

# Brick Geometry

## Bricks by the Bay 2014

Santa Clara CA

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**www.brickpile.com**



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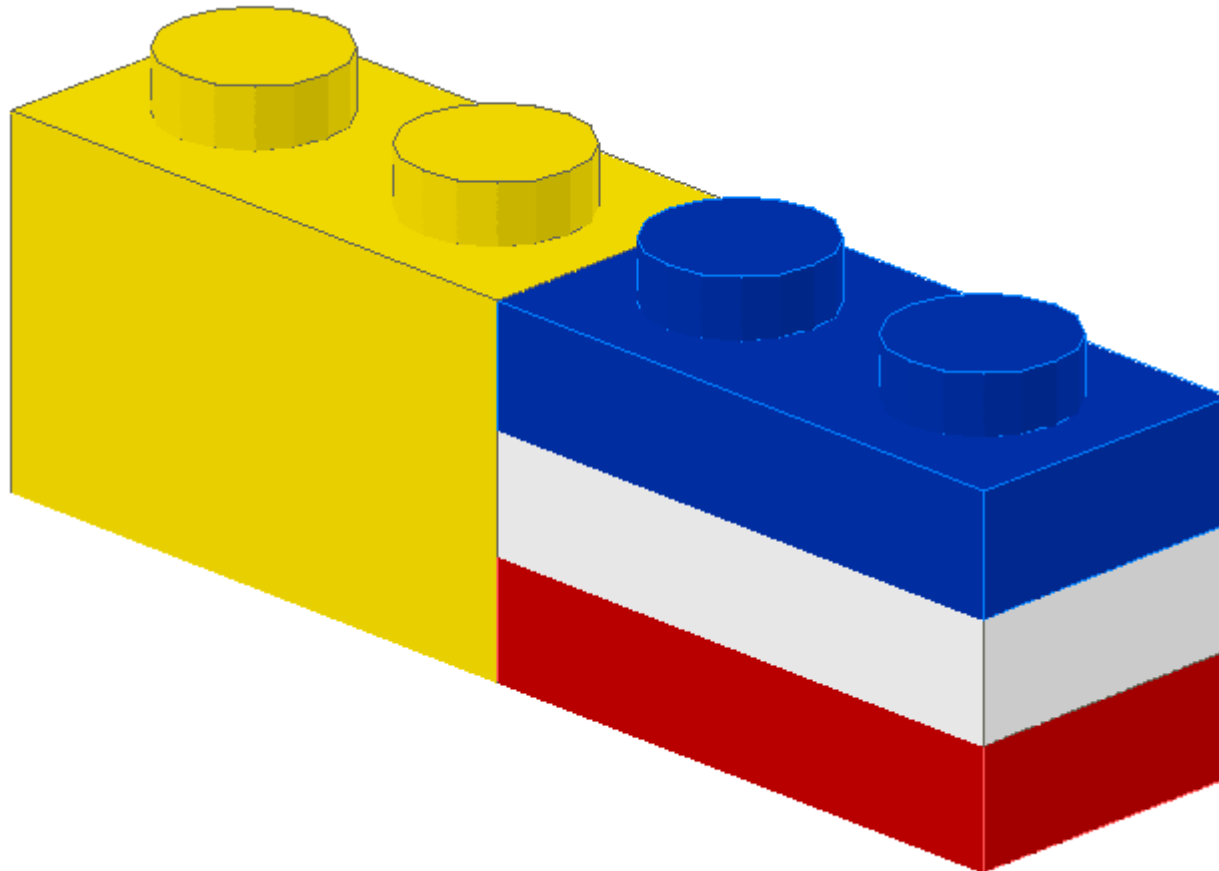


# **Ratios and Dimensions**

# Basic LEGO Geometry

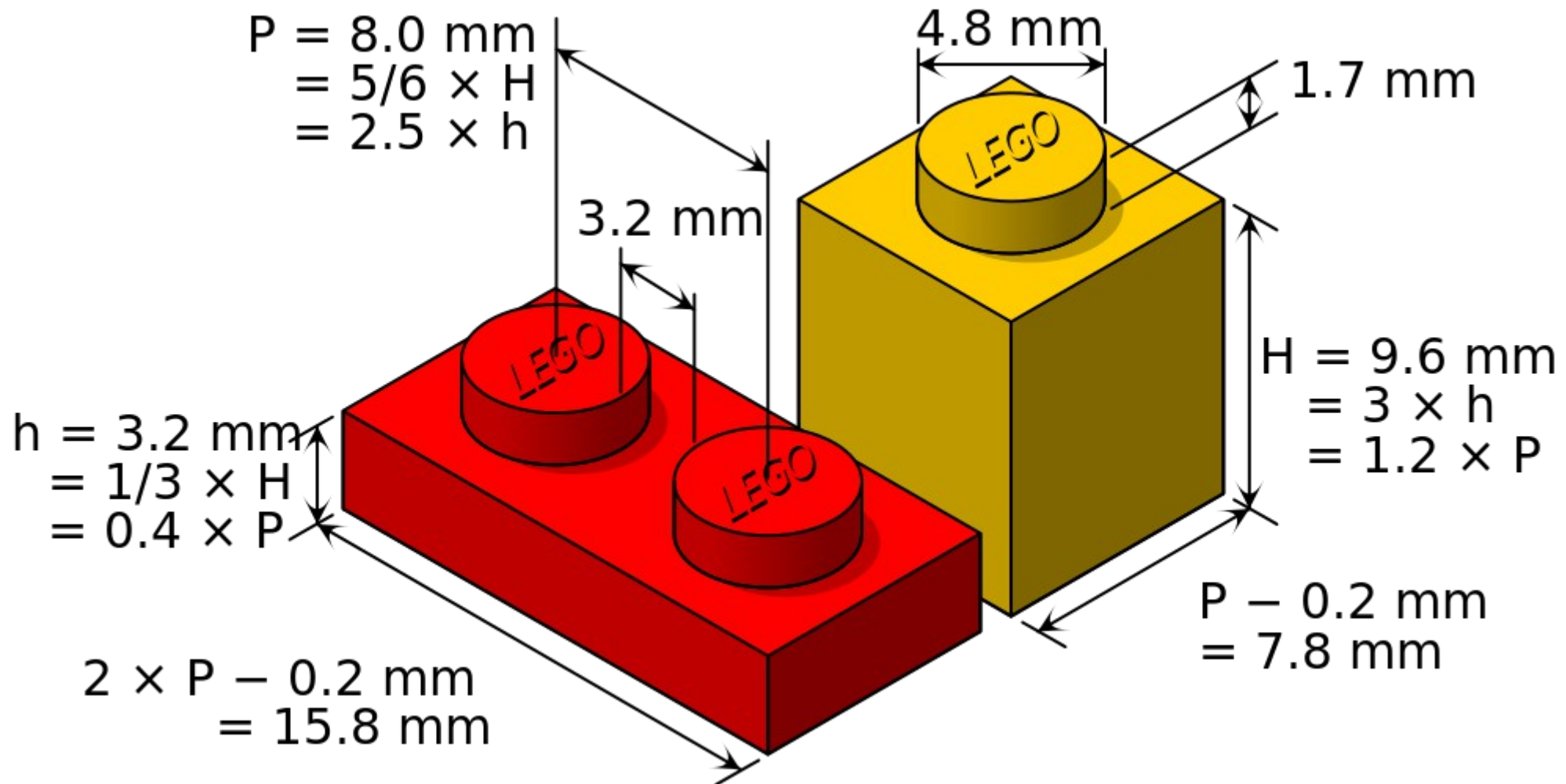
## 1 brick = 3 plates

*Everyone knows this, I hope...*



# LEGO Dimensions

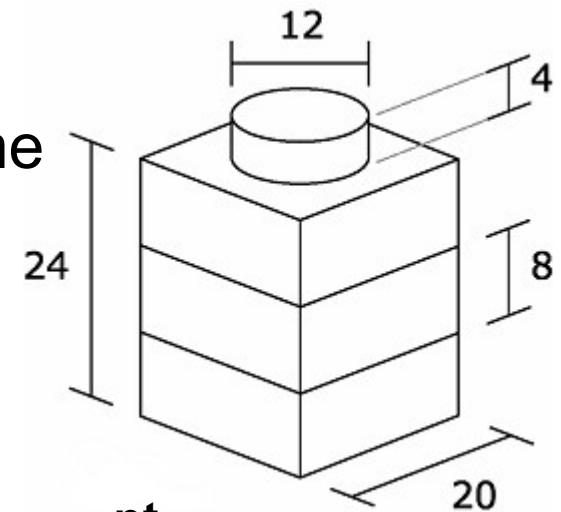
*Quick! Memorize all these numbers. There will be a quiz later.*



# Math is Hard!

## LDU = LDraw Unit

- A 1x1 stud brick or plate is  $5/16$ " or 8mm (0.8cm)
- The height is  $6/16$ " or 9.6mm (0.96cm)
- To make the math easier, LDraw designers came up with the LDraw Unit (LDU)
- Everything is a nice, easy integer this way!



	<u>LDU</u>	<u>studs</u>	<u>bricks</u>	<u>plates</u>	<u>cm</u>	<u>inch</u>	<u>pt</u>
<b>LDU</b>	1	1/20	1/24	1/8	0.04	1/64	9/8
<b>studs</b>	20	1	5/6	5/2	0.8	5/16	45/2
<b>bricks</b>	24	6/5	1	3	0.96	6/16	27
<b>plates</b>	8	2/5	1/3	1	0.32	2/16	9
<b>cm</b>	25	1.25	1.04	3.125	1	0.39	28.3
<b>inch</b>	64	3.2	8/3	8	2.54	1	72
<b>pt</b>	8/9	2/45	1/27	1/9	0.0353	1/72	1

# LEGO Bricks Are Not Square

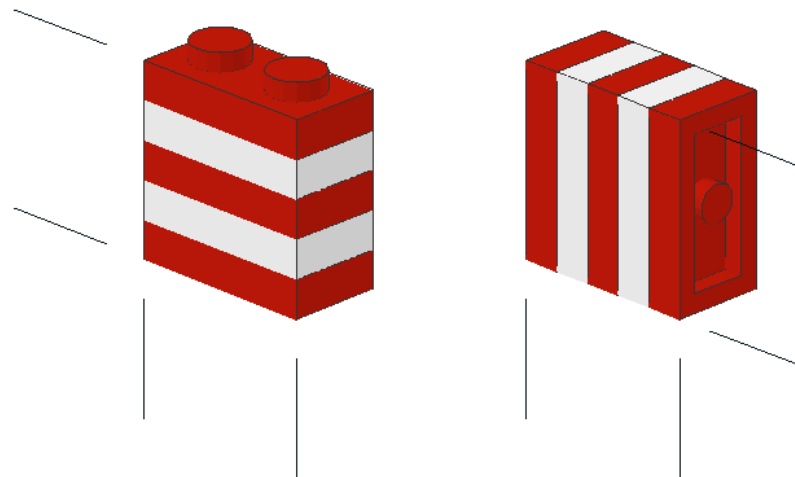
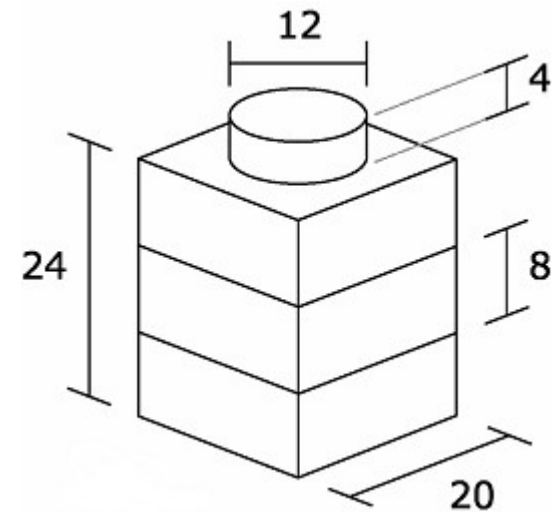
Bricks are 8mm wide by 9.6mm high

How do you make widths and heights match?

