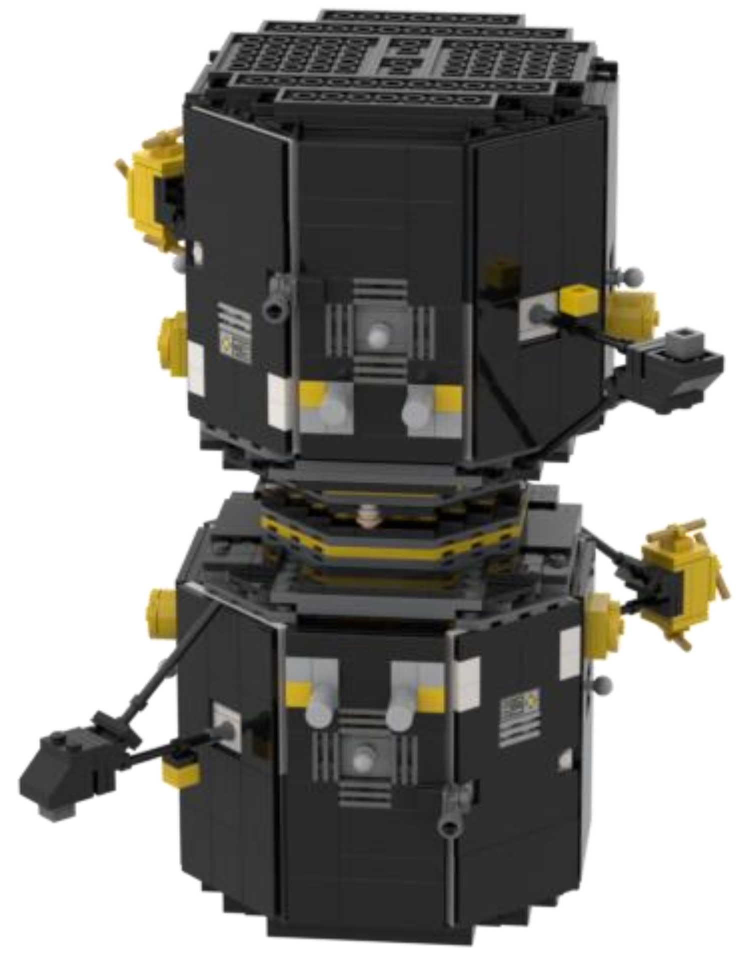
TRACERS
LEGO model build instructions




138x
3070
Black


1x
3070pb009
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1x
3070pb019
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1x
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48x
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2x
15712
Black


8x
5091
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4x
36841
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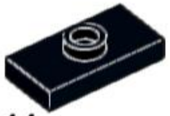
14x
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28x
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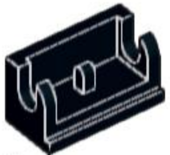
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4x
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4x
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34x
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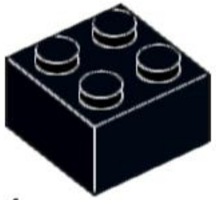
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72x
26603
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16x
3710
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8x
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20x
87079
Black


8x
63965
Black


32x
3666
Black


28x
6636
Black

10x
69729
Black

8x
3032
Black

8x
3034
Black

12x
3958
Black

8x
2445
Black

4x
2412b
Dark Gray

4x
98138
Dark Bluish Gray

4x
3024
Dark Bluish Gray

4x
32002
Dark Bluish Gray

4x
4589
Dark Bluish Gray

4x
36840
Dark Bluish Gray

4x
32828
Dark Bluish Gray

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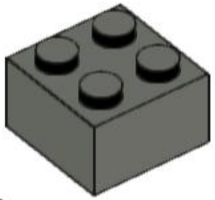
4x
3069pc1
Dark Bluish Gray



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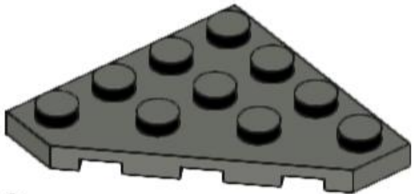
3003
Dark Bluish Gray



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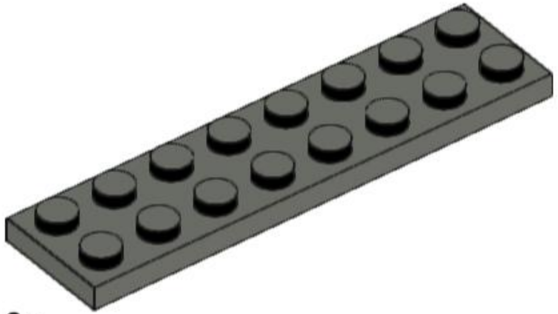

8x
3034
Dark Bluish Gray

4x
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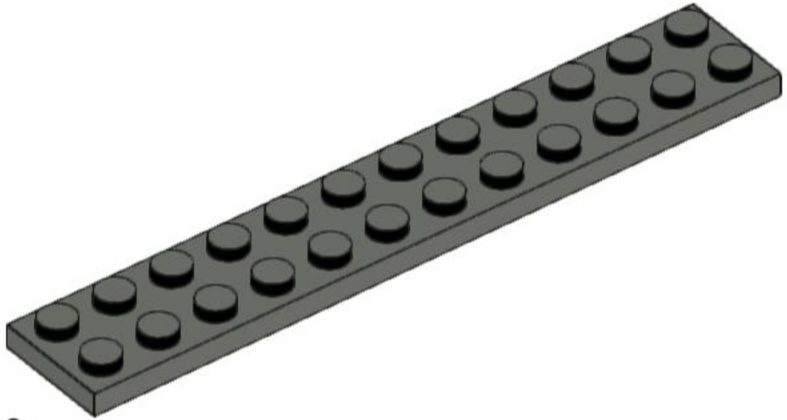
Dark Bluish Gray



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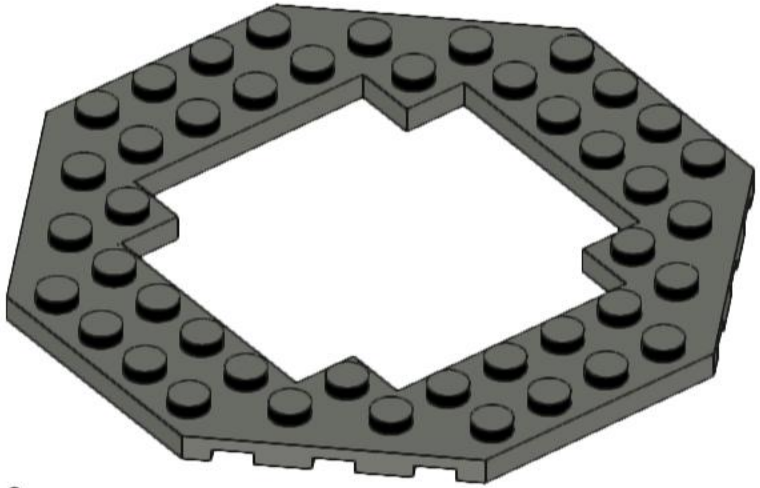

6x
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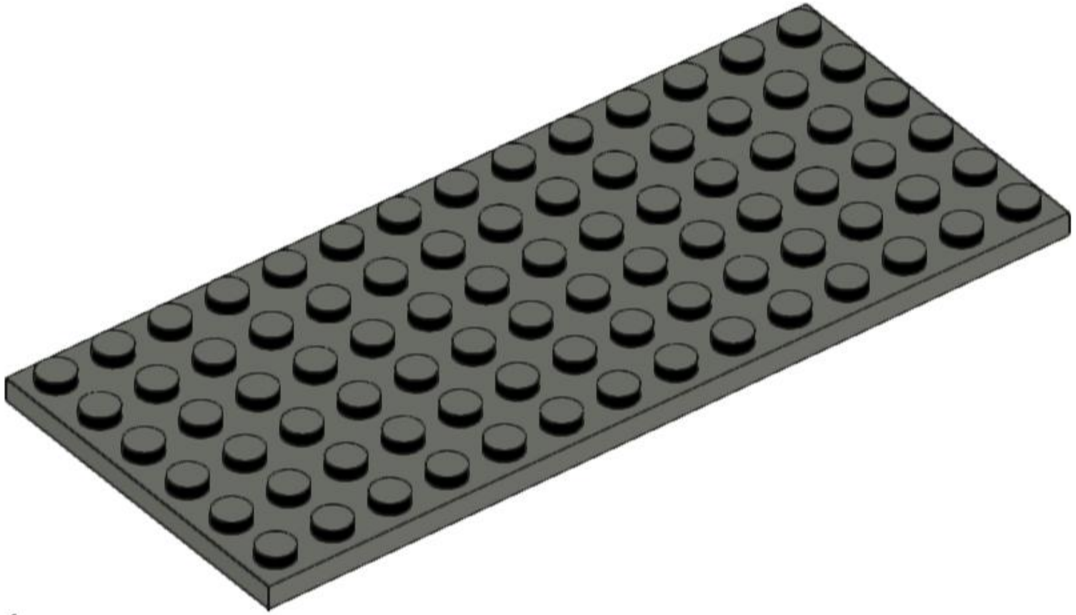

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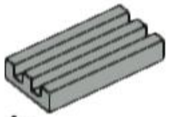
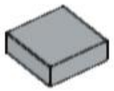
3456
Dark Bluish Gray



4x
2412b
Light Gray



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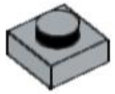
Light Bluish Gray

8x
98138
Light Bluish Gray

8x
4073
Light Bluish Gray



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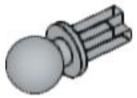
Light Bluish Gray

8x
3062
Light Bluish Gray



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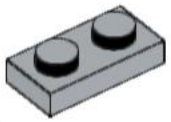

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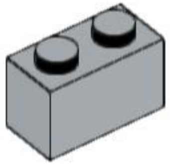
Light Bluish Gray



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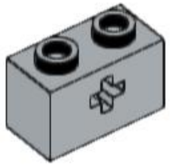
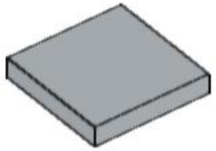
3004
Light Bluish Gray



8x
32064a
Light Bluish Gray



8x
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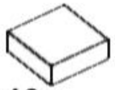
Light Bluish Gray



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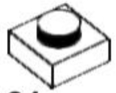
3070
White

4x
85861
White



24x
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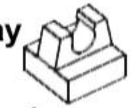

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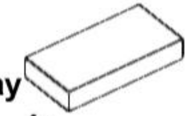

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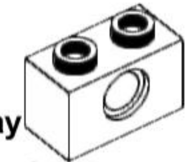

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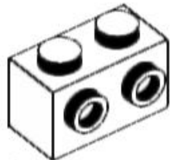

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11211
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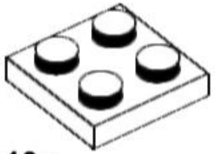
10x
3022
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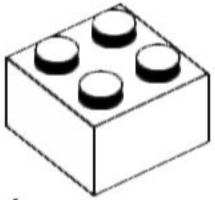
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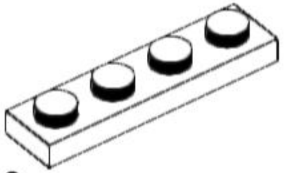
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3710
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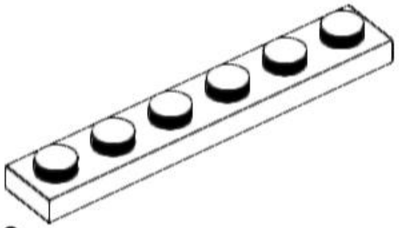
8x
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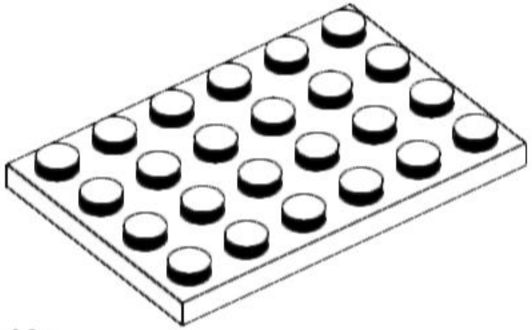
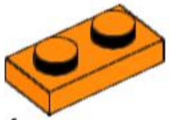
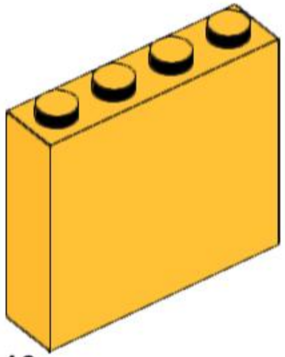

16x
3032
White


32x
87087
Bright Pink


4x
3023
Orange


4x
32828
Light Nougat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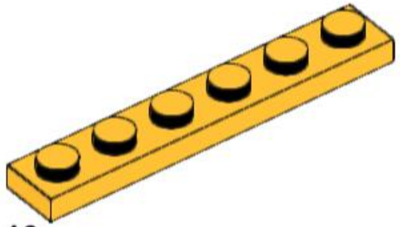
49311
Bright Light Orange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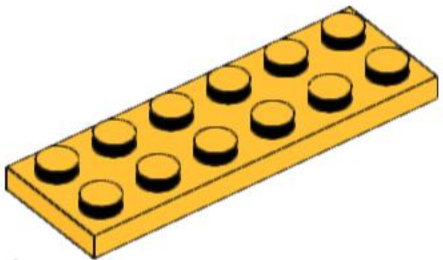
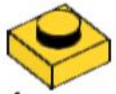
3666
Bright Light Orange


4x
3795
Bright Light Orange


8x
3070
Yellow


4x
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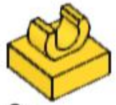
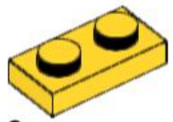
Yellow


