fabrication
- Attach crates together using 12” cable ties on opposite as shown in Figure D:
  - 7 vertical stacks of 3 crates
  - 24 vertical stacks of 2 crates
  - Remaining crates are singles

Put 7 crates side by side all touching to see the ACTUAL DIMENSION for containment. D, E, F, G dimensions is noted for imperial lumber, using uline crates.
Crate Terrain for Legged Robots

Layout

- Start in one corner with pattern.
**Dexterity**

**PURCHASE LIST:**
- [7] 48 x 96 x 1/2 in. OSB
- [5] 4 x 4 96 in Post
- [25] 2 x 4 x 96 in. Post
- [8] 12 x 12 x 10 1/2 in crate
  (https://www.uline.com/Product/ProductDetailRootItem?modelnumber=S-16317)
- 25 lbs of weights
- [10] T-Nuts 8 mm (5/16 in) threaded
  https://www.amazon.com/gp/product/B06XCK35C1/
- **Galvanize Pipe**
  - [2] ¾ nipples
  - [1] Tee
  - [1] ¾” X 6” Threaded pipe
  - [1] ¾” flange
- [30] 2 ID in x 2 in. - Pipe (C)
- [30] 2 in. – Caps (D)

**CUT LIST FOR SHELVES**
- [3] 48 x 96 x 1/2 in. OSB (A)
- [1] 48 x 96 x 1/2 in. OSB (F)
- [10] 2 x 4 x 48 in. Post (G)

**CUT LIST FOR ENCLOSURE**
- [3] 48 x 96 x 1/2 in. OSB (F)
- [3] 16 x 48 x 1/2 in. OSB (H)
- [2] 2 x 4 x 48 in. Post (I)
- [2] 2 x 4 x 13 in. Post (J)
- [6] 2 x 4 x 8 in. Post (K)

**Enclosure and Shelf Fabrication**
- Attach Posts G to Panel A as shown in **Figure A. Repeat for second panel.**
- Attach Posts G to Panel F as shown in **Figure B. Repeat for second panel.**
- Assemble side panels with back panel as shown in **Figure C.**
  *NOTE: Interior dimension must be 48 in., so shelf unit slides in easily.*
Dexterity

**CUT LIST FOR THE TERRAIN:**
- [2] 48 x 96 x 1/2 in. OSB (A)
- [4] 4 x 4 x ~63 5/8 in. Post (NOTE: cut to fit) arrow head on both ends. (B)
- [4] 2 x 4 x 96 in. Post (C)
- [4] 2 x 4 x 45 in. Post (D)
- [4] 2 x 4 x 12 in. Post (E)

**CUT LIST FOR RAILS:**
- [7] 2 x 4 x 48 in. post (I)
- [7] 4 x 4 x 12 in post (L) cut on a 45°
- [30] 2 ID in x 2 in. - Pipe (M)
- [30] 2 in. – Caps (N)

**CUT LIST FOR SHELVES**
- [3] 16 x 48 x 1/2 in. OSB (H)
- [2] 2 x 4 x 48 in. Post (I)
- [2] 2 x 4 x 13 in. Post (J)
- [6] 2 x 4 x 8 in. Post (K)

**Terrain Fabrication**
- Attach Posts C and D to OSB panel A as shown in Figure A.
- Attach Post E centered as shown in Figure D.
- Cut to fit Post B and insert into frame.

**Weight T Fabrication**
- Assemble as shown in Figure E.

**Linear Rail Fabrication**
- Assemble as shown in Figure F. repeat for 4 additional rails.
- Assemble ONE linear rail with t- nut inserts as shown in Figure F

**Small Shelf Fabrication**
- Assemble as shown in Figure G. repeat for 1 additional shelf
- Second Shelf insert posts as shown in Figure H
Dexterity

PURCHASE LIST:
- [2] 48 x 96 x 1/2 in. OSB
- [4] 4 x 4 96 in. Post
- [7] 2 x 4 x 96 in. Post
- [8] 12 x 12 x 10 1/2 in crate

(https://www.uline.com/Product/ProductDetailRootItem?modelnumber=S-16317)

CUT LIST:
- [2] 48 x 96 x 1/2 in. OSB (A)
- [4] 4 x 4 ~63 5/8 in. Post (NOTE: cut to fit) arrow head on both ends. (B)
- [4] 2 x 4 x 96 in. Post (C)
- [4] 2 x 4 x 45 in. Post (D)
- [4] 2 x 4 x 12 in. Post (E)

Terrain Fabrication

- Attach Posts C and D to OSB panel A as shown in Figure A.
- Attach Post E centered as shown in Figure A.
- Cut to fit Post B and insert into frame.

FIGURE A
Task Panel (10)

PURCHASE LIST:
- [2] 48 x 96 x 1/2 in. OSB
- [2] 2 x 4 x 96 in. post
- [3] 4 x 4 x 96 in. post
- [6] 2 ID in. x 96 in. PVC Pipe
- [6] 1.5 ID in. x 96 in. PVC Pipe
- [1] Blue duct tape
- [1] Velcro
- [1] Red/Black Markers

CUT LIST:
- [10] 13 x 13 x 1/2 in. – OSB (A)
- [10] 4 x 4 x 12 in. Post 45° Mitre cut long to long point (B)
- [20] 4 x 4 x 4 in. Post 45° Mitre cut sq. to long point (C)
- [20] 2 x 4 x 12 in. Post (D)
- [90] 2 ID in x 4 in PVC Pipe
- [90] 1.5 ID in x 3 in PVC Pipe