LDU makes the math easy....

How many plates = how many studs?

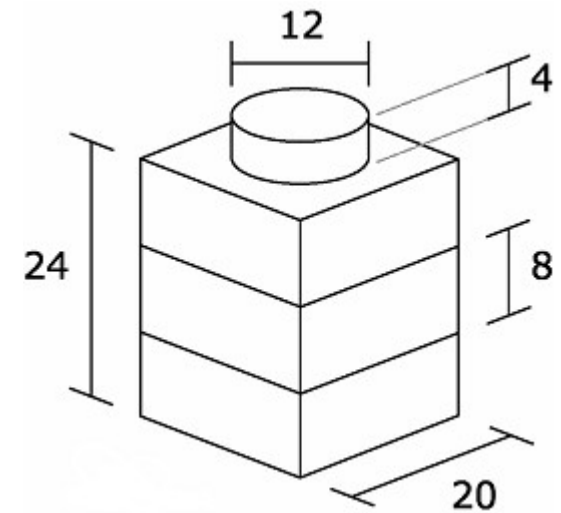
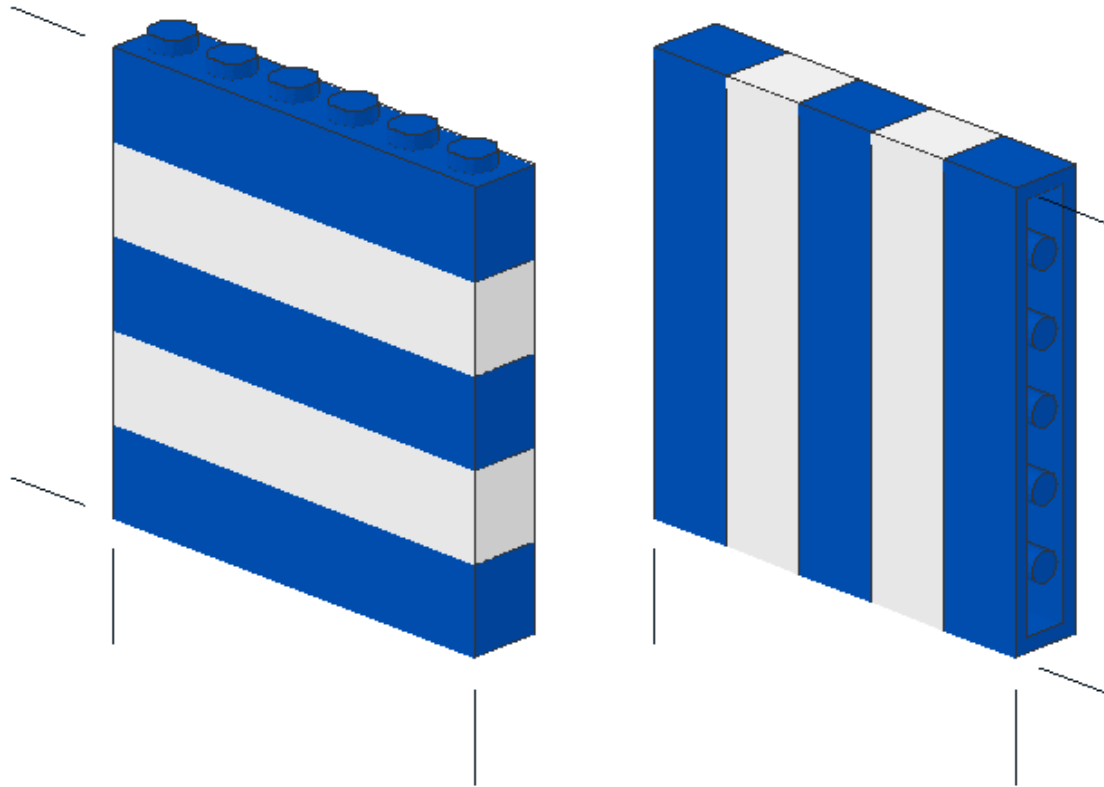
- 2 studs =  $2 \times 20 = 40$  LDU
- 5 plates =  $5 \times 8 = 40$  LDU



# 6:5 Brick Ratio

How many bricks = how many studs?

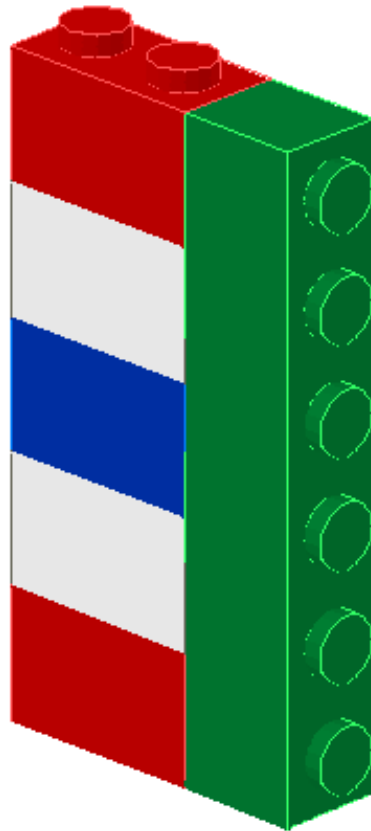
- 6 studs =  $6 \times 20 = 120$  LDU
- 5 bricks =  $5 \times 24 = 120$  LDU



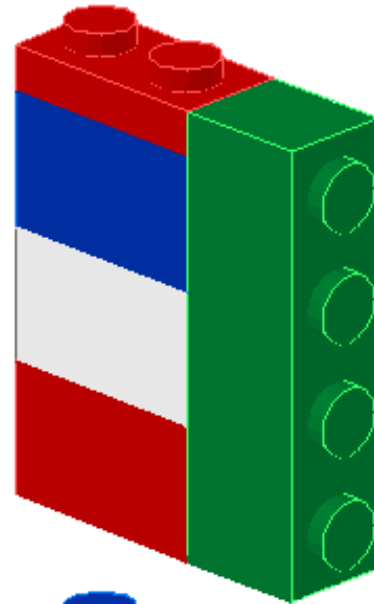
# Even Numbers of Studs

Any even number of studs corresponds to a combination of bricks and plates, since  $2 \text{ studs} = 5 \text{ plates}$

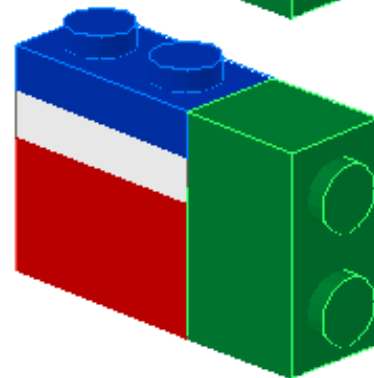
6 studs =  
5 bricks =  
120 LDU  
(or 15 plates)



4 studs =  
 $3 \frac{1}{3}$  bricks =  
80 LDU  
(or 10 plates)



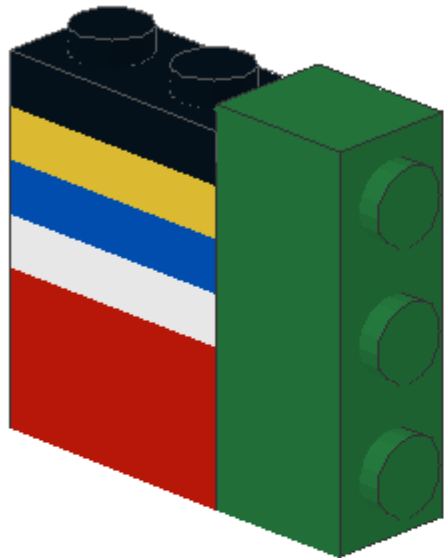
2 studs =  
 $1 \frac{2}{3}$  bricks =  
40 LDU  
(or 5 plates)





# Odd Numbers of Studs

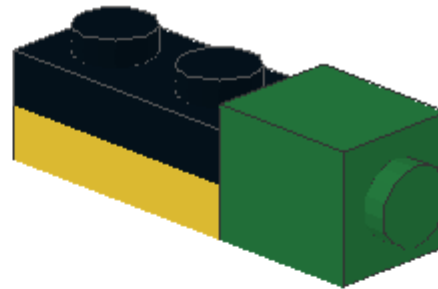
Since 1 stud =  $2\frac{1}{2}$  plates, no combination of plates adds up to exactly one stud



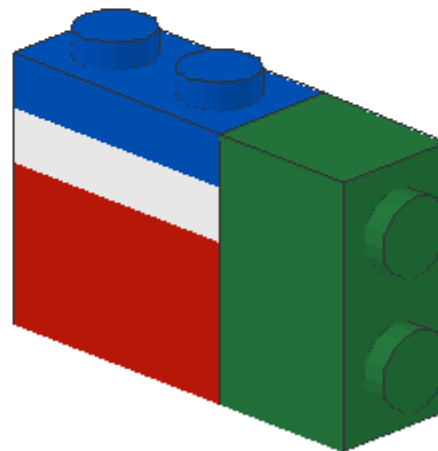
3 studs = 60 LDU

1 brick + 4 plates = 56 LDU

?? = 4 LDU  
(Missing  $\frac{1}{2}$  plate!)