6x
15712
Yellow


8x
36840
Yellow


4x
87087
Yellow


6x
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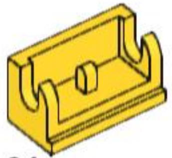
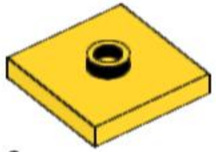
Yellow


64x
3937
Yellow


6x
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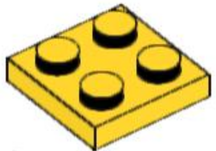
Yellow


4x
18674
Yellow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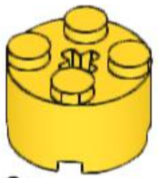
Yellow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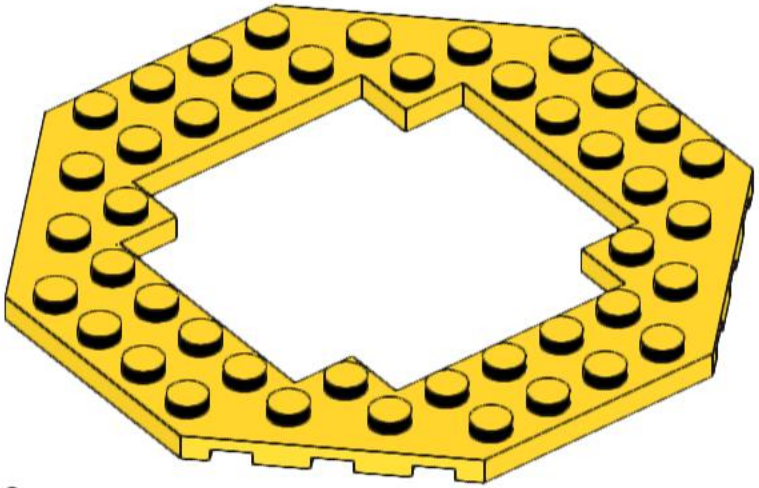
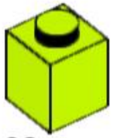
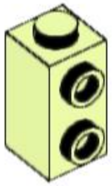
3941
Yellow



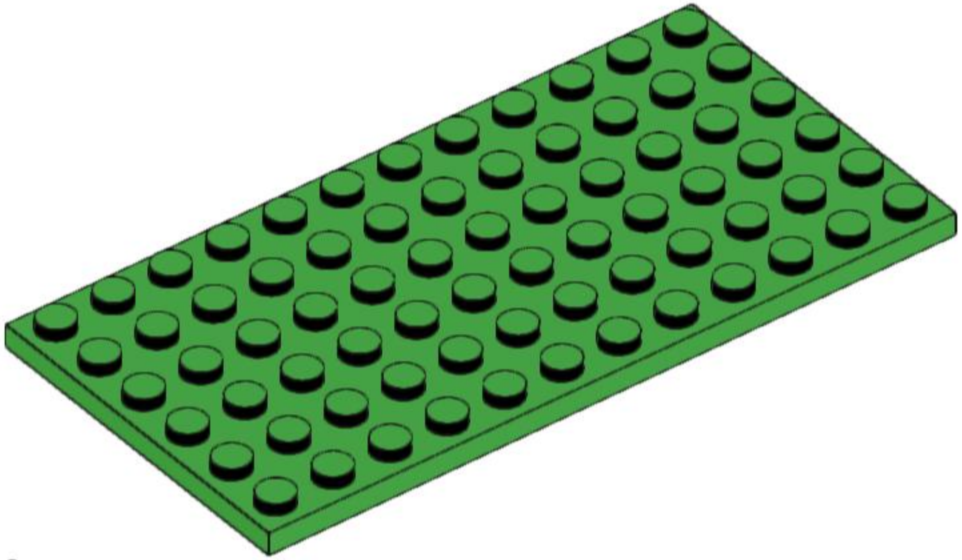
2x
6063
Yellow



32x
3005
Lime

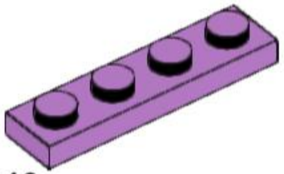


16x
32952
Yellowish Green



2x
3028
Bright Green

48x
26604
Medium Blue



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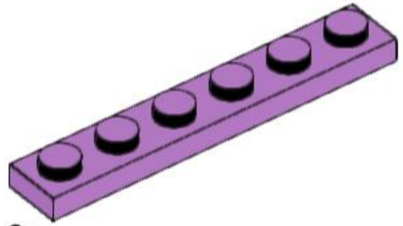
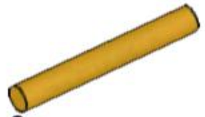
3710
Medium Lavender



6x
3666
Medium Lavender

248x
3024
Trans-Yellow

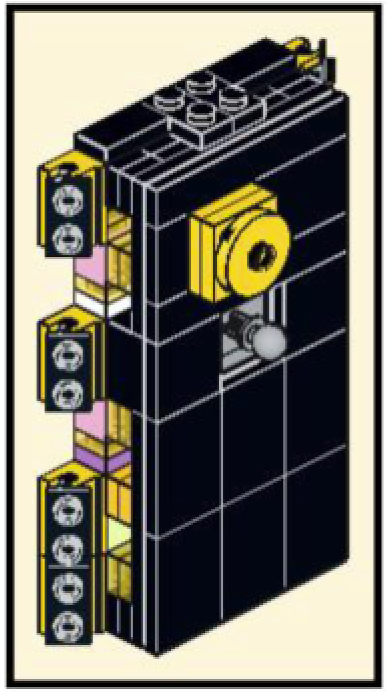
32x
4073
Pearl Gold

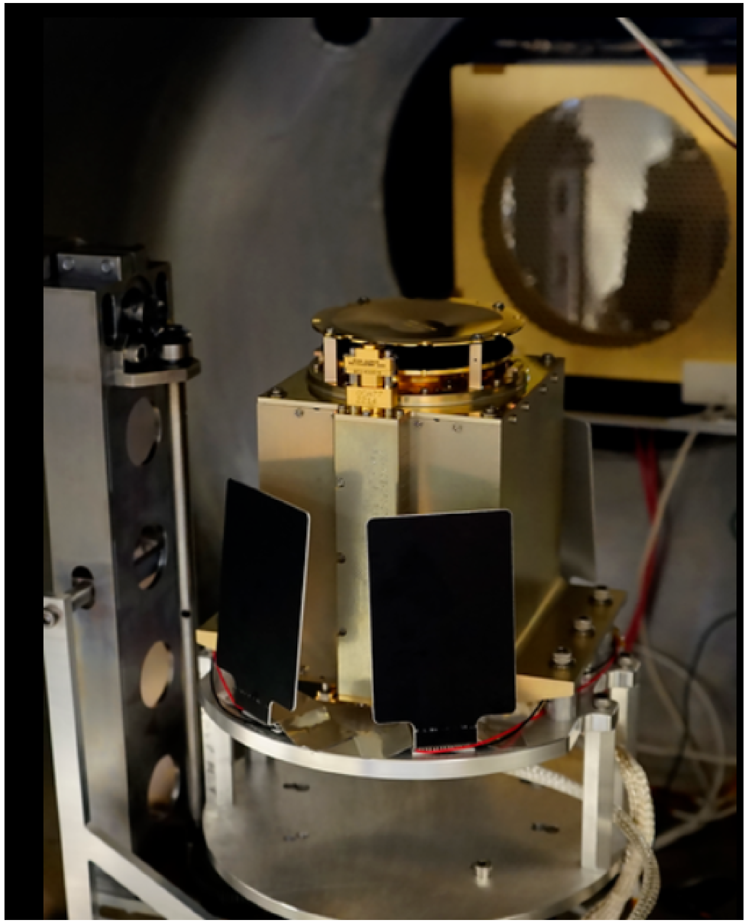


6x
87994
Pearl Gold

ACE (Analyzer for Cusp Electrons)

Electrons follow tightly wound helical paths along magnetic field lines.
When the orbit takes the two TRACERS spacecraft into the cusp,
the ACE instruments measure the distribution of electrons
and resolve the fluxes of electrons as a function of energy and direction.
This provides a complete picture of the properties of both
downward-going (precipitating) and upward-going electrons.
Therefore, the ACE measurements of precipitating electrons
allows for precise determination of the extent of the funnel-shaped
magnetospheric cusp.





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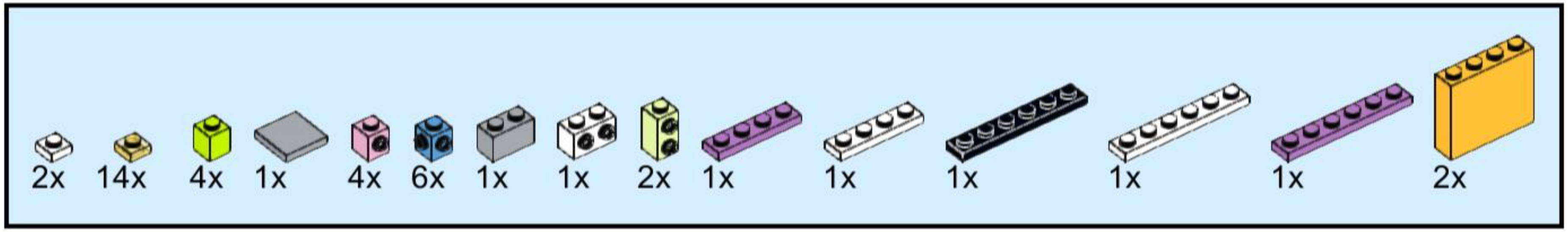
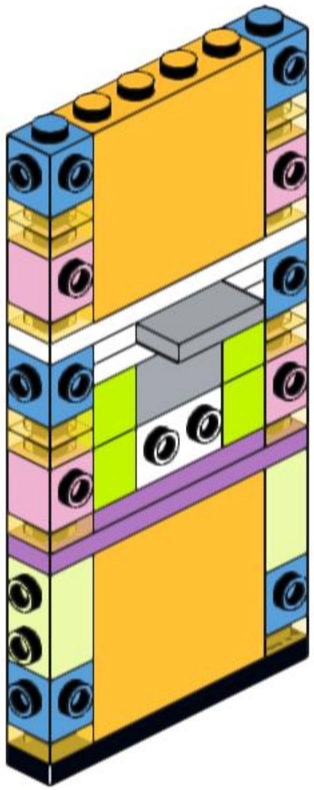
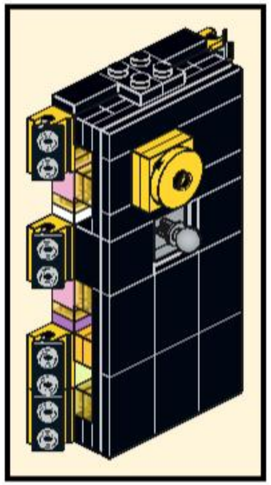
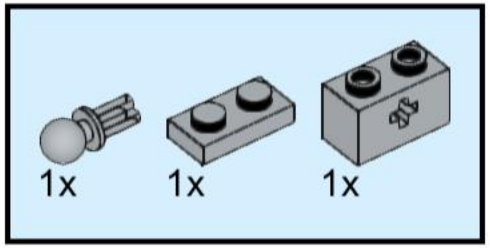


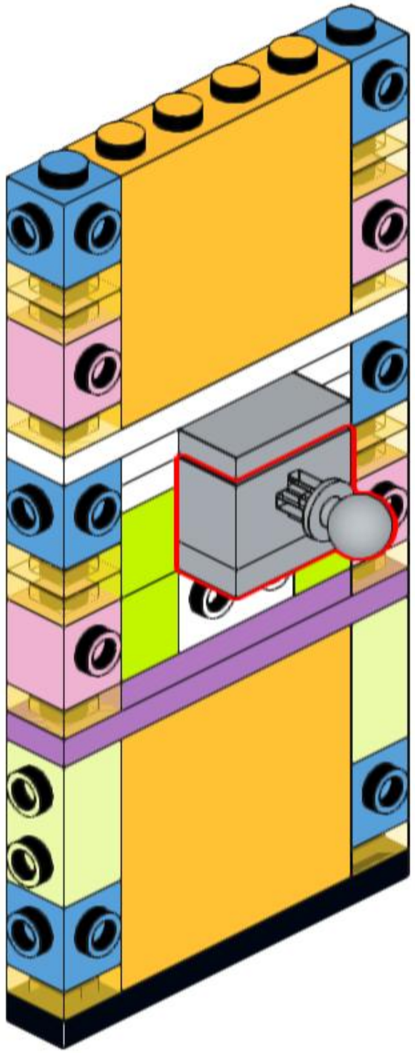




ACE

2





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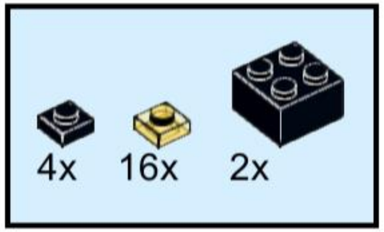