Fabrication
- Attach angled posts (B and C) together as shown in Figure A.
- Attach caps as shown in Figure B.
- Attach post (D) to backside of OSB Panel (A) as shown in Figure B. Note: the 1/2 in. offset from edge.
- Attach pipes to caps.
- Wrap top of 50 mm pipe with blue tape as shown in Figure C.
- Mark top of treadered plug as shown in Figure C.
- Insert 1 1/2 in. pipe into the threaded plug. Wrap 1/4 in. Velcro at the end of the pipe as shown in Figure C.
PURCHASE LIST:
- [1] 48 x 96 x 1/2 in. OSB
- [3] 2 x 4 x 96 in. post
- [2] 4 x 4 x 96 in. post
- [25] Small Round Abrasive Flap Wheel Sanders 1 in. diam high friction cylinder Shaft: .25 in. diameter, at least 1 in. long
  https://www.amazon.com/dp/B07ZRQ9YL3/
- [25] Large Round Abrasive Flap Wheel Sanders 2 in. diam high friction cylinder Shaft: 0.25 in. diameter, at least 1 in. long.
  https://www.amazon.com/gp/product/B0821B4RZN/
- [50] T-Nuts 5/16 in. threaded
  https://www.amazon.com/gp/product/B06XCK35C1/

CUT LIST:
- [5] 13 x 13 x 1/2 in. OSB (A)
- [10] 2 x 4 x 12 in. Post (B)
- [10] 4 x 4 x 12 in. Post 45° Mitre cut long to long point (C)
- [10] 4 x 4 x 4 in. Post 45° Mitre cut sq. to long point (D)
- [5] 2 x 4 x 48 in. Post (E)

Omni (5)
- Attach angled posts (C and D) together as shown in Figure A.
- Drill 5/16 in. holes as shown in Figure A. Insert T-Nuts into holes
- Attach post (B) to backside of OSB Panel (A) as shown in Figure A. Note: the 1/2 in. offset from edge.

Linear (5)
- Attach post C to post E as shown in Figure B.
- Drill 5/16 in. holes as shown in Figure A. Insert T-Nuts into holes
- [12] 12 x 12 x 10 1/2 in crate
  (https://www.uline.com/Product/ProductDetailRotItem?modelnumber=S-16317)
- [12] 4 x 4 x 10 in. post (A)
- [12] Large Round Abrasive Flap Wheel Sanders
  2 in. diam high friction cylinder Shafts: 0.25 in. diameter, at least 1 in. long. (B)
  https://www.amazon.com/gp/product/B0821B4RZN/
- [12] T-Nuts 5/16 in. threaded
  https://www.amazon.com/gp/product/B06XCK35C1/
- [48] 2 ID in. x 2 in. PVC Pipe (C)
- [48] 2 in. PVC Caps (D)
- [12] Battery operated speaker (E)
- [24] 4 in. Hazmat Stickers (F)
- [24] QR code (G)
- [12] 1 in screw (H)
- [12] 2 in. Magnet (I)
- [500] Hand Warmers (J)
Tools and Admin Section
- (1) – Dispatch board
- (100+) - Magnets
- (1) HDMI Computer Monitor >21 in
- (20) Clipboards
- (30) Gloves
- (5) Safety Glasses
- (2) Ear Muff
- (10) Clip on nail pouch
- (1) First Aid Kit
- Fire extinguishers/sand buckets/etc… should be stationed at the operator stations, team paddock and battery charging stations.

- (1) Shipping Scale 440 LB/200 KG Capacity

- (5) Torx T25 Shaft 5/16 in. (it must fit into the t-nuts)
- Cordless drills and accessories
  - [4] Cordless drills
  - [6] Battery chargers
  - [12] Total batteries

- [2] Corded drill

- [1] Circular Saw
- [1] Miter Saw

- Drill sets
  - Typical size drill bits
  - Nut drivers
  - Torx/Star bit sets
  - Screw Driver bits

- Paddle Bit Set
  - [3] 1-4 cm (1/2 - 1.5 in)
- Hole saw
  - [3] 15 cm (6 in) diameter
  - [3] 5 cm (2 in) diameter

- Tape Measure
  - [2] 30m/100ft tape measure
  - [4] 8m/25ft tape measure

- Cable Ties
  - [200] Various sizes
  - [5] Cable tie cutters

- Duct tape
  - [5] Rolls of Safety Yellow duct tape
  - [5] Rolls of Safety Orange duct tape
  - [5] Rolls of Safety Red duct tape
  - [5] Rolls of Blue duct tape
  - [5] Rolls of Black /Yellow diagonal stripe tape
Star/Torx bit screws with washer heads

- [500] 12 mm (1 in) long
- [1000] 40 mm (1 1/2 in) long
- [2000] 60 mm (2 ½ in) long
- [500] 120 mm (4 in) long
- [50] Matching star/torx bits for each size

Hardware

- [8] Hinges 100 mm (4 in)
- [200] washers 25 mm (1 in)

- [10] Power cords
- [30] Power Strips
- Color printer and copier with supplies
  - [1] Color inkjet printer/copier
  - **USB and power cables**
  - Printer driver software
  - [4] Spare paper packs
  - [4] Spare ink colors and black

- Briefing/planning/task list support
  - [3] Dry erase whiteboards
  - [3] Sets of markers/erasers

- Office supplies
  - [2] Stapler, staples
  - [4] **scissors**
  - [1] Scotch (clear) tape
  - [50] Pencils
  - [100] paper clips
  - [10] Black permanent Sharpie Markers-large
  - Various sizes binder clips
AV equipment
- [3] Large LCD display
- [2-3] Pan Security Camera with cable
- Ability to switch between the cameras
- PA system
Additional Materials Needed
Additional lumber:

[5] sheets of 5/8 in. OSB plywood
[10] sheets of 1/2 in. OSB plywood
[20] 2 x 4 x 96 in. post
[10] 4 x 4 x 96 in. post

[300] 6 in concrete block