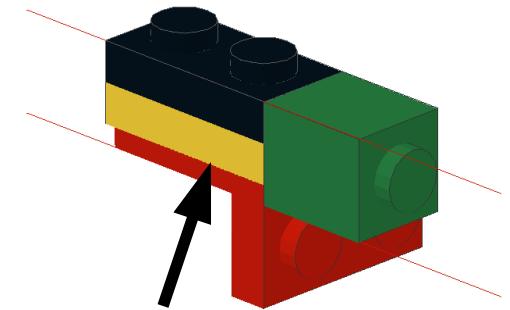
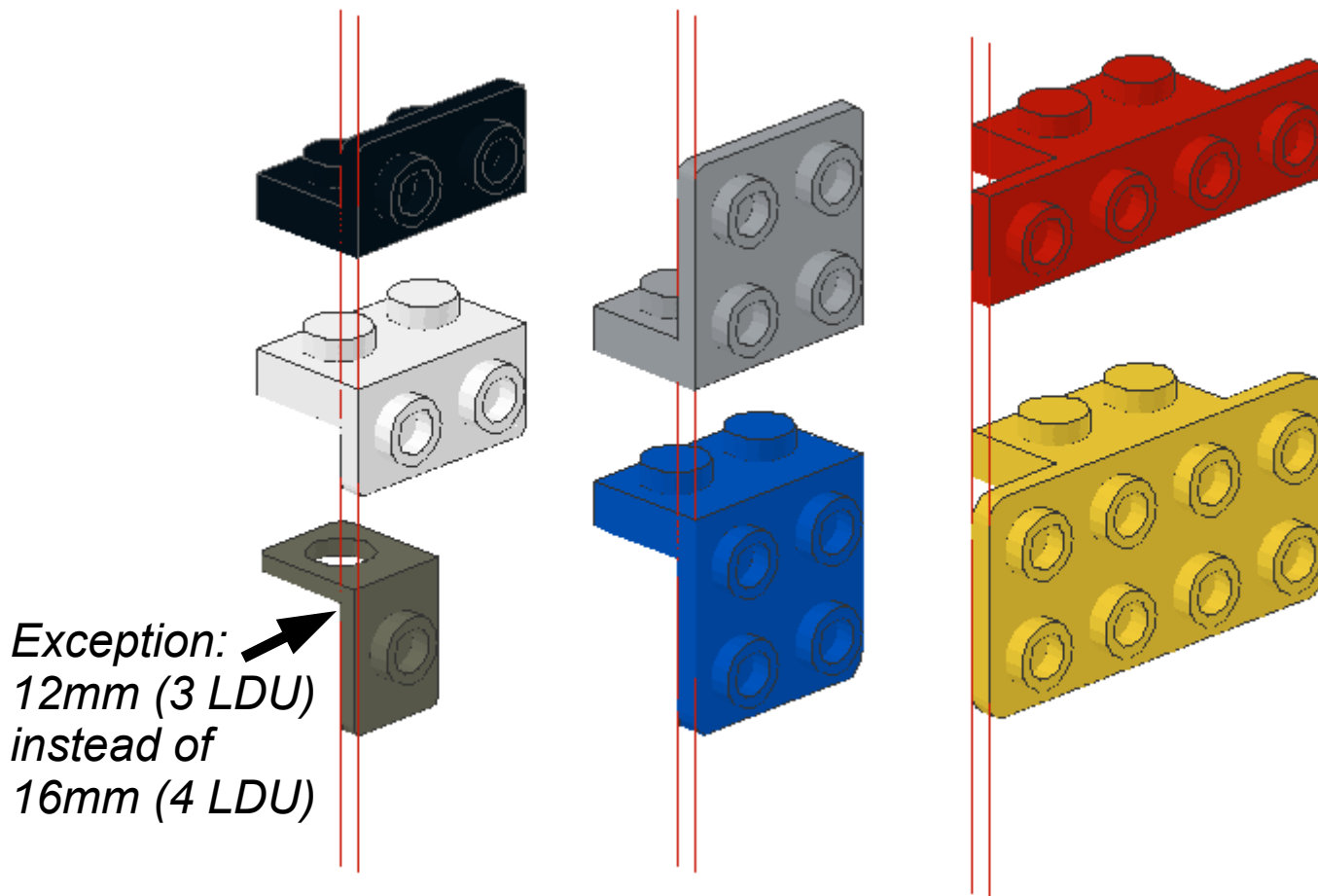
1 stud = 20 LDU  
2 plates = 16 LDU  
?? = 4 LDU  
(Missing  $\frac{1}{2}$  plate!)



2 studs = 40 LDU  
5 plates = 40 LDU  
(OK)

# But where do you get $\frac{1}{2}$ plate?

One answer: brackets. The thin vertical plate is  $\frac{1}{2}$  the thickness of a normal plate, or 4 LDU



1 plate = 8 LDU thick  
1 stud brick = 20 LDU  
2 plates + bracket =  
 $8 * 2 + 4 =$   
20 LDU

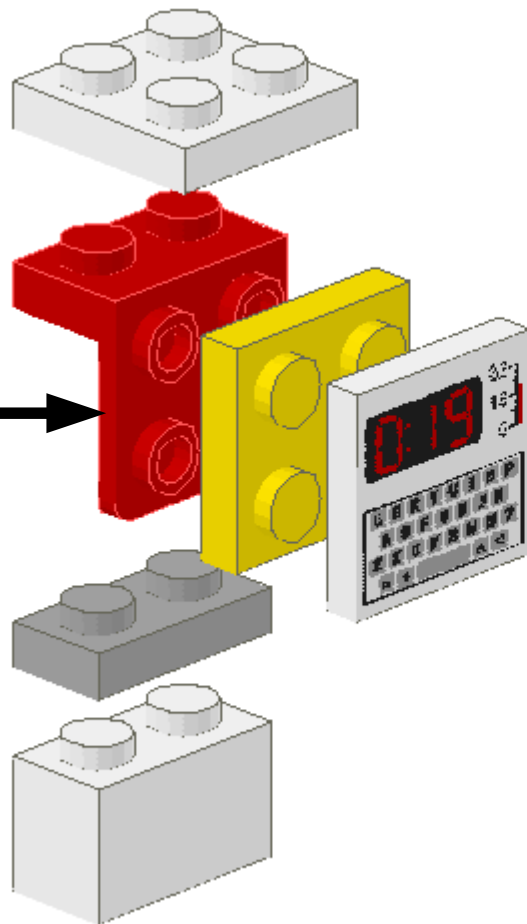


# **SNOT**

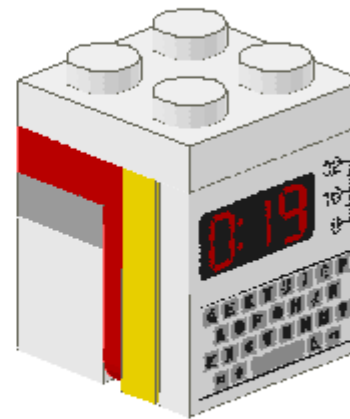
## **Studs Not On Top**

# Using $\frac{1}{2}$ plate thickness from brackets

Bracket vertical part is  $\frac{1}{2}$  plate thick



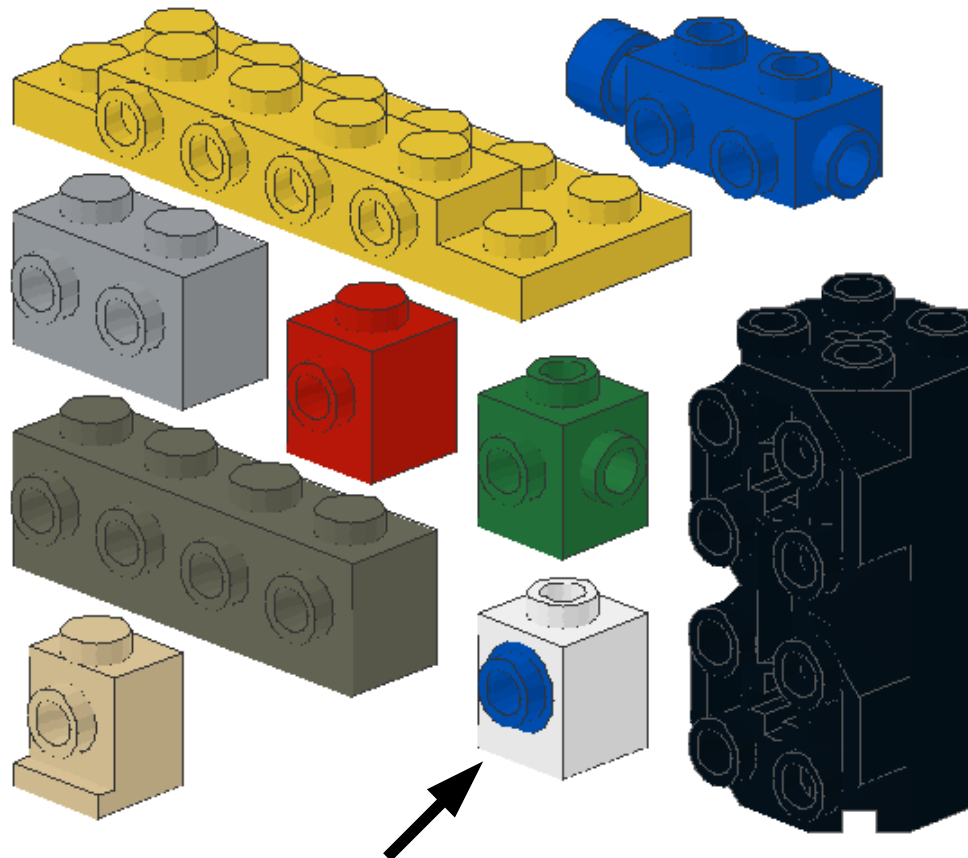
$\frac{1}{2}$  plate from bracket  
+ 1 plate + 1 tile  
=  $2 \frac{1}{2}$  plates, same as 1 stud



Computer tile is flush with edge of white 2x2 plate.

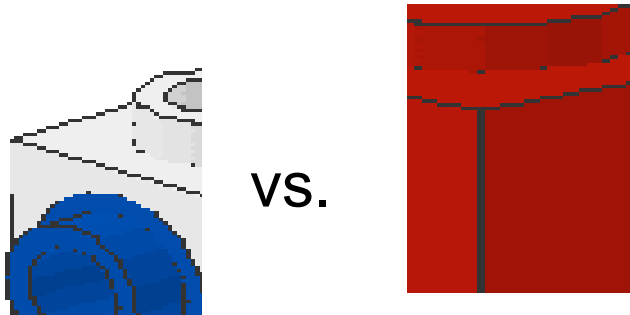
# Bricks with Studs on the Side

*LEGO has plenty of parts that have studs on the side, useful for SNOT (Studs Not On Top) design, similar to the brackets.*