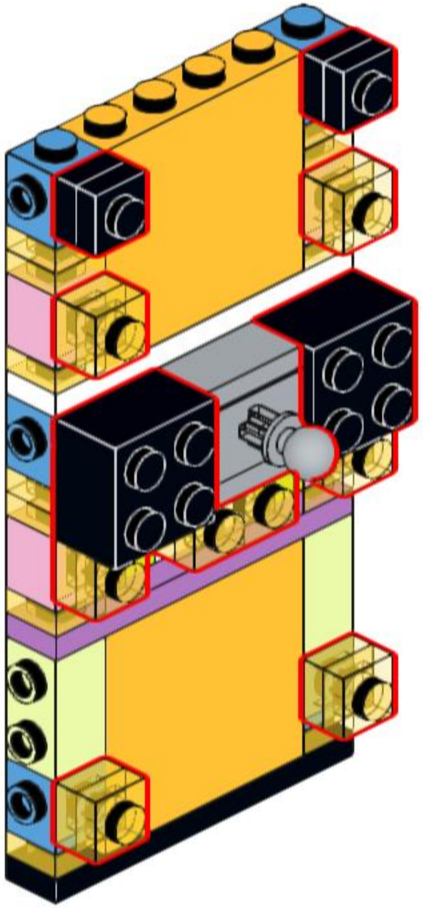

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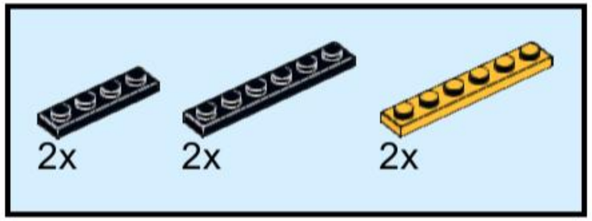
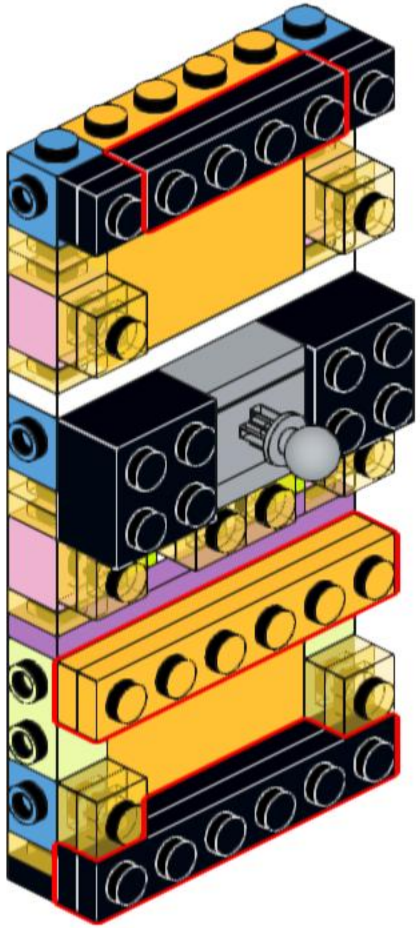
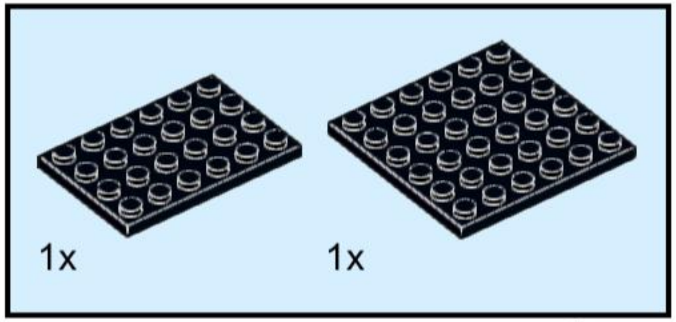
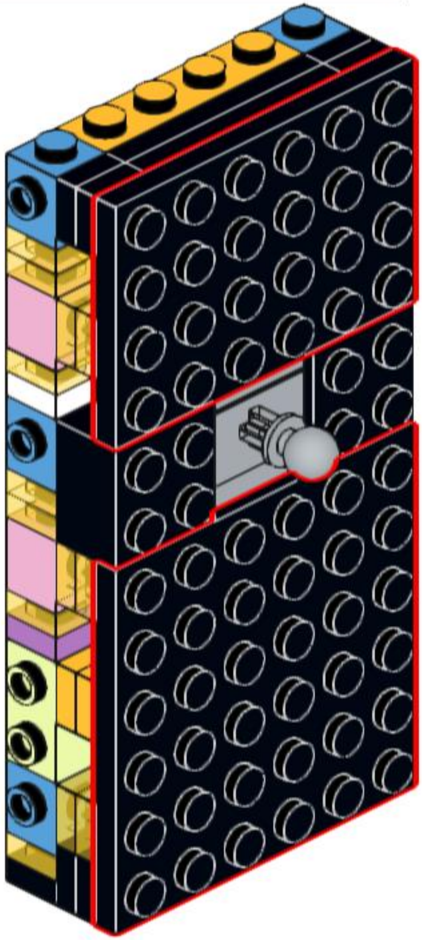




these attach to the backs
of the plates in front of them.
see step 5.

5





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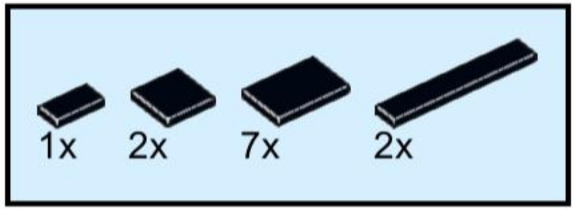
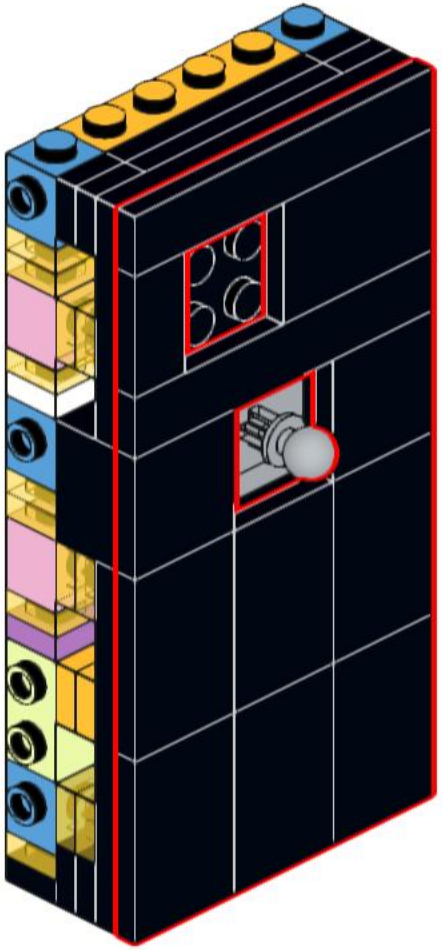
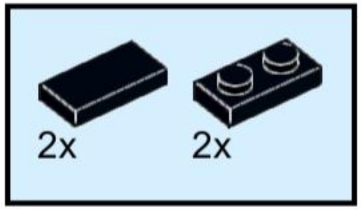
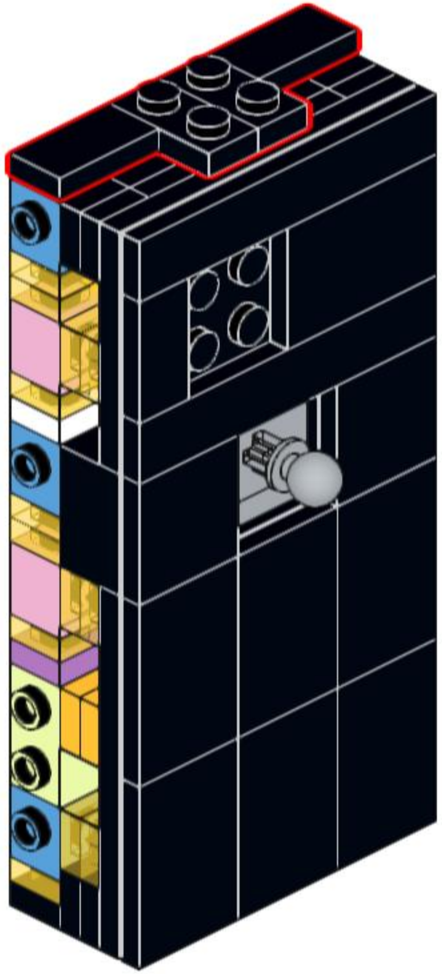




7





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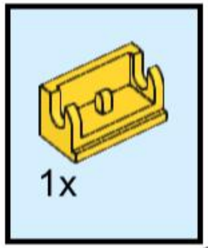

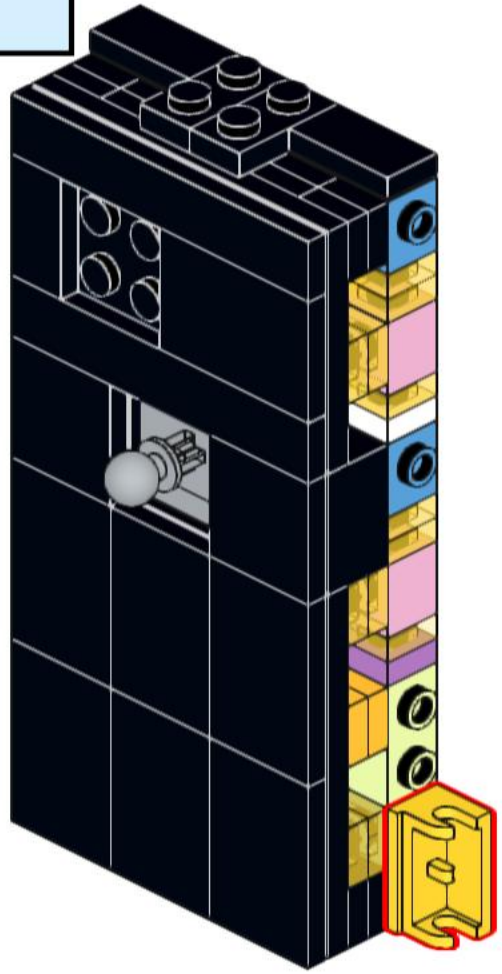

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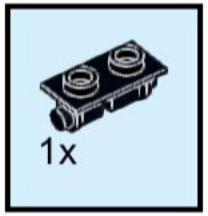

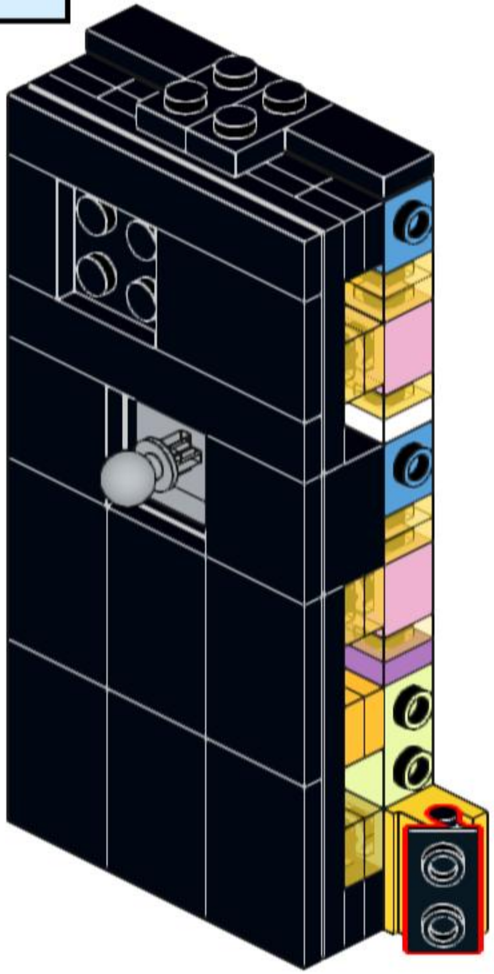

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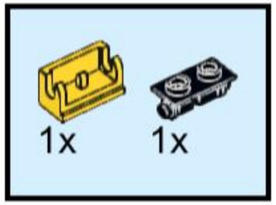

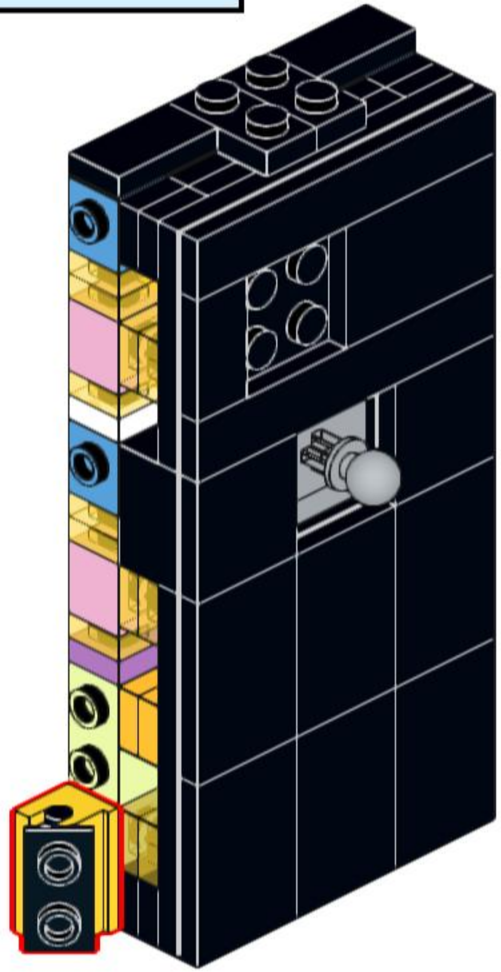

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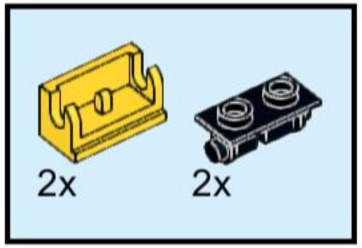

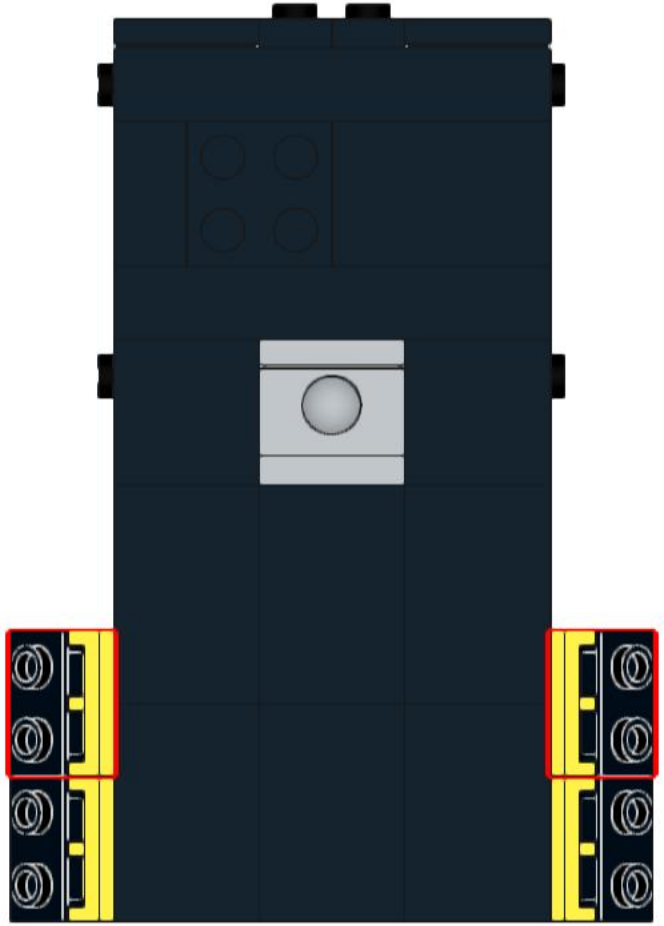

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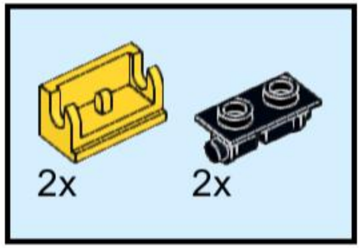

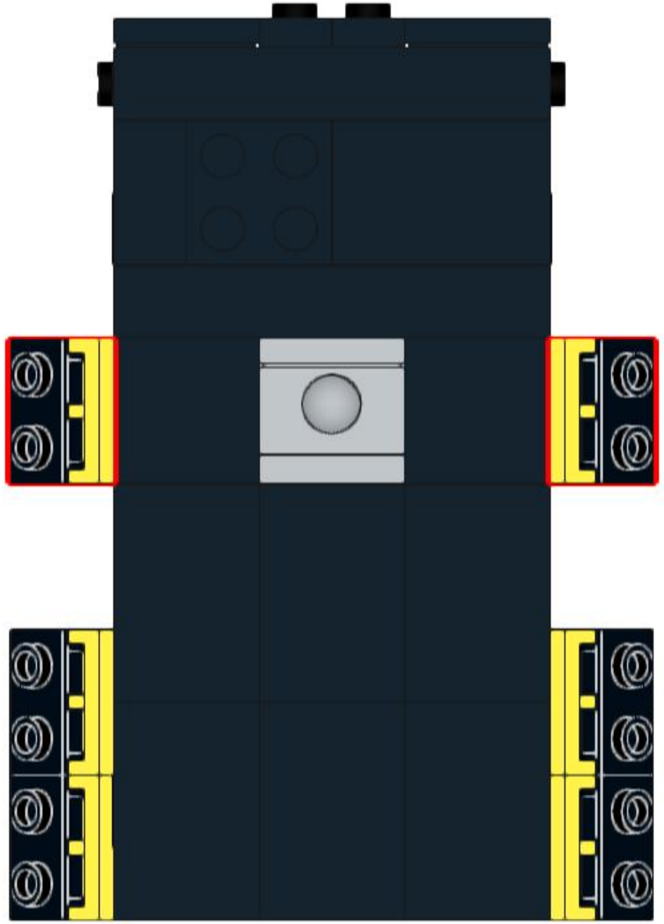

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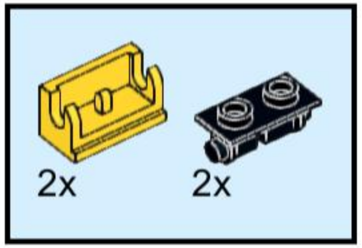

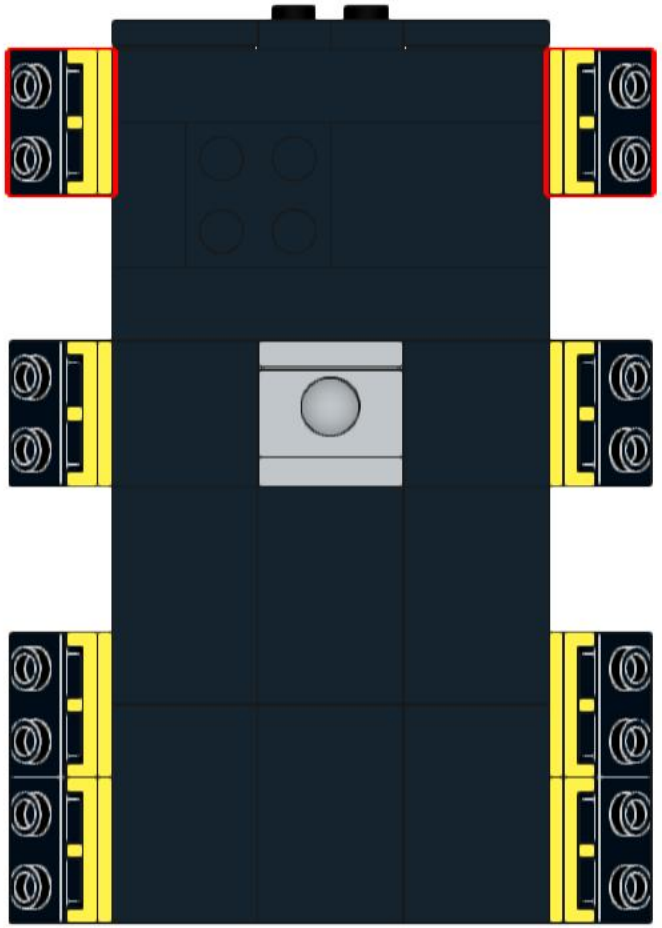

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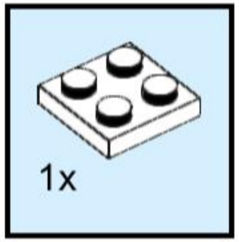

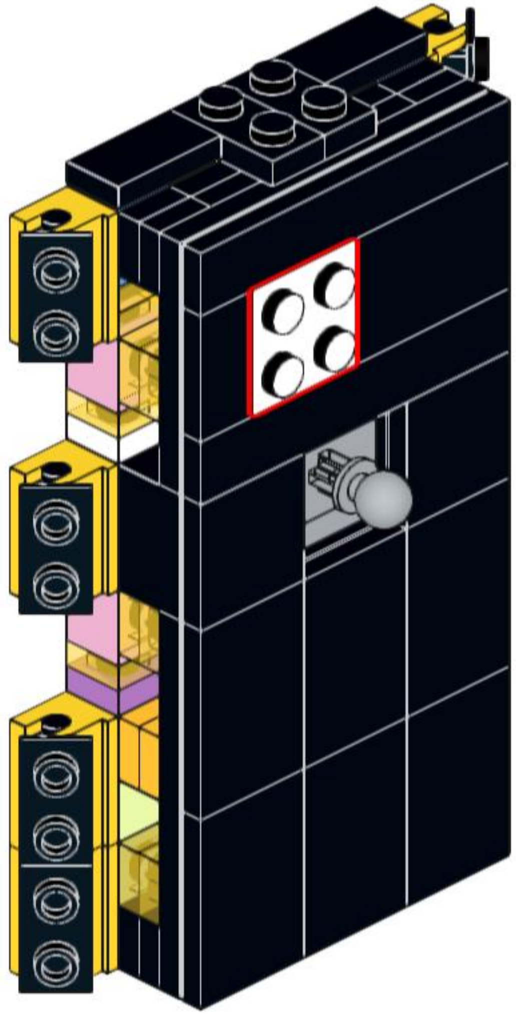

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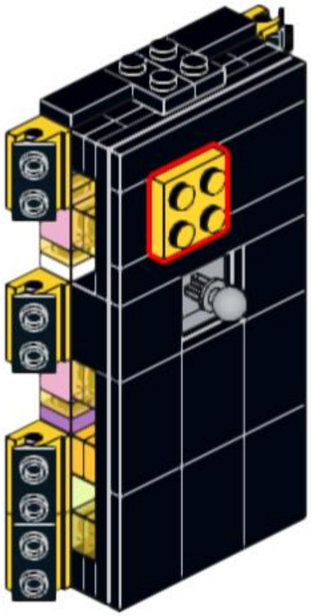

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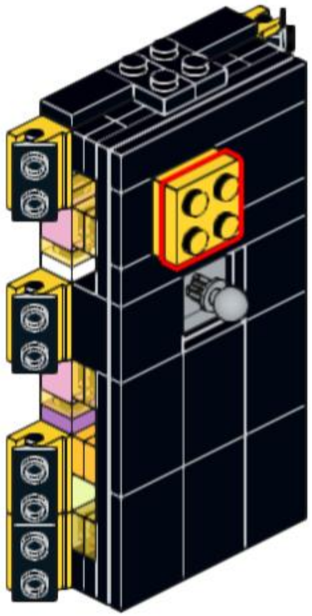

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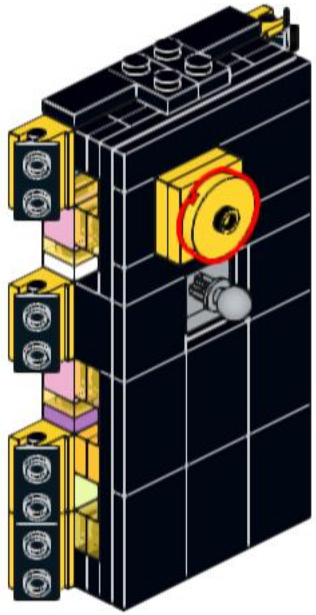

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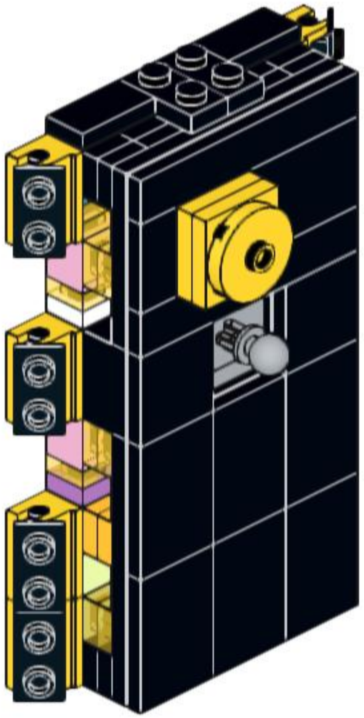
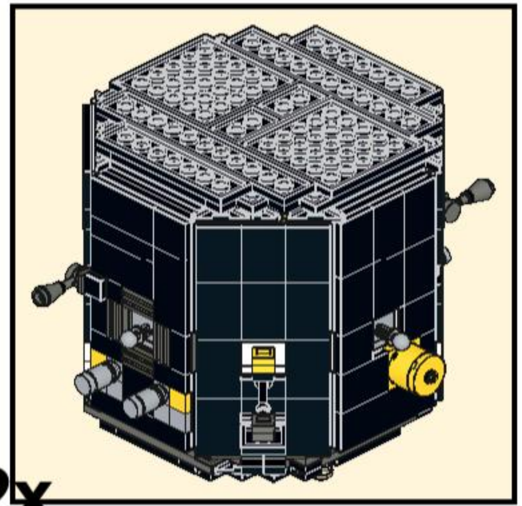




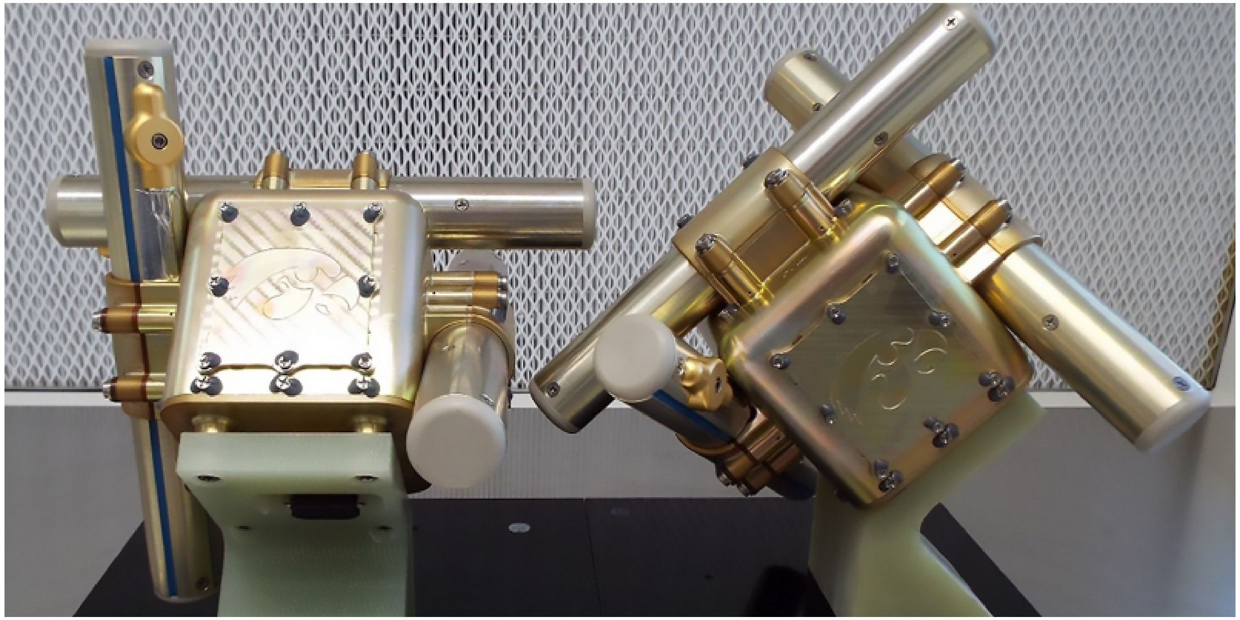
2x

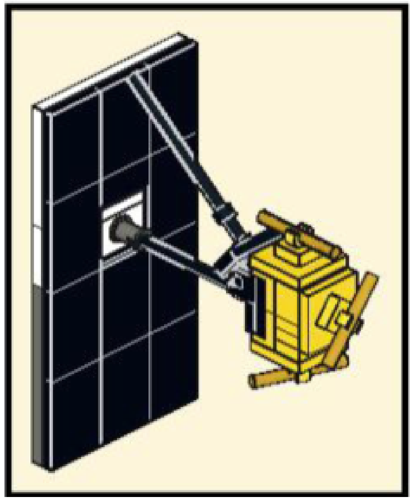
For Model 2

Note: You will build every panel twice, for the two identical models.