*\* Technic brick with ½ pin is not quite the same – see next page*

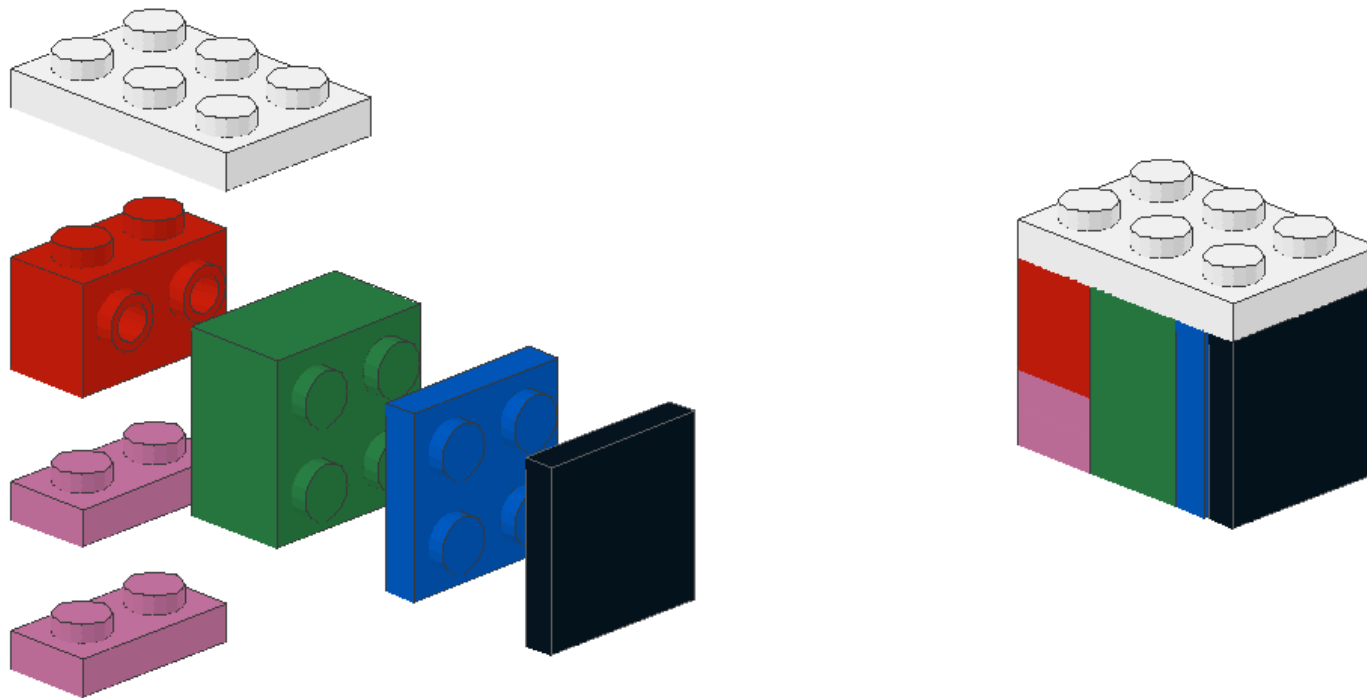
# Caveat – Technic Pin Alignment



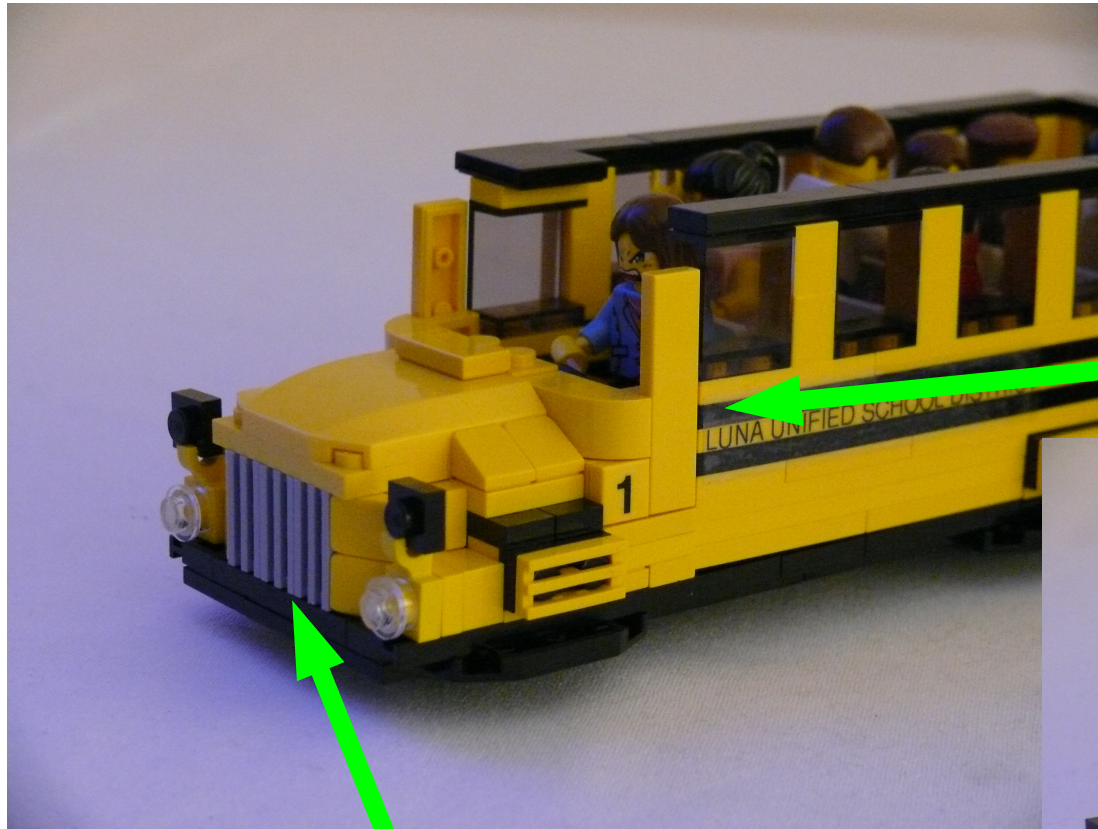
- *Technic pin hole placement is just a little higher (about 0.2mm) than stud-on-side placement.*
- *Some models may have alignment problems due to this.*
- *Reason: early Technic brick molds needed thicker plastic between pinhole and bottom of brick.*
- *Result: LEGO now produces more bricks with studs on side instead of using  $\frac{1}{2}$  pins in Technic bricks – better for us anyway*

# Bricks with studs on sides to mount flush

Use bricks with studs on sides to attach assemblies at 90 degrees.  
To mount them flush, remember that 5 plates = 2 studs = 40 LDU.

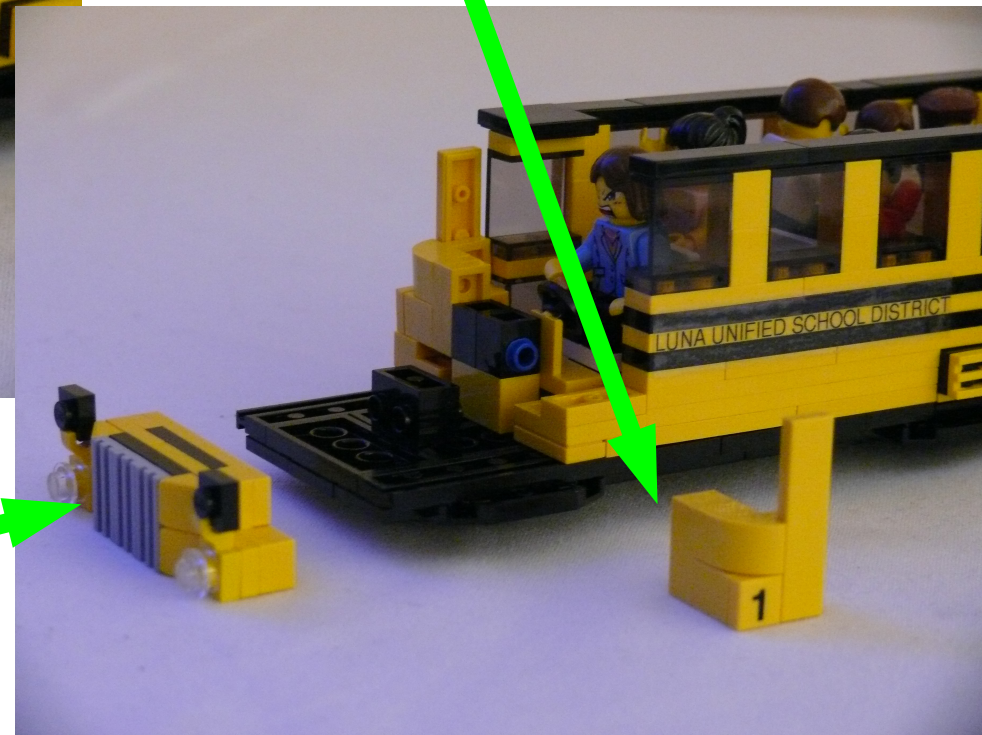


# Flush tile examples



My School Bus model used this technique in two places  
Side panel

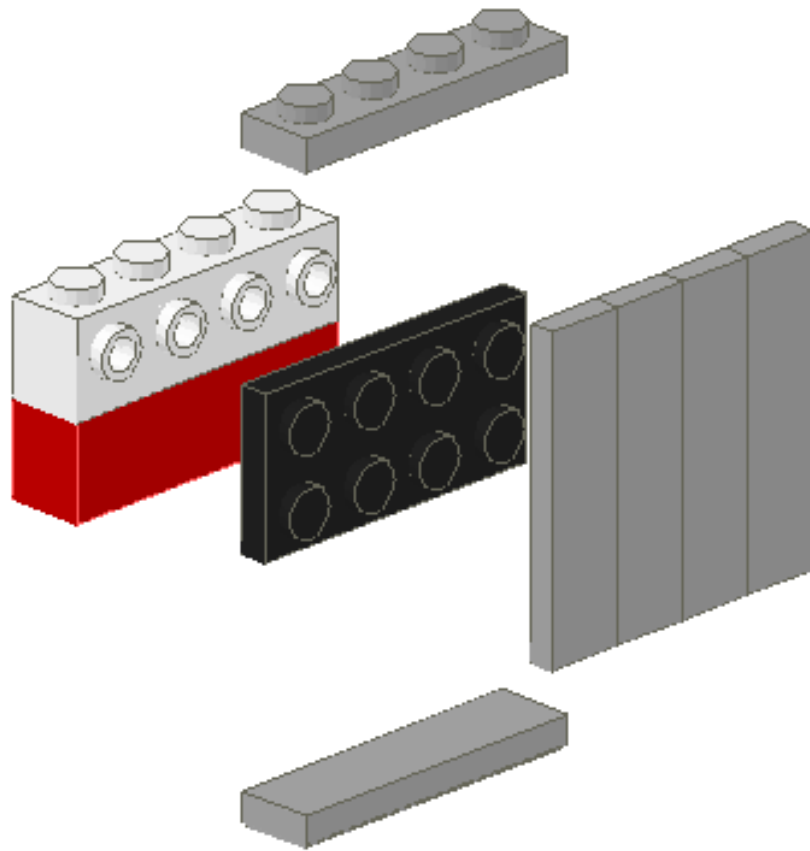
Grille and headlight assembly  
Both are flush since  $5 \text{ plates} = 2 \text{ studs} = 40 \text{ LDU}$



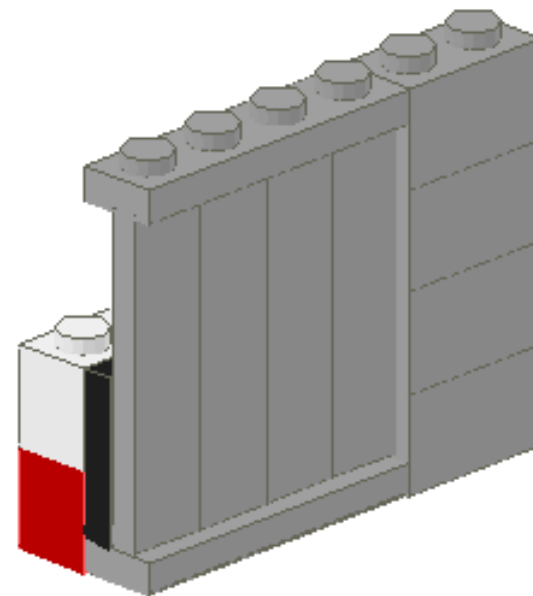


# Inset Panels

Use half-plate offsets to add texture to an otherwise flat wall



1 plate + 2 studs (1  $\frac{2}{3}$  brick)  
= 2 bricks



*Tiles are  $\frac{1}{2}$   
plate inset*

2 plates + 4 studs (3  $\frac{1}{3}$  bricks)  
= 4 bricks

# Inset panels example



*Panels inset by  $\frac{1}{2}$  plate*

My F40PH Caltrain locomotive

Photo by Drew Dirschell: <https://www.flickr.com/photos/7333042@N06/4639456044>

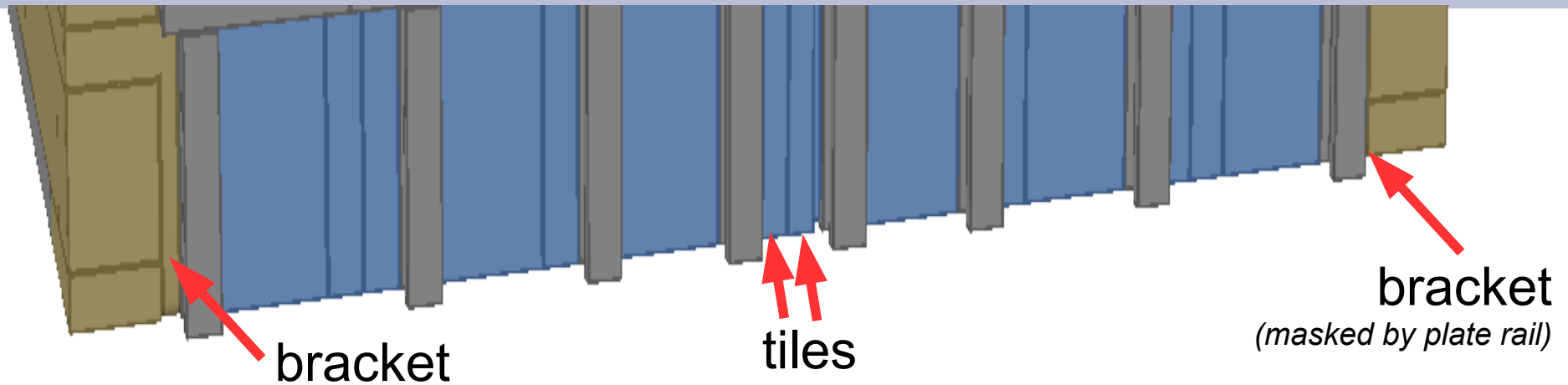
# “De Vier Gekroonden”

This model by Vincent “Mr. Tomato Bread” Kessels uses some of these techniques.

*Photos used with permission*



# Sideways Building with Brackets



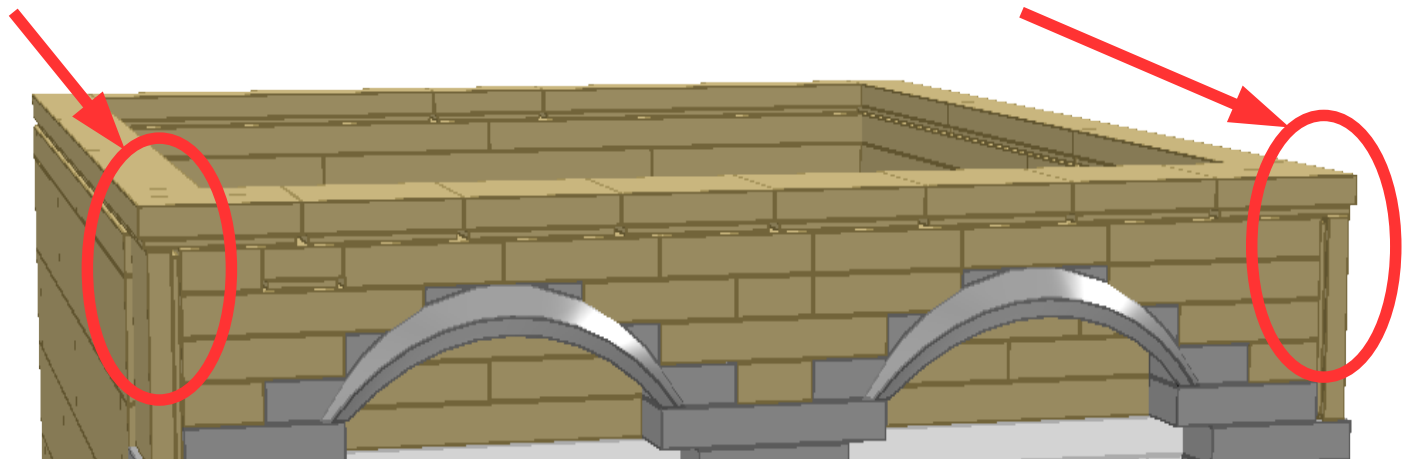
- Stack bricks and plates with a tile on the end
- Mount on bracket on each side facing inward
- $3 \text{ bricks} = 3 \times 24 = 72 \text{ LDU}$   
 $7 \text{ plates} + 1 \text{ tile} = 8 \times 8 = 64 \text{ LDU}$   
 $\text{bracket} = 4 \text{ LDU}$   
 $\text{Total} = 140 \text{ LDU} = 7 \text{ studs}$
- Tiles on the ends press together and friction holds it all together

Model:  
"De Vier Gekroonden"  
by Vincent Kessels  
a.k.a.  
"Mr. Tomato Bread"

# The Problem with Jumper Plates

- Requirement: 5-stud wide window openings with 6-stud wide arches above.
- Solution: offset the arches by  $\frac{1}{2}$  stud using jumper plates
- Side effect: How to fill  $\frac{1}{2}$  stud gap on ends?
- Imperfect solution: attach tile mounted sideways.
- $\frac{1}{2}$  stud = 10 LDU. Tile = 8 LDU. Gap of 2 LDU ( $\frac{1}{4}$  plate) cannot be filled by any LEGO part. Any better ideas to fill a 10 LDU space?

Model:  
"De Vier Gekroonden"  
by Vincent Kessels  
a.k.a.  
"Mr. Tomato Bread"



# Mosaic Dates on LEGO Modular Sets



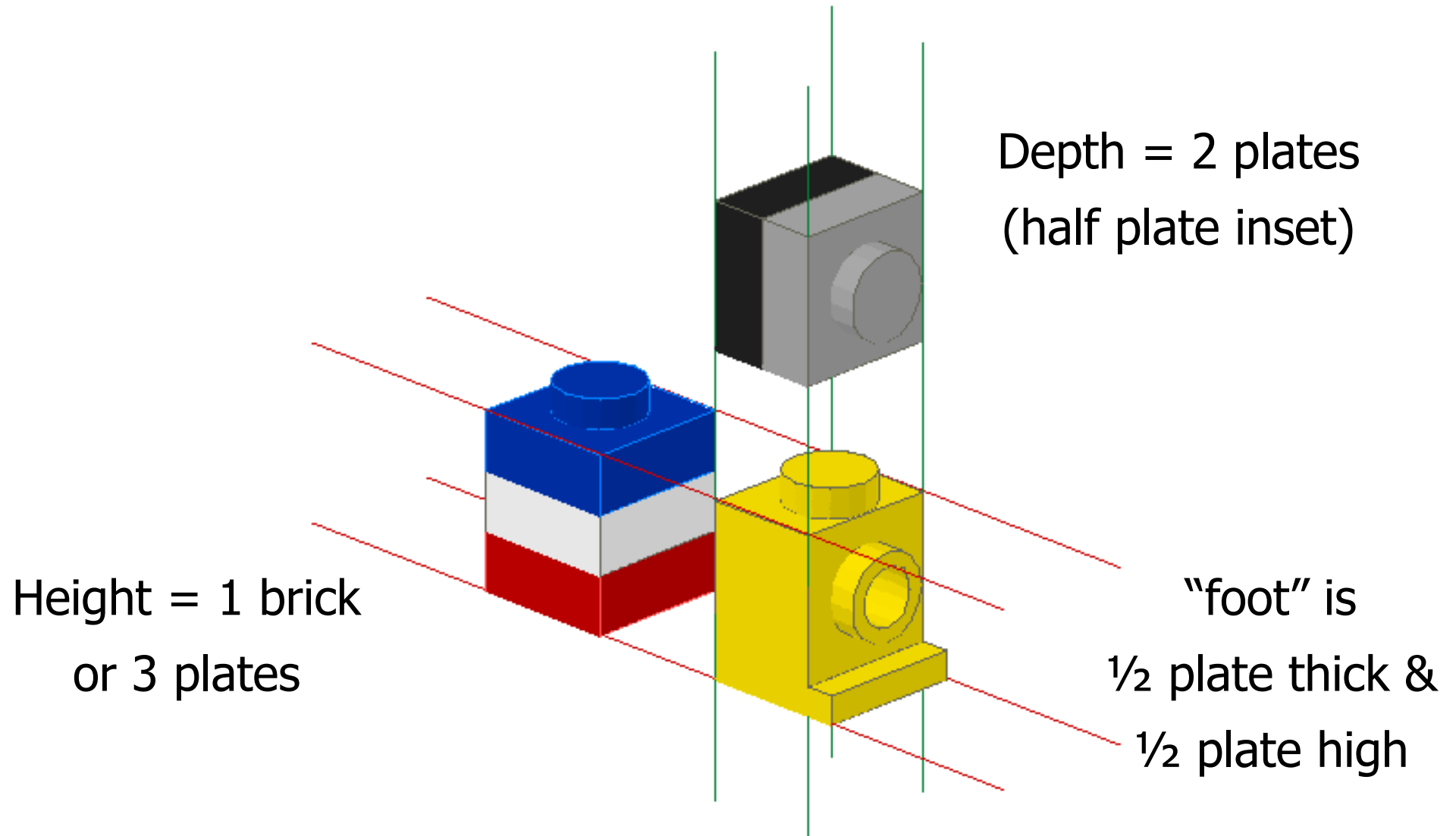
These sets (#10197 & 10224) use plates and tiles to create SNOT dates on the buildings.