MSC (Magnetic Search Coil)

The MSC instruments are critical to answering the third TRACERS science objective - determining to what extent dynamic structures in the funnel-shaped cusp are associated with temporal vs. spatial reconnection at the distant magnetopause. The Magnetic Search Coil (MSC) measures high-frequency time varying magnetic fields (from about 1 Hz to 1,000 Hz) to identify Alfvén and other electromagnetic waves.
Each MSC consists of three identical search coil sensors mounted in a tri-axial configuration with their corresponding electronics. Two of the sensors are oriented parallel to the two electric dipole antennas and the third parallel to the spacecraft spin axis





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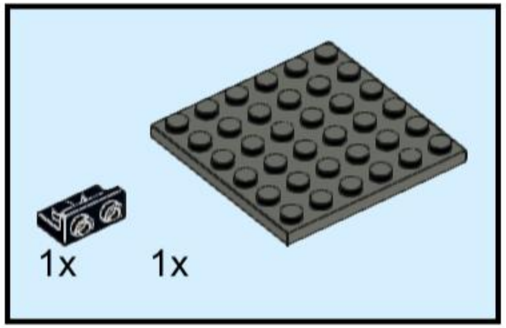

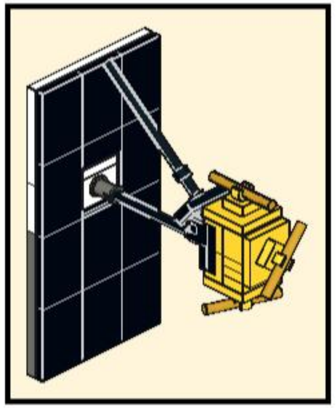

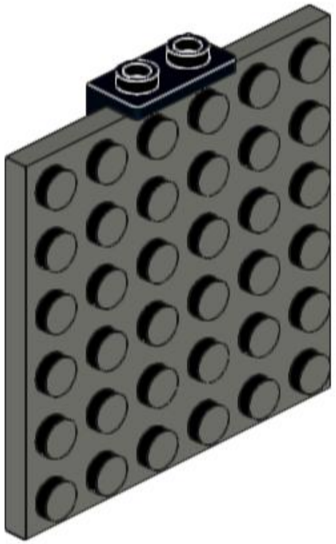

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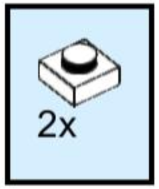

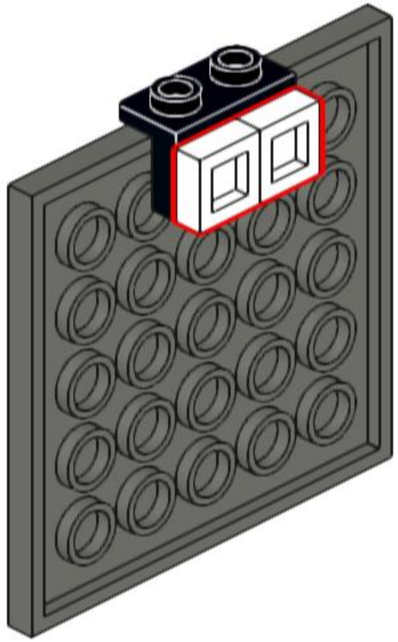

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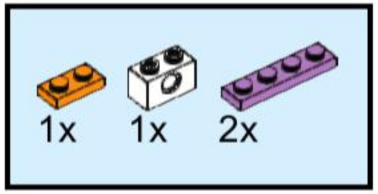

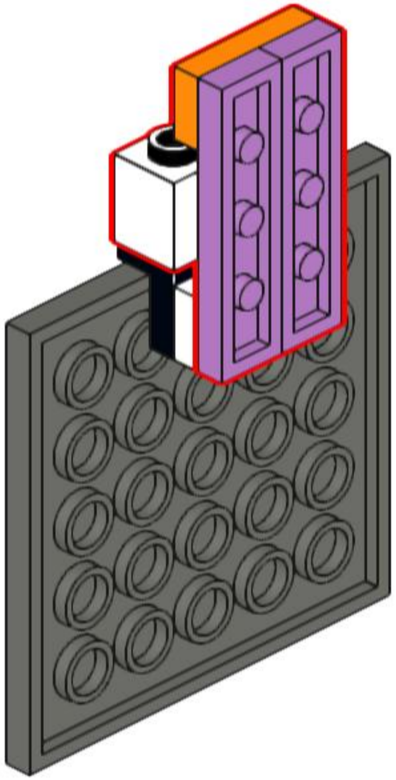

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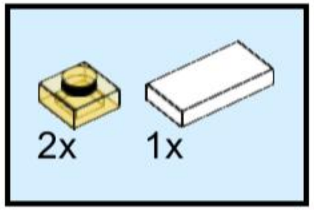

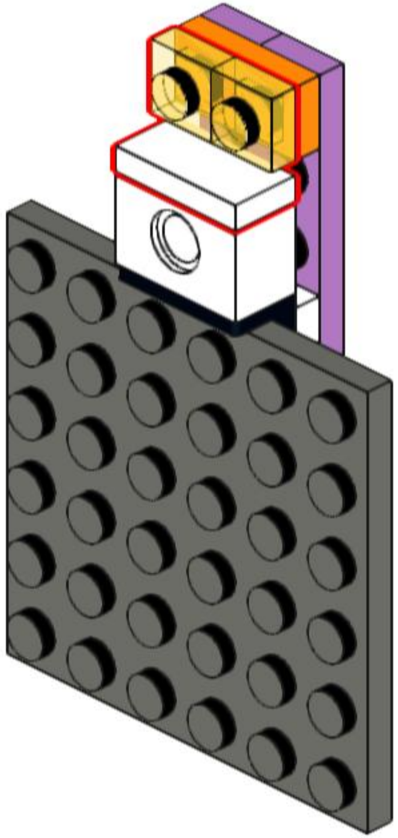

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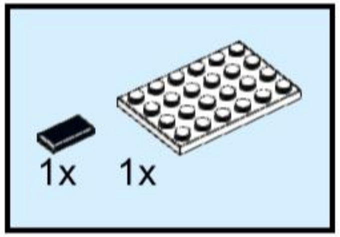

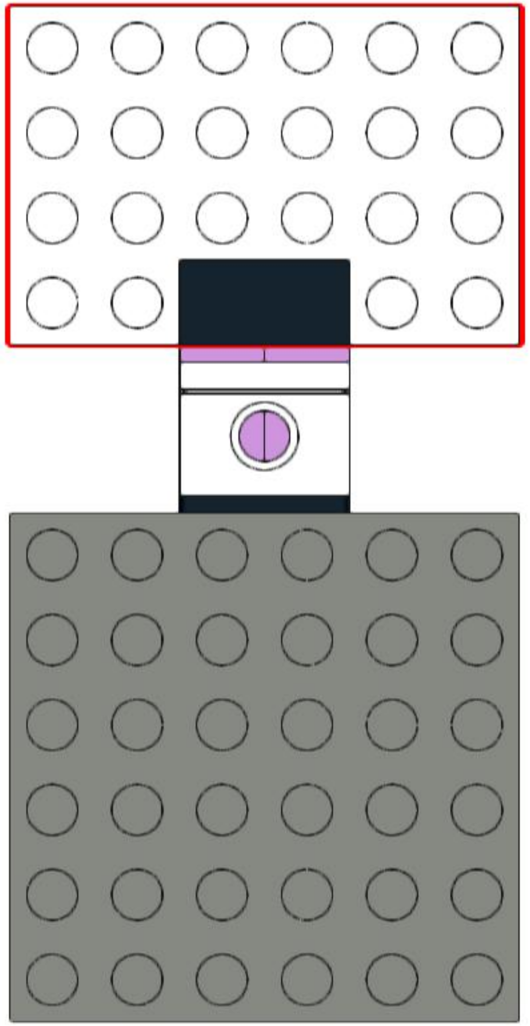

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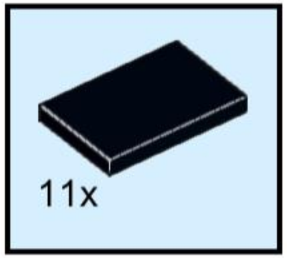

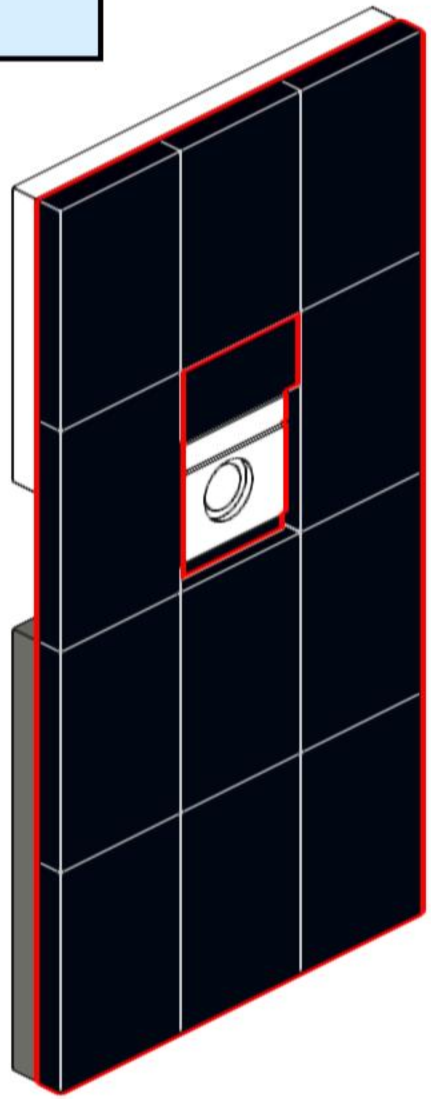

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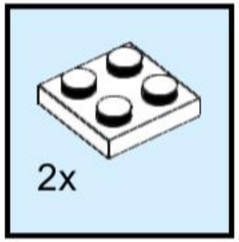

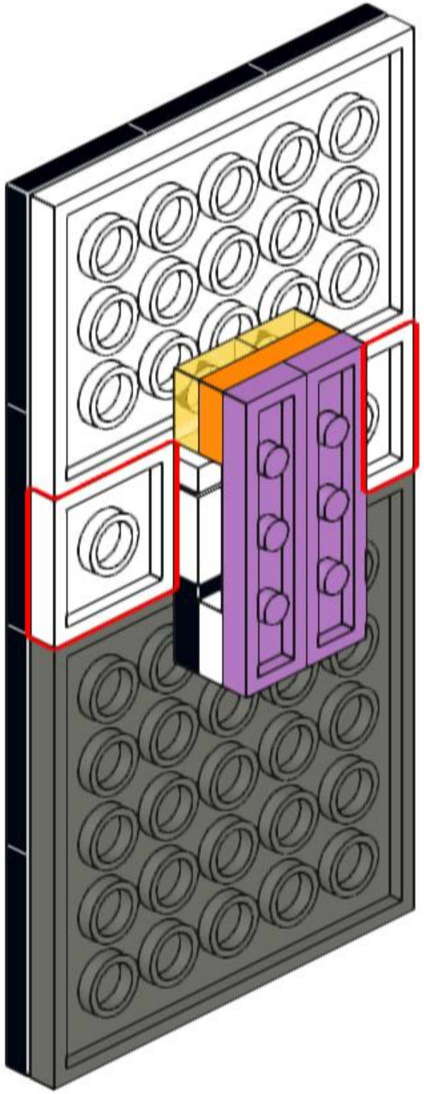

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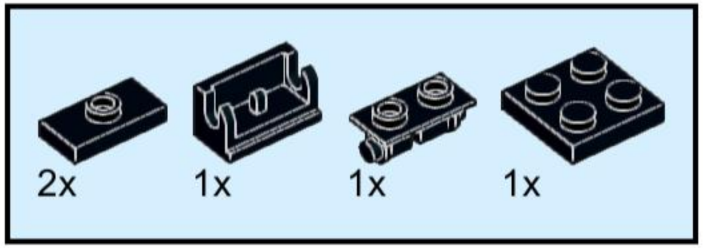

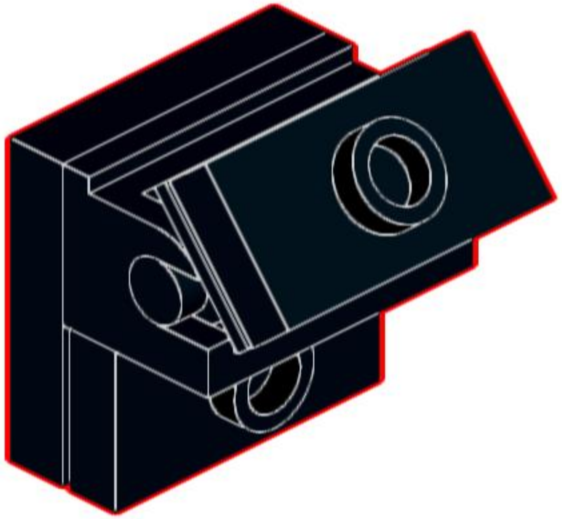

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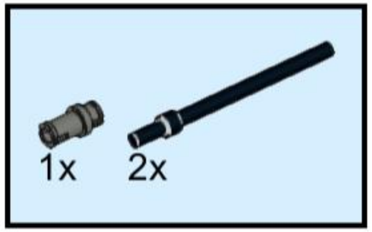