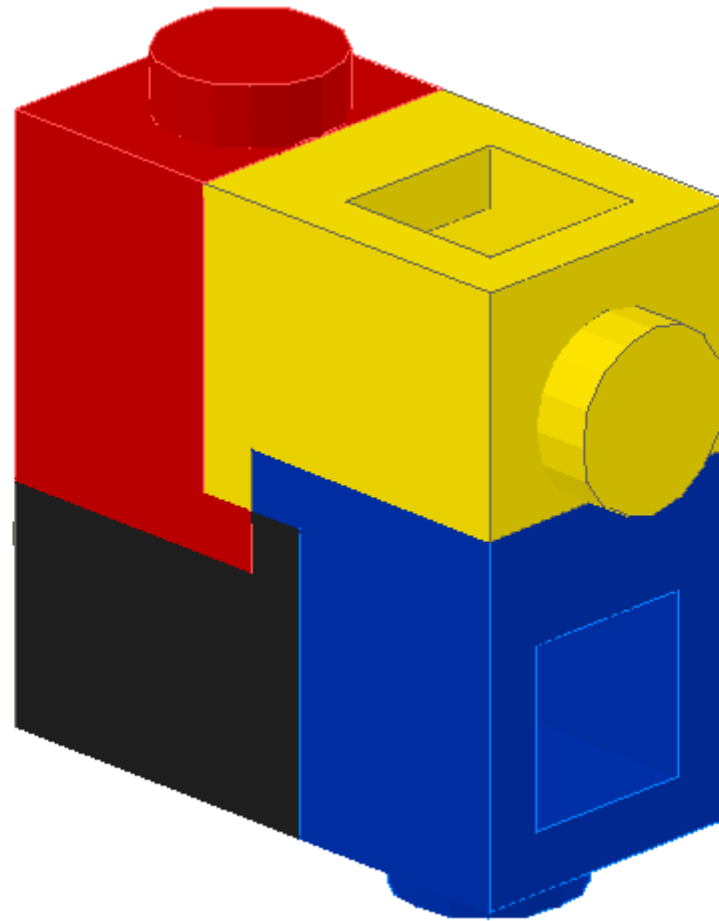
# **Fun with Headlight Bricks**

# Headlight Brick Dimensions





# Four headlight bricks



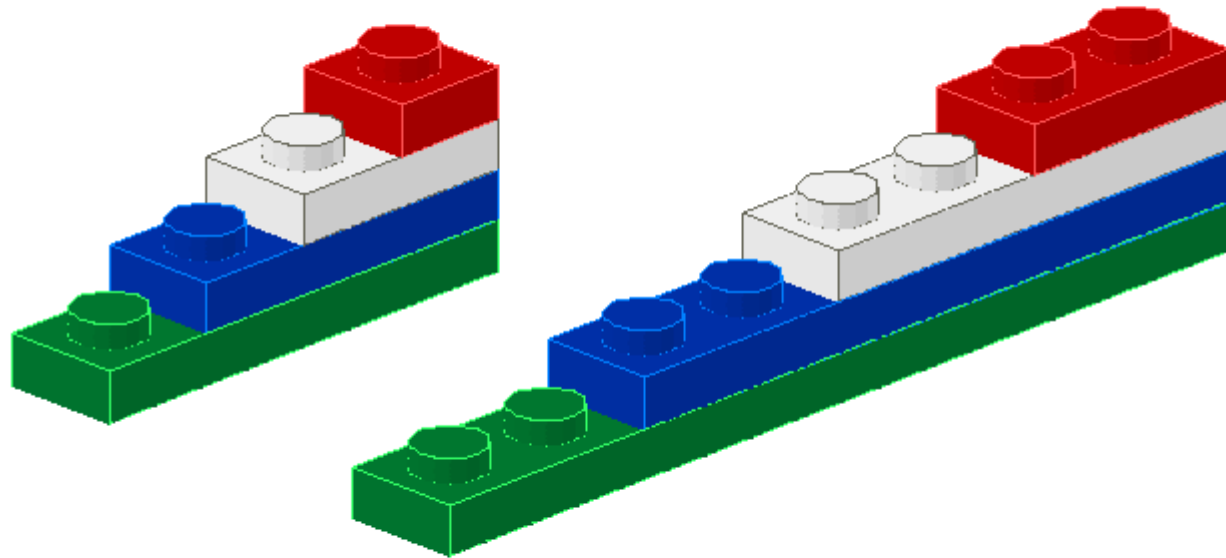
2 plates (red) +  
3 plates (yellow) =  
5 plates = 2 studs

Result: 5 plates or 2 studs in each of 4 directions.

# Problem: Gradual Steps

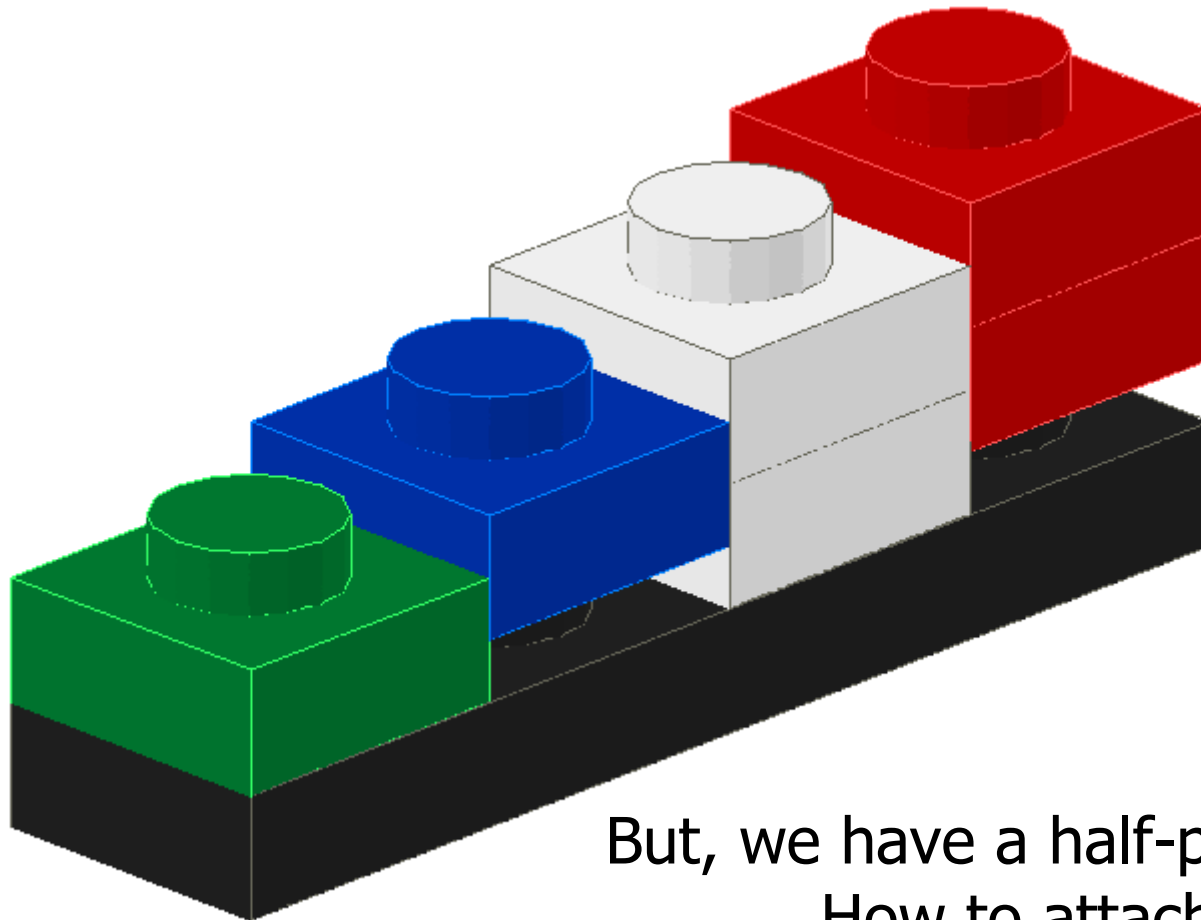
How do you make a gentle slope?

What if these are too steep?



# Gradual Steps

For a more gradual slope, we'd like to mount every other one  $\frac{1}{2}$  plate higher

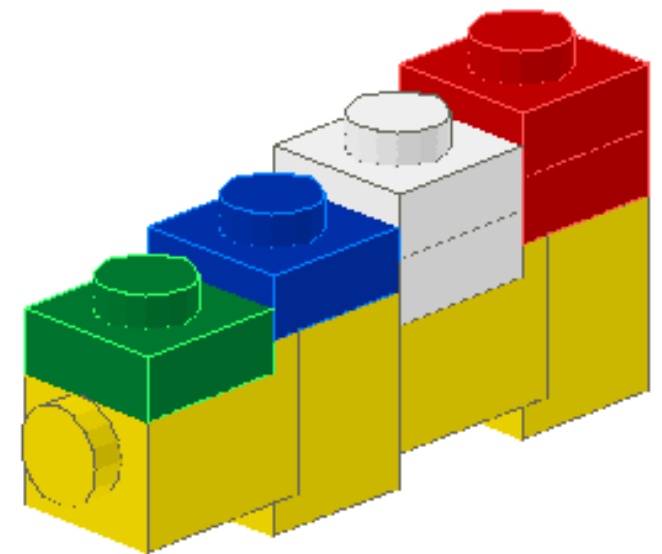
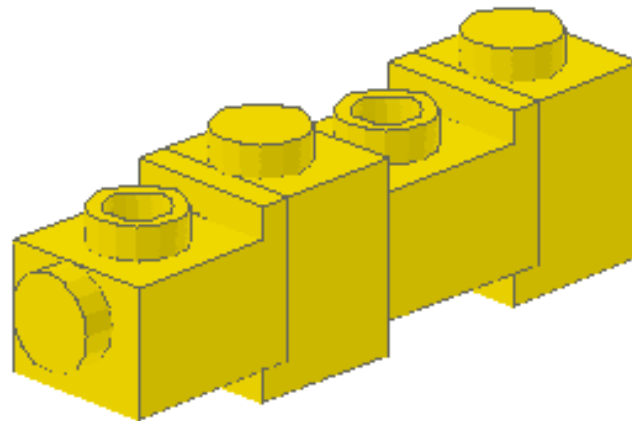


But, we have a half-plate hole to fill!  
How to attach these?

# Solution: Headlight Bricks

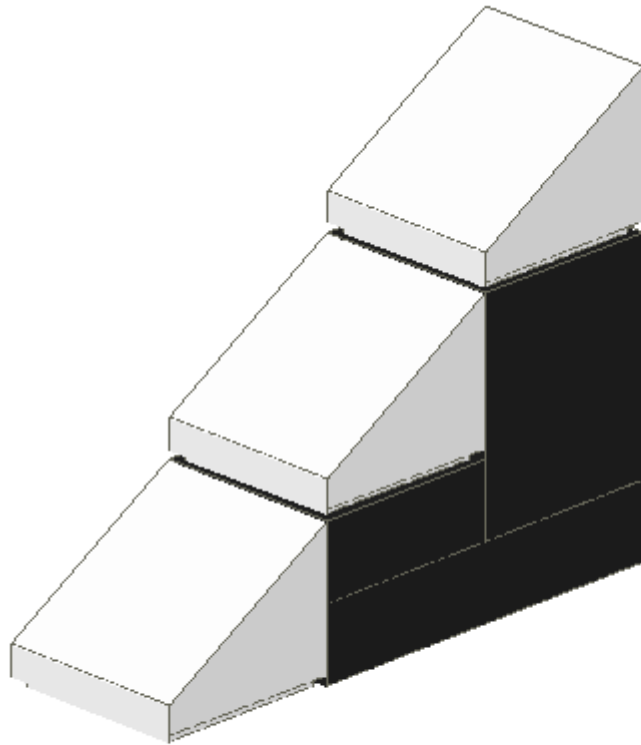
Alternate rotations for headlight bricks to take advantage of  $\frac{1}{2}$  plate offset in "foot"

2 plates +  $\frac{1}{2}$  plate = 1 stud



Half-plate lift from "foot"

# Problem with “cheese slope”: Stairstep effect

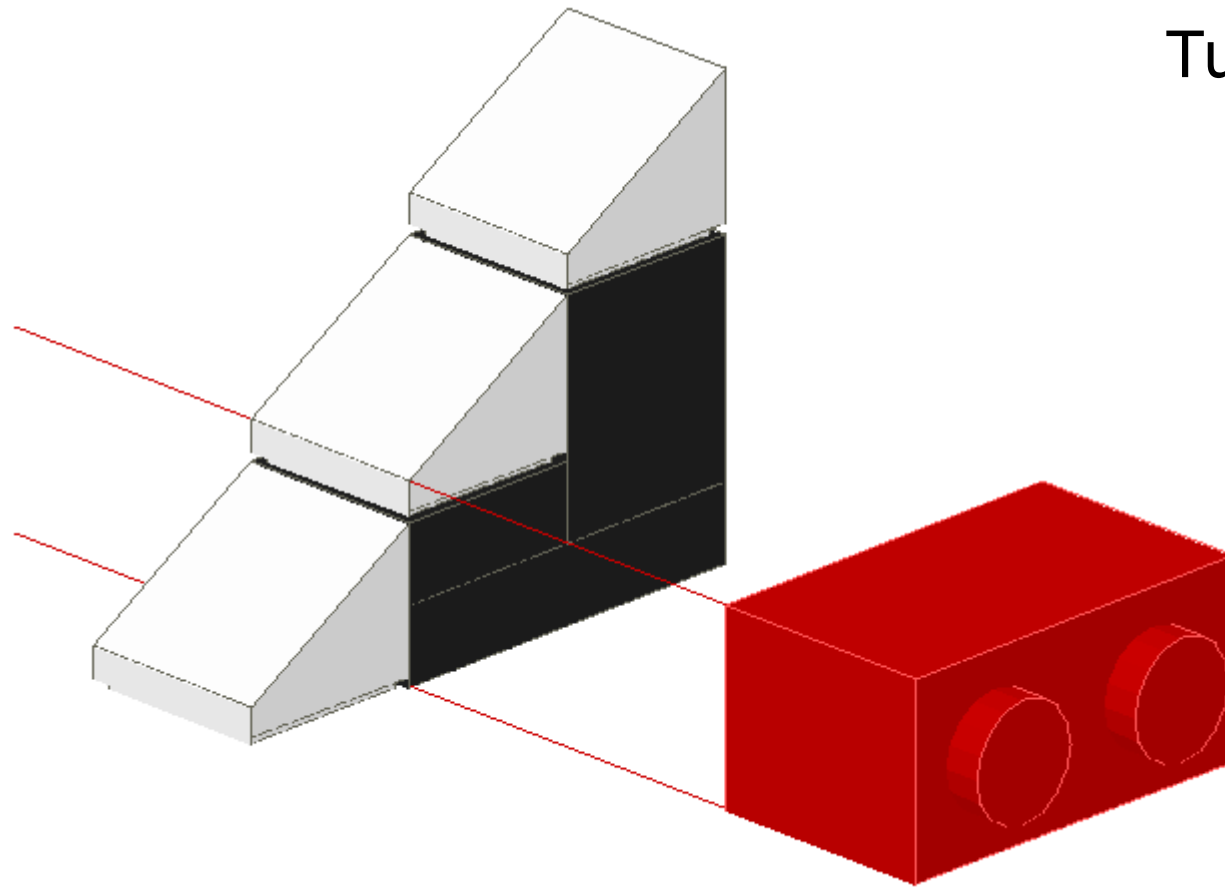


The 1x1 “cheese slope” is a very useful part but doesn't combine well with others of its kind to make a smooth slope.

This notch is needed for it to fit a stud inside, but is ugly.

# Problem with “cheese slope”: Stairstep effect

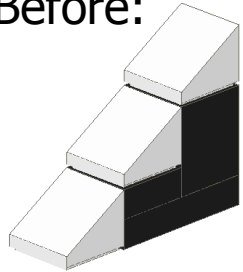
Turns out that “notch”  
is  $\frac{1}{2}$  plate thick.



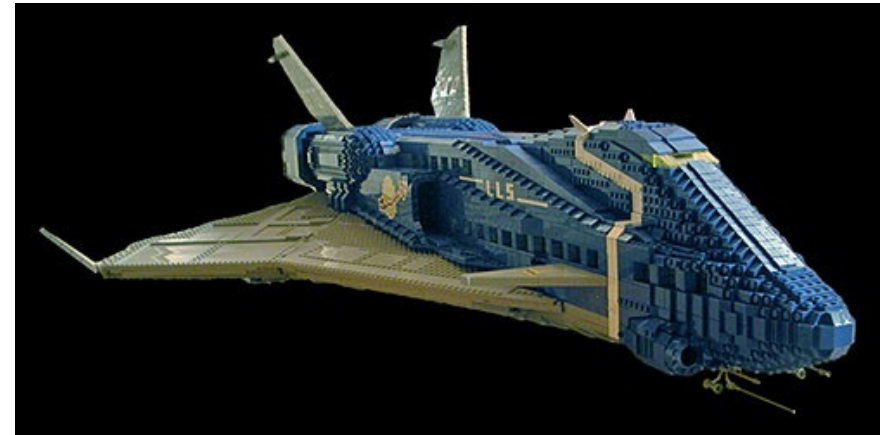
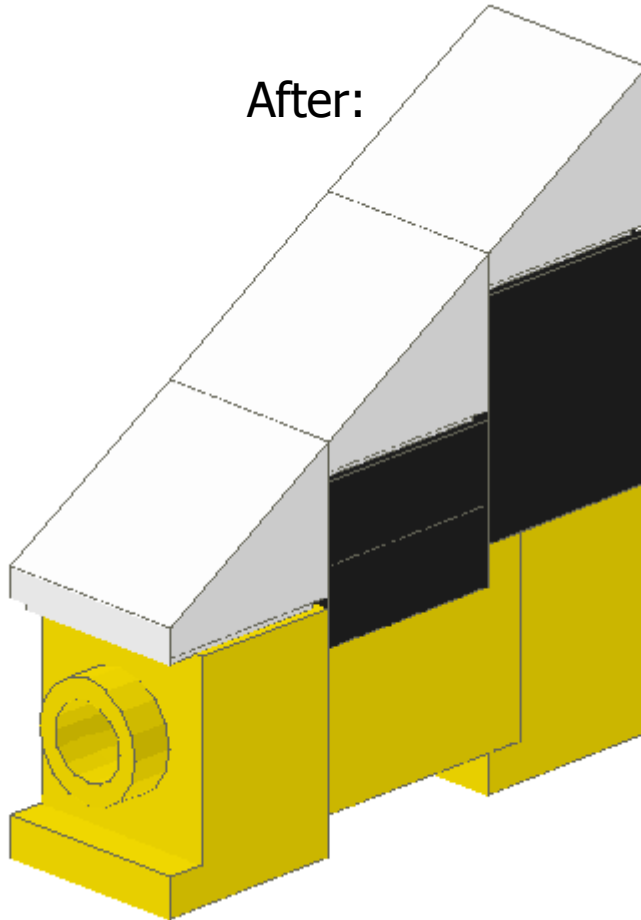
2 plates (height of cheese slope) +  $\frac{1}{2}$  plate  
= 1 stud

# Solving the stairstep effect

Before:



After:

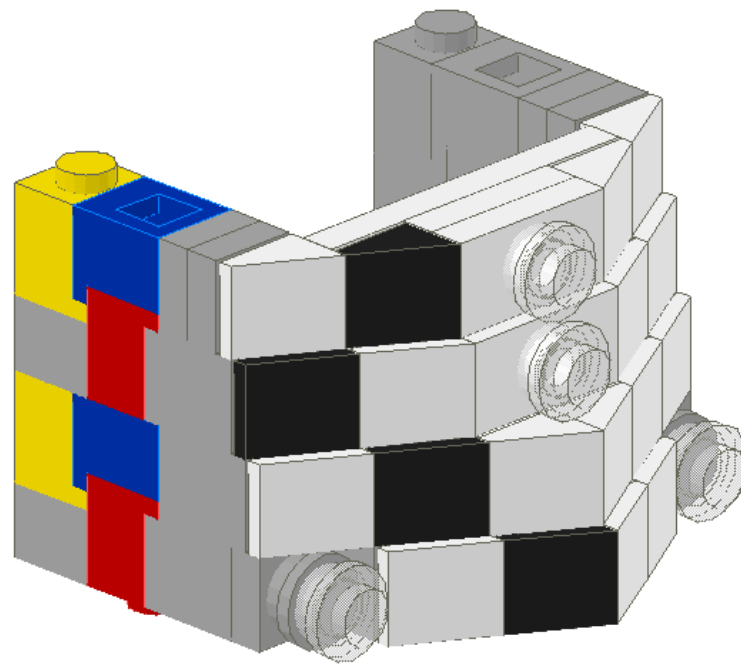
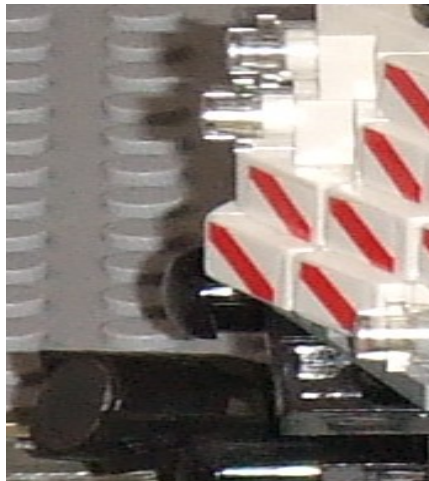


Used in Bram Lambrecht's  
"Legoland Spacelines 979"  
seen at BrickCon 2007

<http://www.flickr.com/photos/bram/1461137007/>  
(used with permission)

Mount the center slope 1/2 plate lower for a smooth surface!