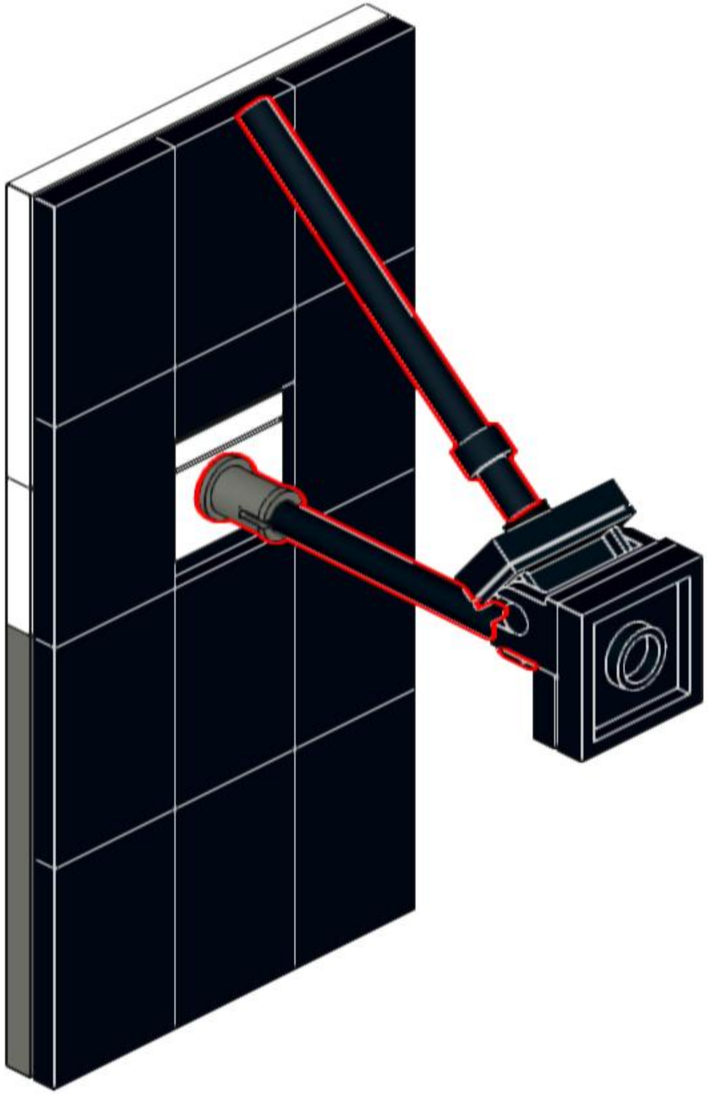

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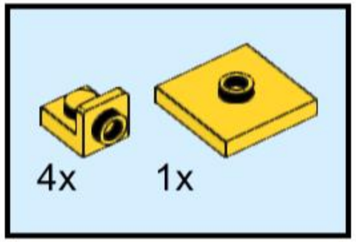

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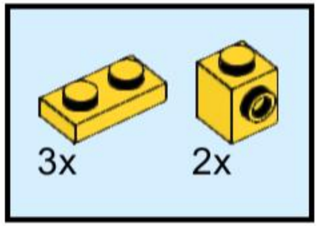

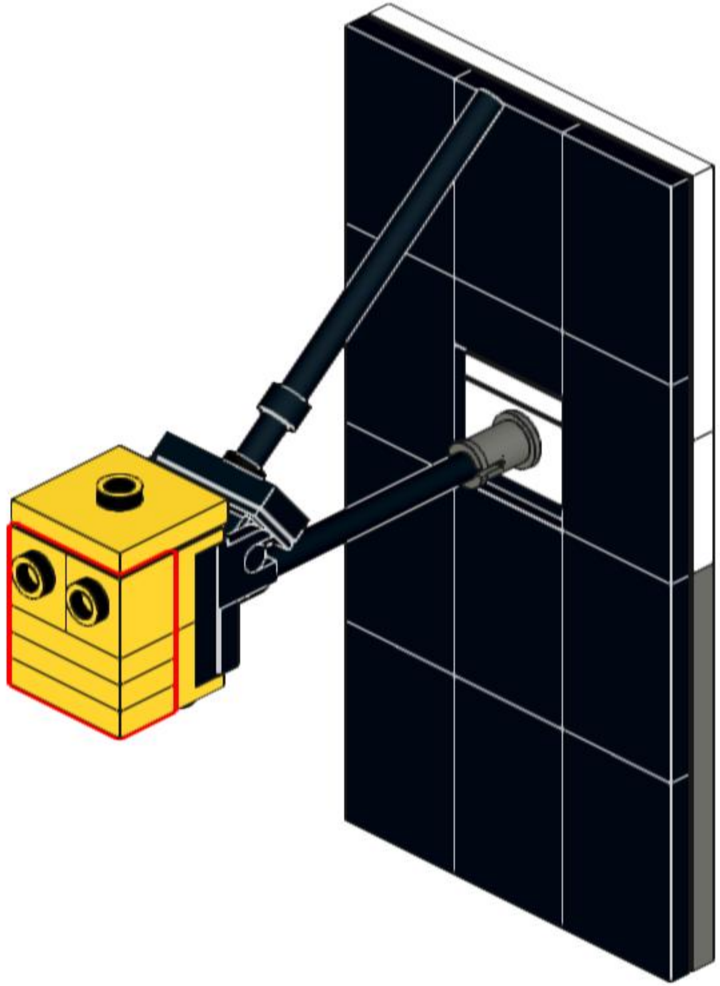

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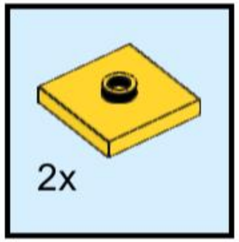

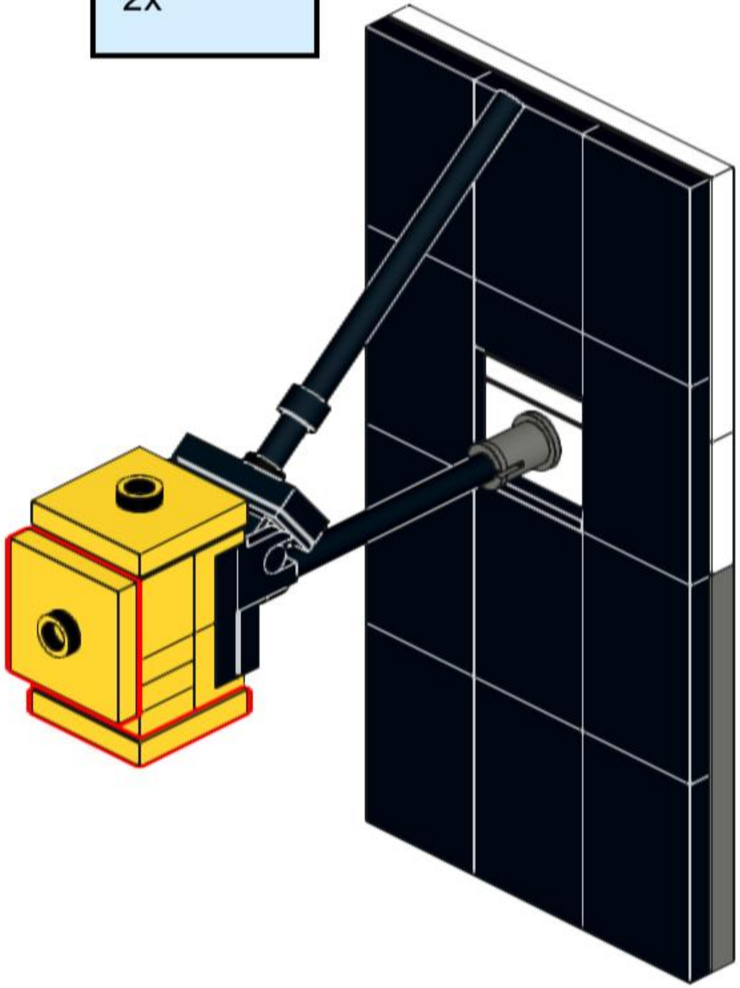

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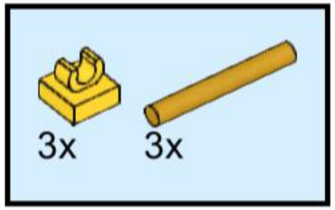
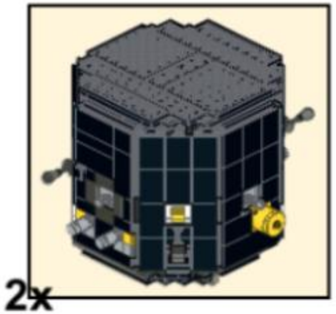
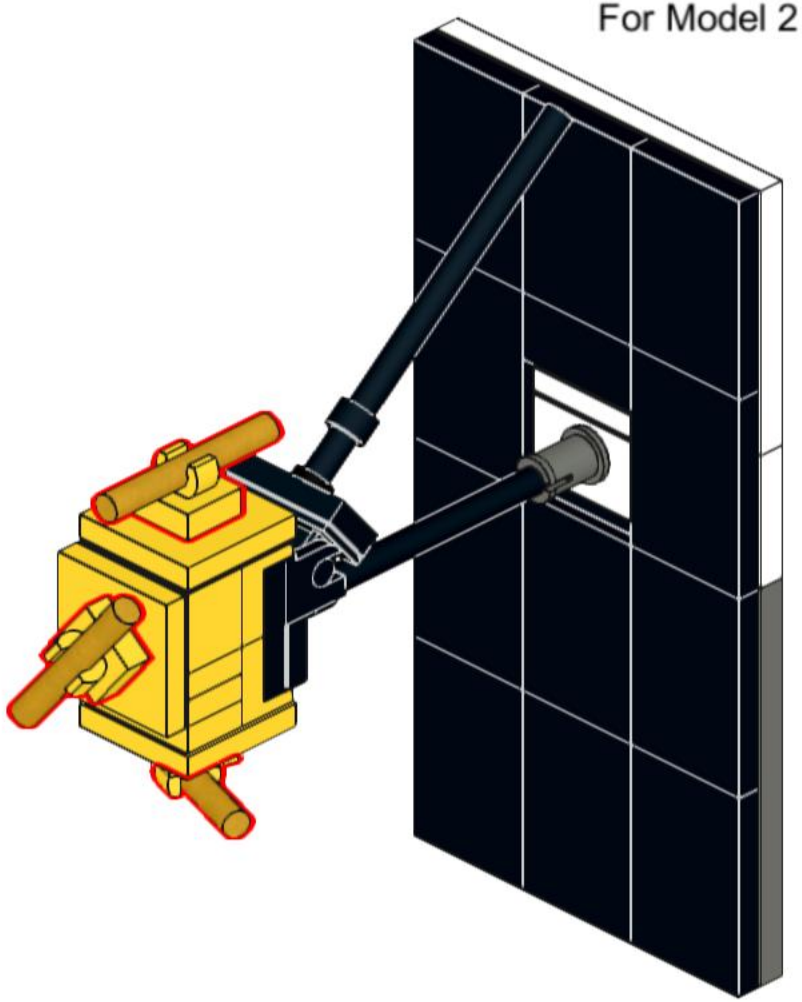



2x
For Model 2



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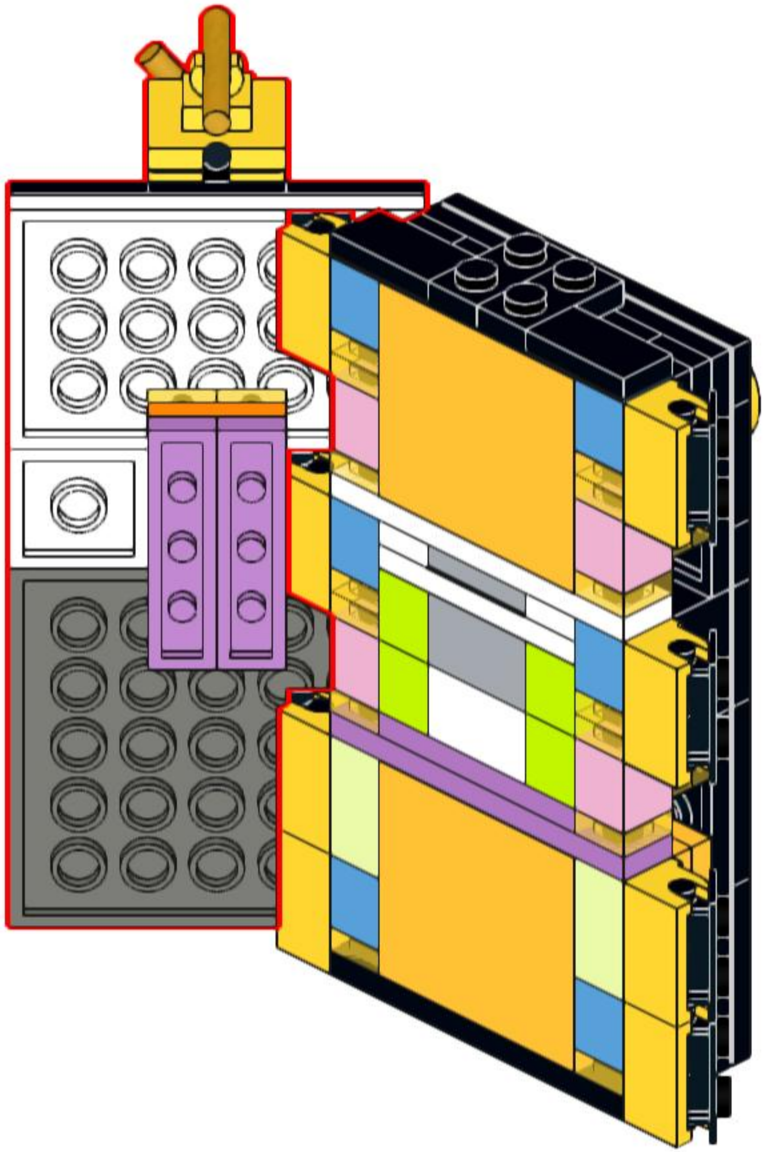
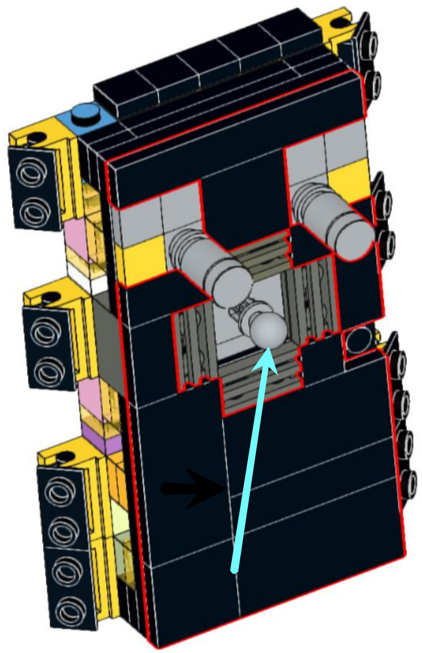


Note: you might find it difficult to attach the panels together by the hinges later on as the octagon gets tighter. Before trying to press one panel into another, make sure the black hinges are all oriented in a straight line with each other.