# Useful for trains, too



My F40PH Caltrain locomotive

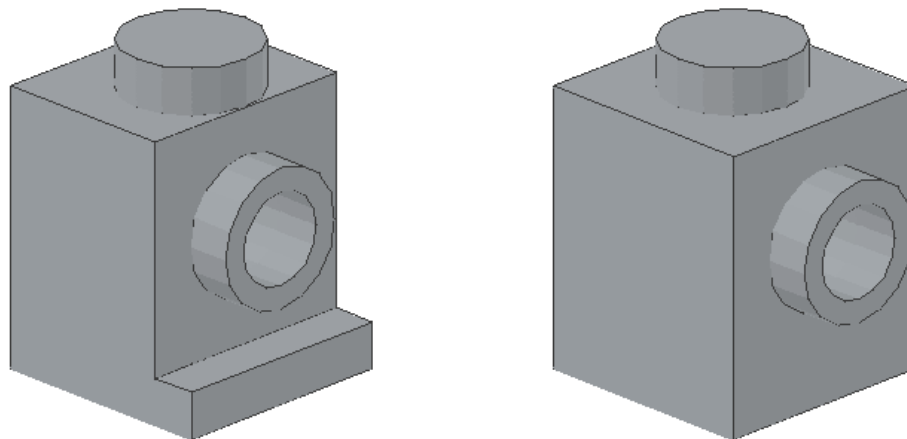


# “Headlight Brick” vs. “Brick 1 x 1 with Stud on 1 Side”

Headlight Brick depth = 2 plates = 16 LDU

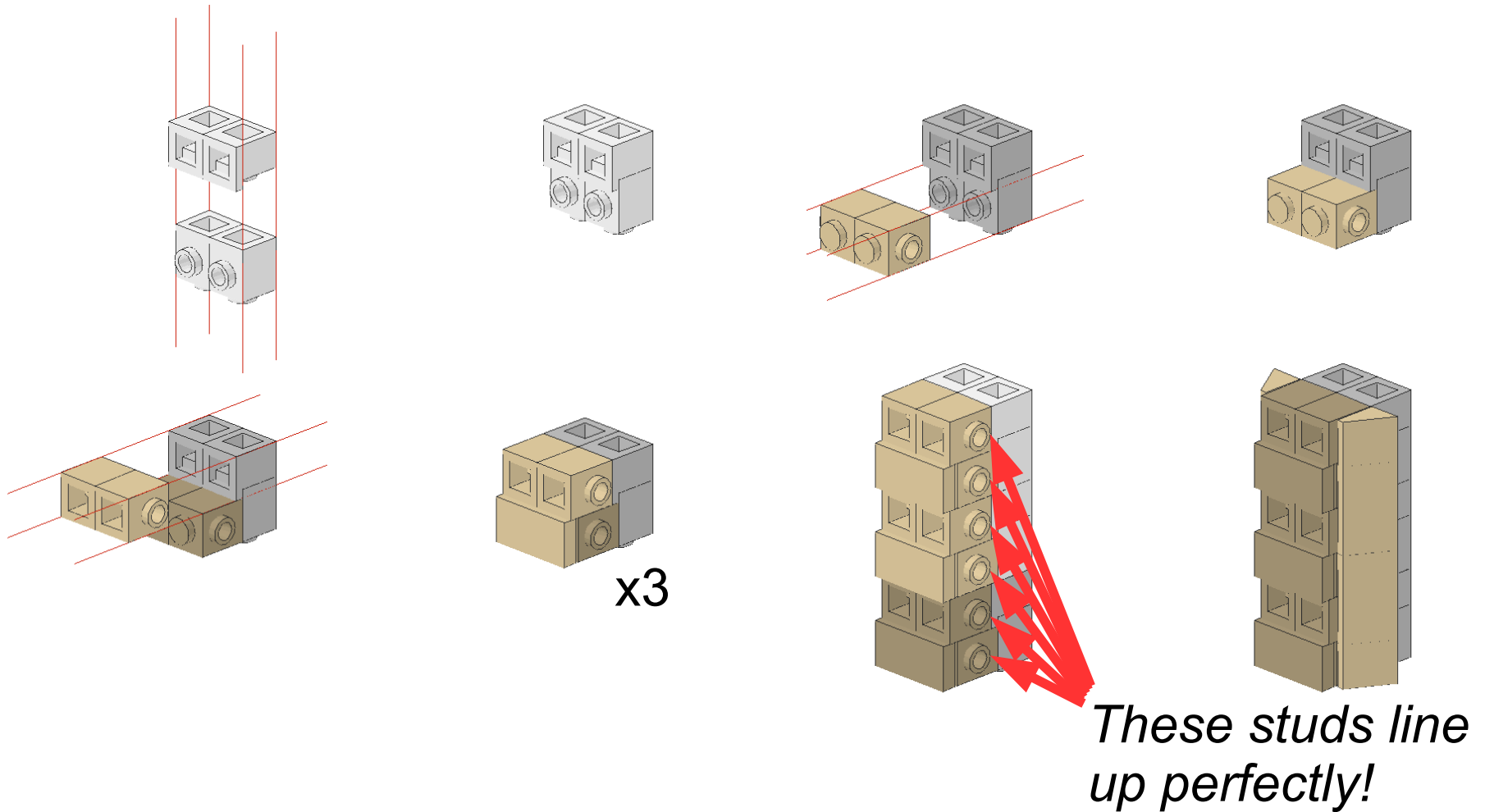
Brick depth = 2 ½ plates = 20 LDU

Combine these to achieve ½ plate differences in depth!



# Hospital Bay Window example

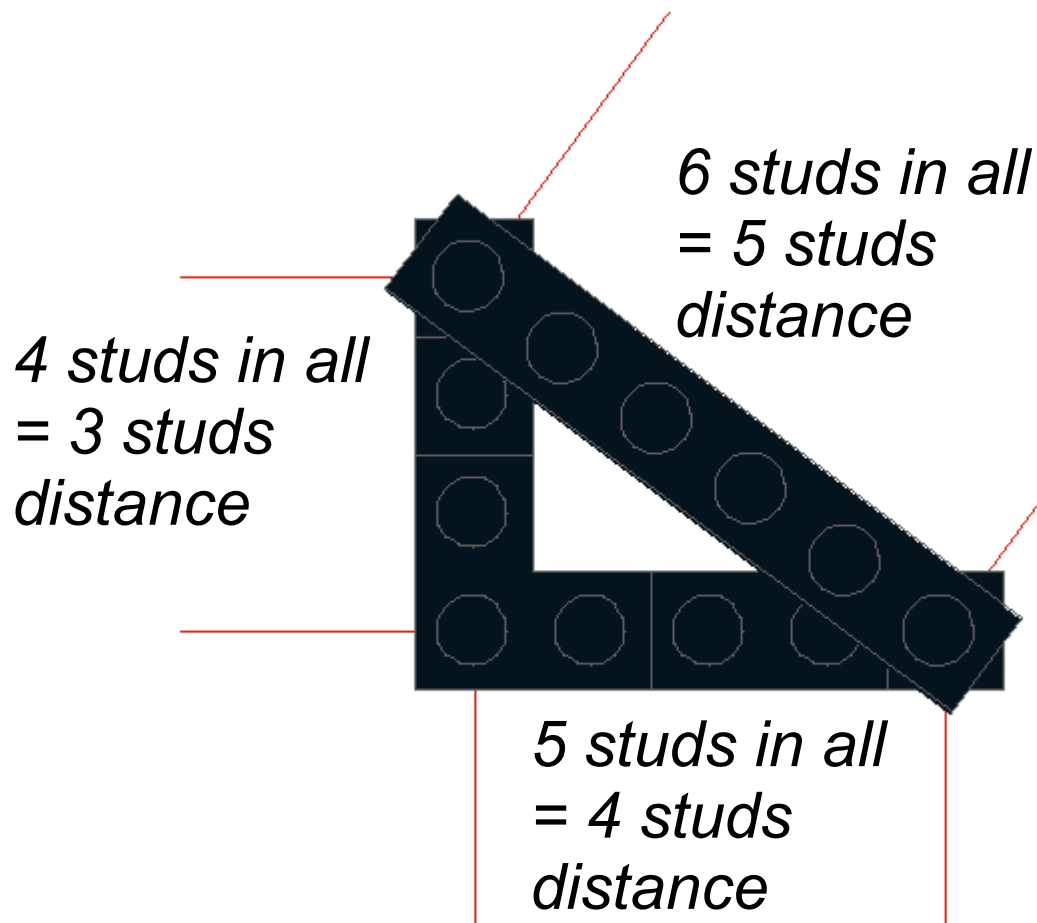
Windows (bottoms of bricks) are inset by  $\frac{1}{2}$  plate





# Triangles

# Pythagorean Triples



Pythagorean Triples are right triangles where the sides are all integers. The 3-4-5 triangle is easy to make in LEGO.

Trick is, count between the *centers* of the studs! Each side is one stud longer than you might expect.

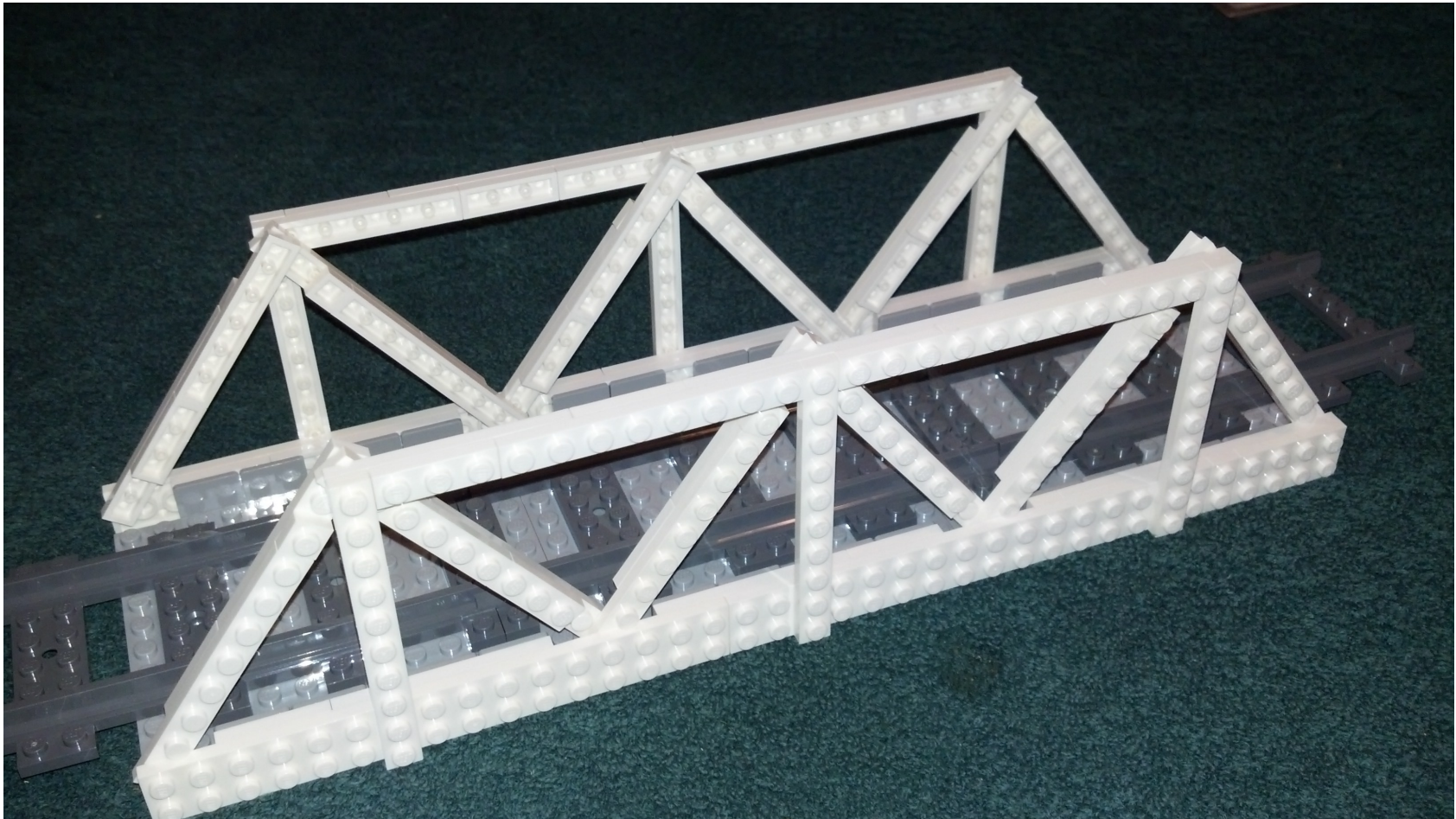
Note: You may need spacer plates for the diagonal to clear the studs.

# More Pythagorean Triples

- There are only 4 triples with the diagonal of length 25 or less:
  - (3, 4, 5); (5, 12, 13); (8, 15, 17); (7, 24, 25)
- Additional ones can be made by multiplying these values by a scaling factor.
  - Example: (6, 8, 10) = 2x(3, 4, 5)
- Any other triangle with integer sides will *not* be a right triangle!

# Pythagorean Triple Example: Truss Bridge

*Trusses made from (6, 8, 10) Pythagorean triangles*



# Additional Resources

- “Offset” page on brickwiki  
<http://www.brickwiki.info/wiki/Offset>
- Reinhard Beneke, BrickFest PDX '04  
<http://www.brickshelf.com/cgi-bin/gallery.cgi?f=74539>
- Previous versions of this presentation:
  - BrickCon 2008: Half Plate Offsets  
<http://www.brickpile.com/2008/10/07/half-plate-offsets-slides/>
  - BBTB 2013 & BrickCon 2013: Brick Geometry  
<http://www.brickpile.com/2013/10/17/slides-for-brickcon-brick-geometry-presentation/>



**Q&A**



# Thank you

*Contact me if you have any further questions...*

**bill@wards.net**  
**www.brickpile.com**

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