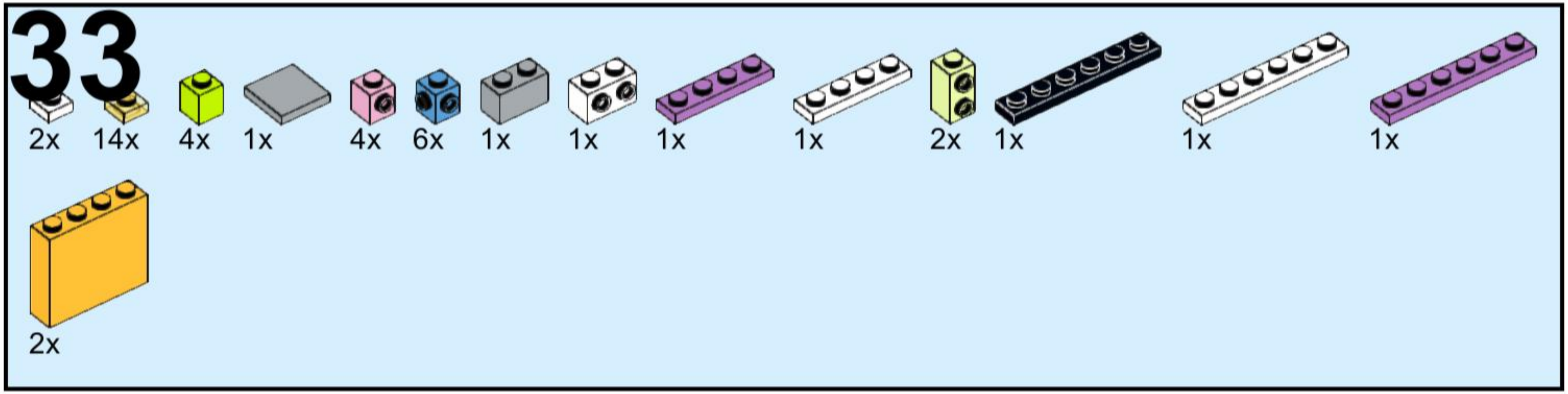
Alternatively, it may be easier to assemble the model by placing the black hinge-yellow clasp assembly onto the thinner, corner pieces first by the black hinge, and then snapping the thicker cardinal direction pieces onto the yellow clasps. You can build all the panels first, and assemble them at the end as well.

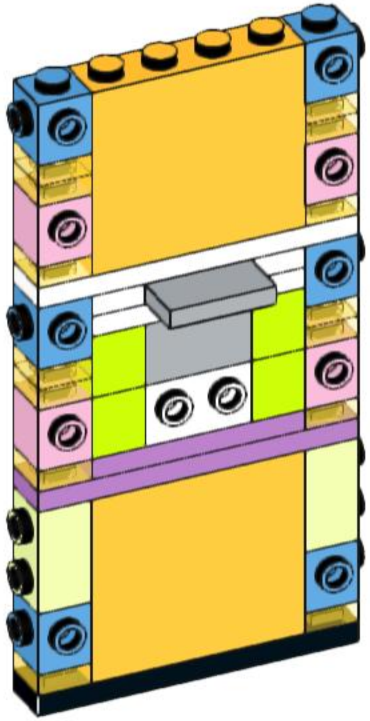
EFI (Electric Field Instrument)

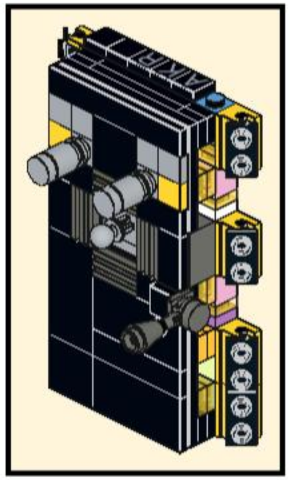


The EFI instruments measure the ambient electric field associated with plasma flow and electromagnetic fluctuations in the low-altitude cusp. EFI allows us to estimate the primary components of the electric field. This is accomplished by measuring the differences in electric potential between two spatially separated pairs of electrodes (or antennas), at frequencies from DC to nearly 10 MHz. Field-aligned current systems and the lowest frequency electric field variations quasi-statically and dynamically couple energy and momentum from the magnetopause reconnection site into the low-altitude cusp region. The higher frequency variations (up to 1 kHz and from 100 kHz up to 10 MHz) can couple those larger-scale energy sources into local ionospheric heating and exhibit natural resonance frequencies in the plasma that provide accurate estimates of local plasma density.

33







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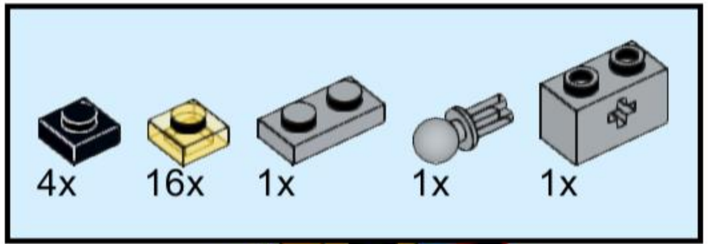

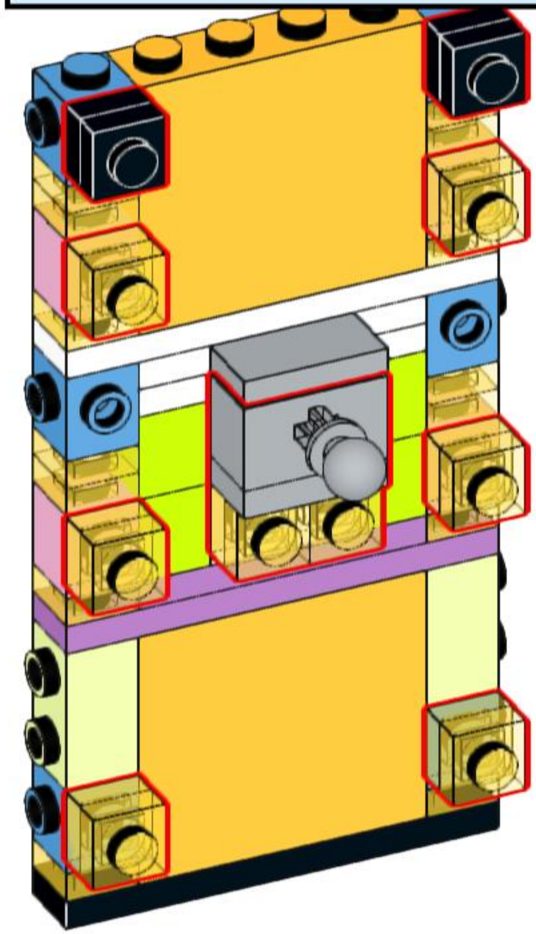

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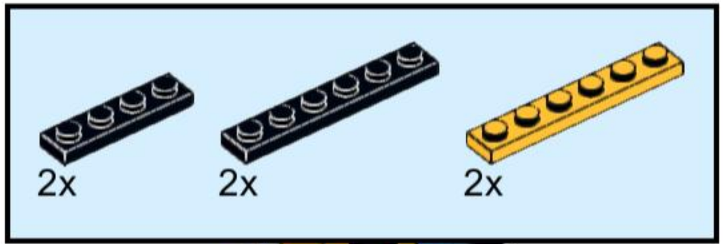

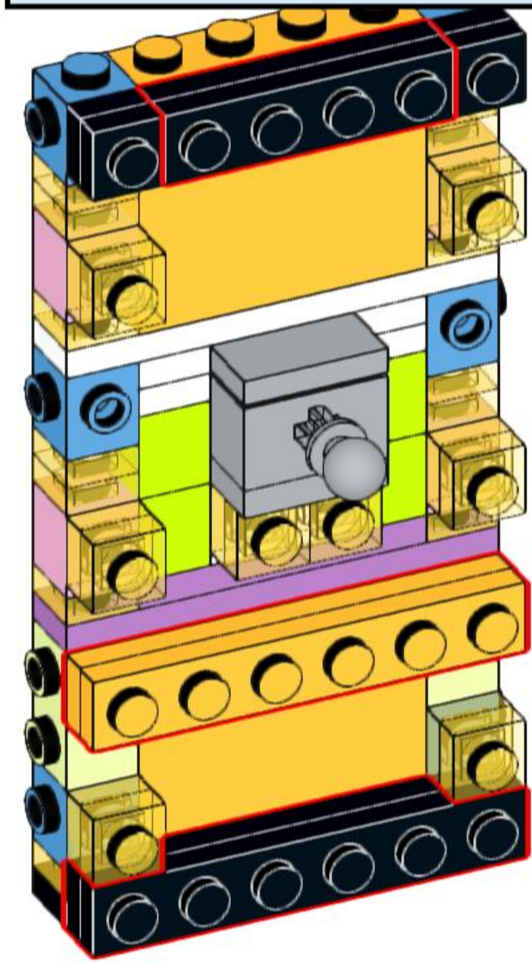

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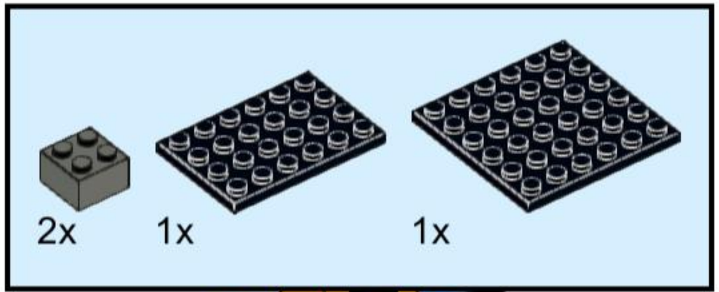

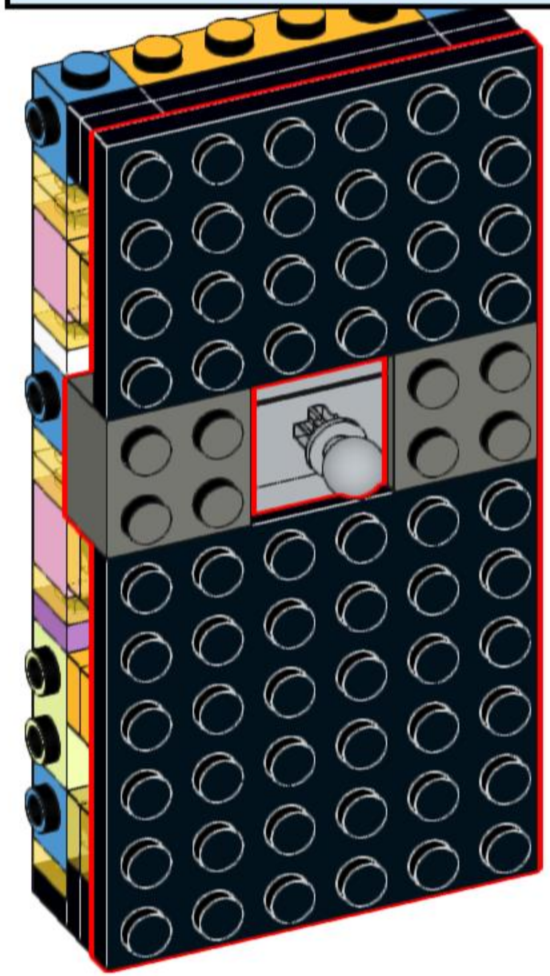

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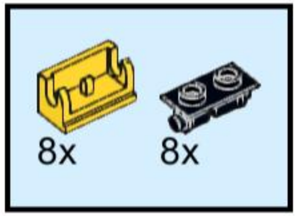

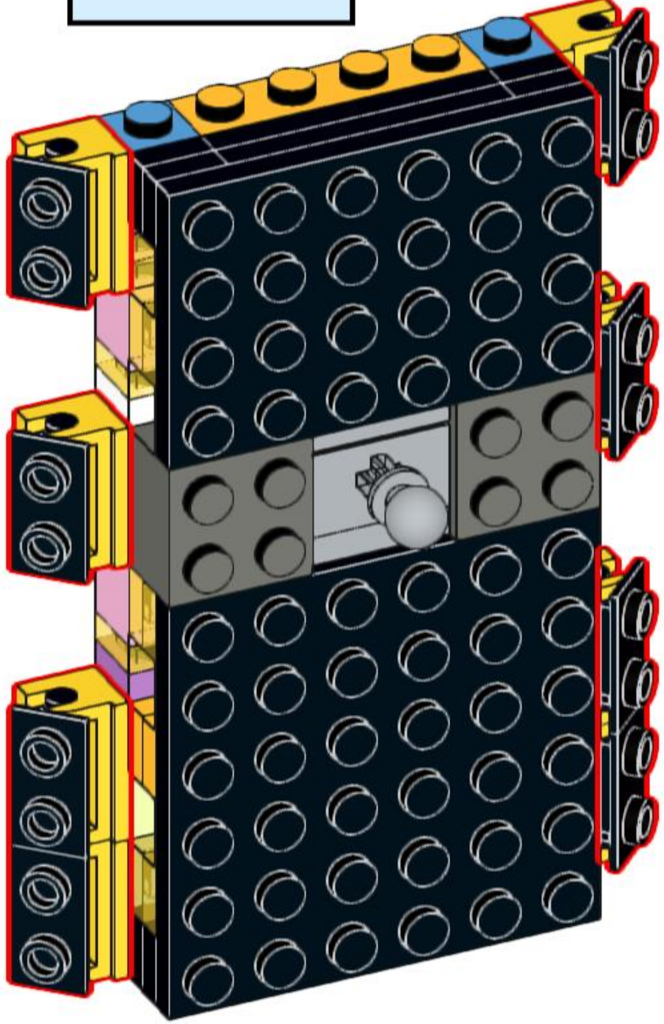

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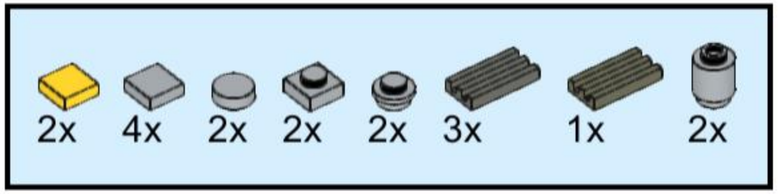

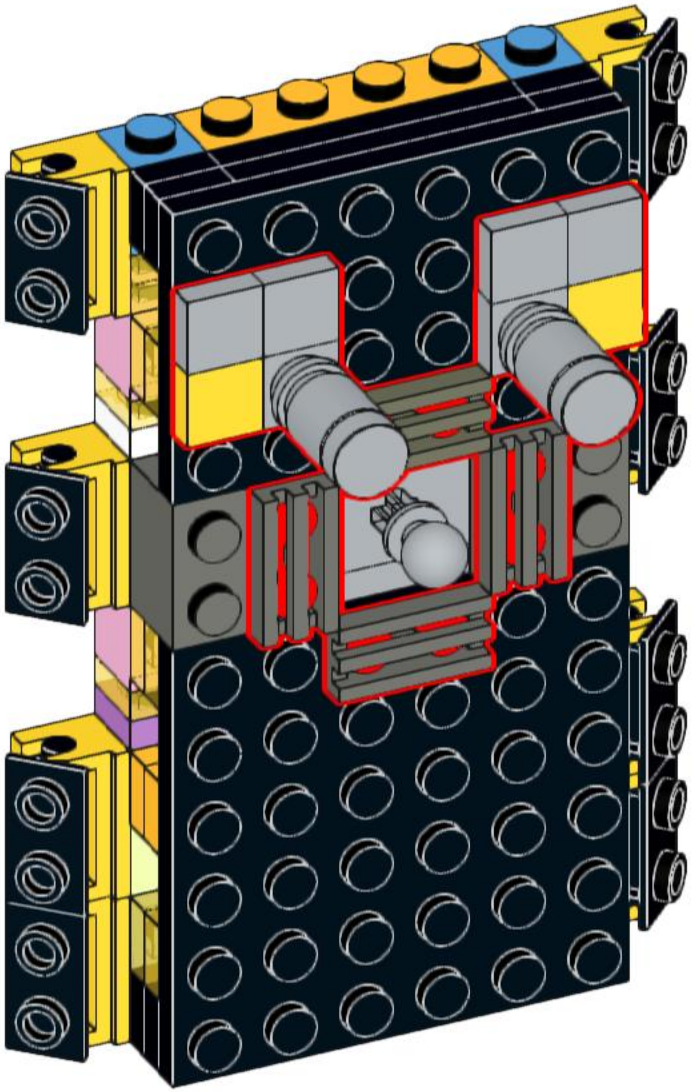

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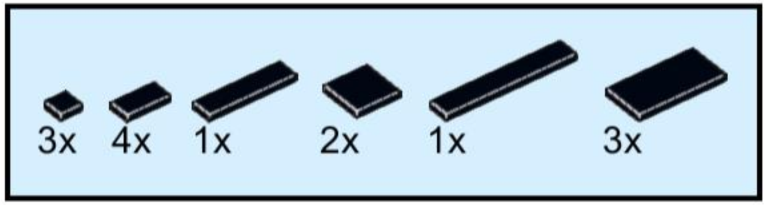

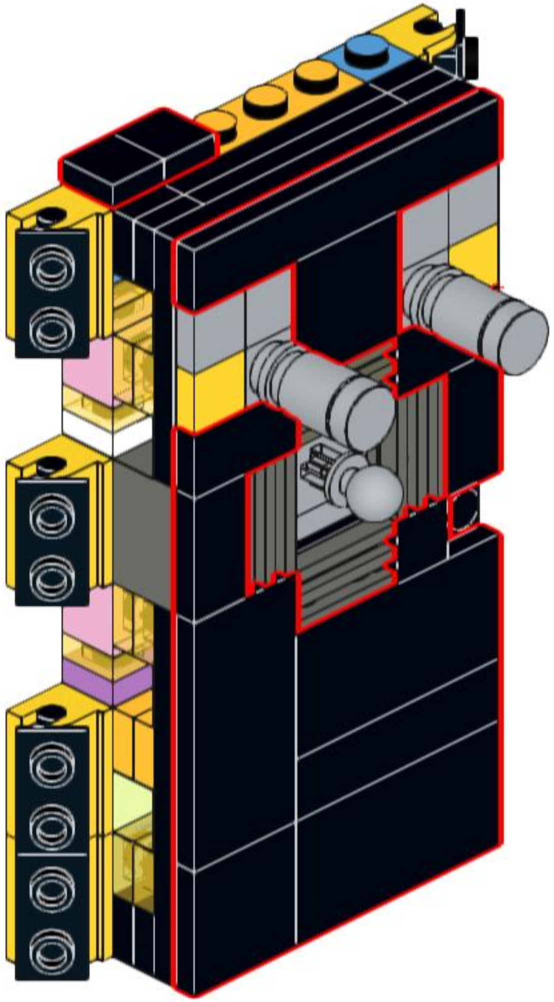

40

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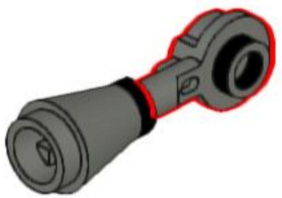
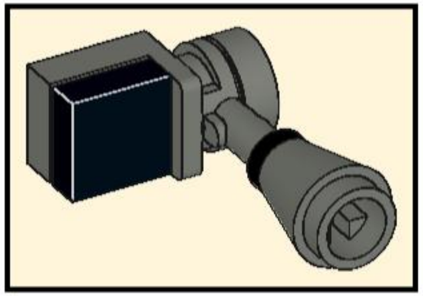
41

1x

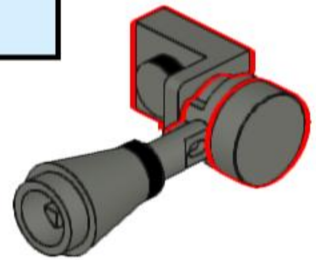




42

1x

1x



43

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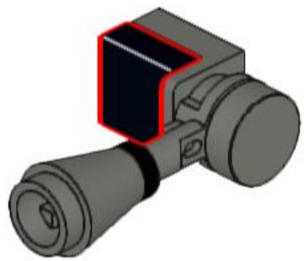

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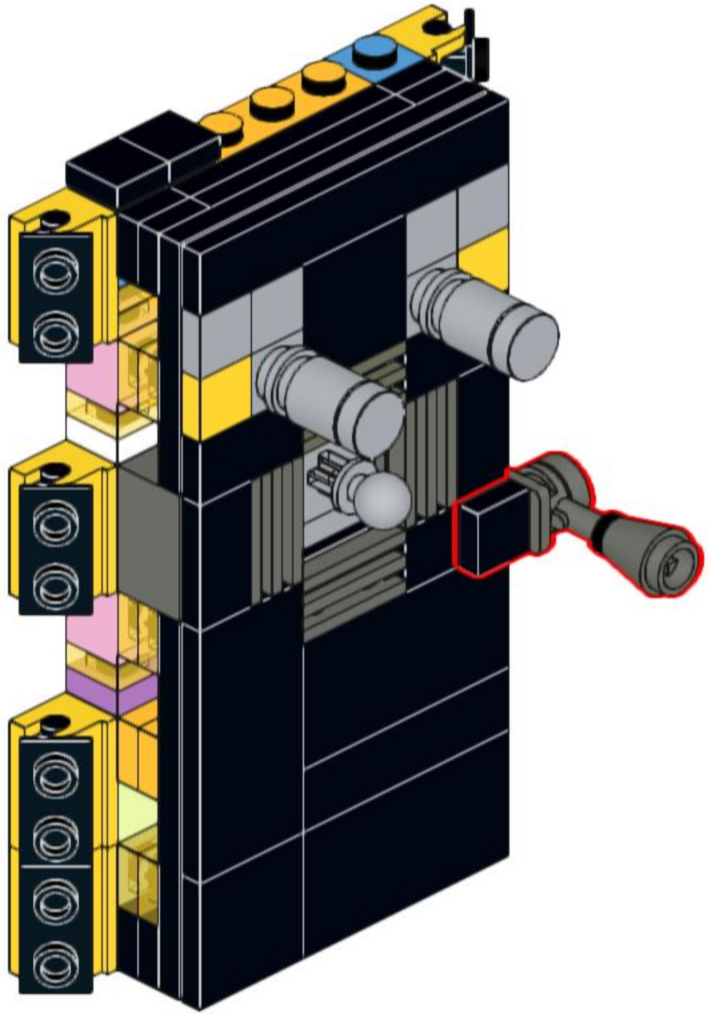

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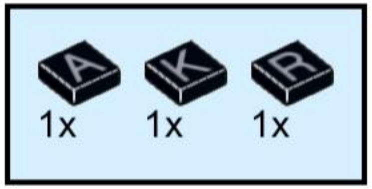

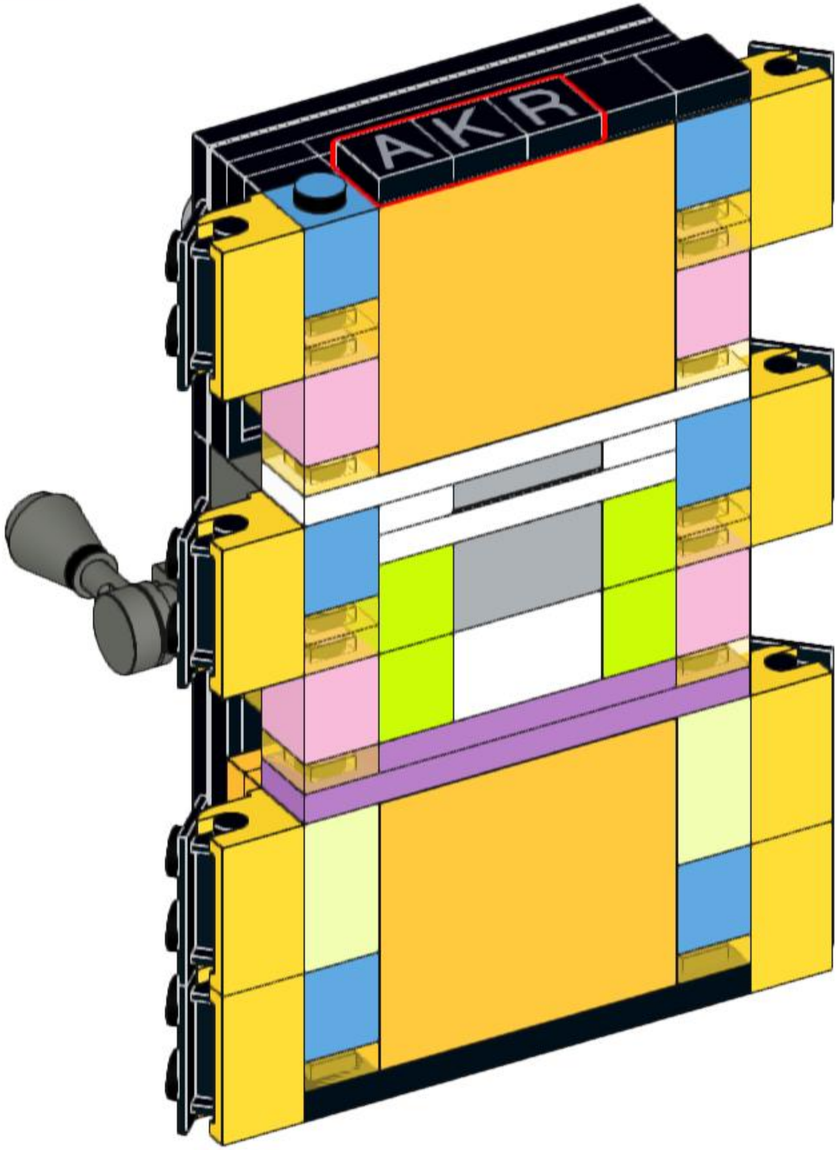

2x

For Model 2

Note: second model does not include the AKR easter egg

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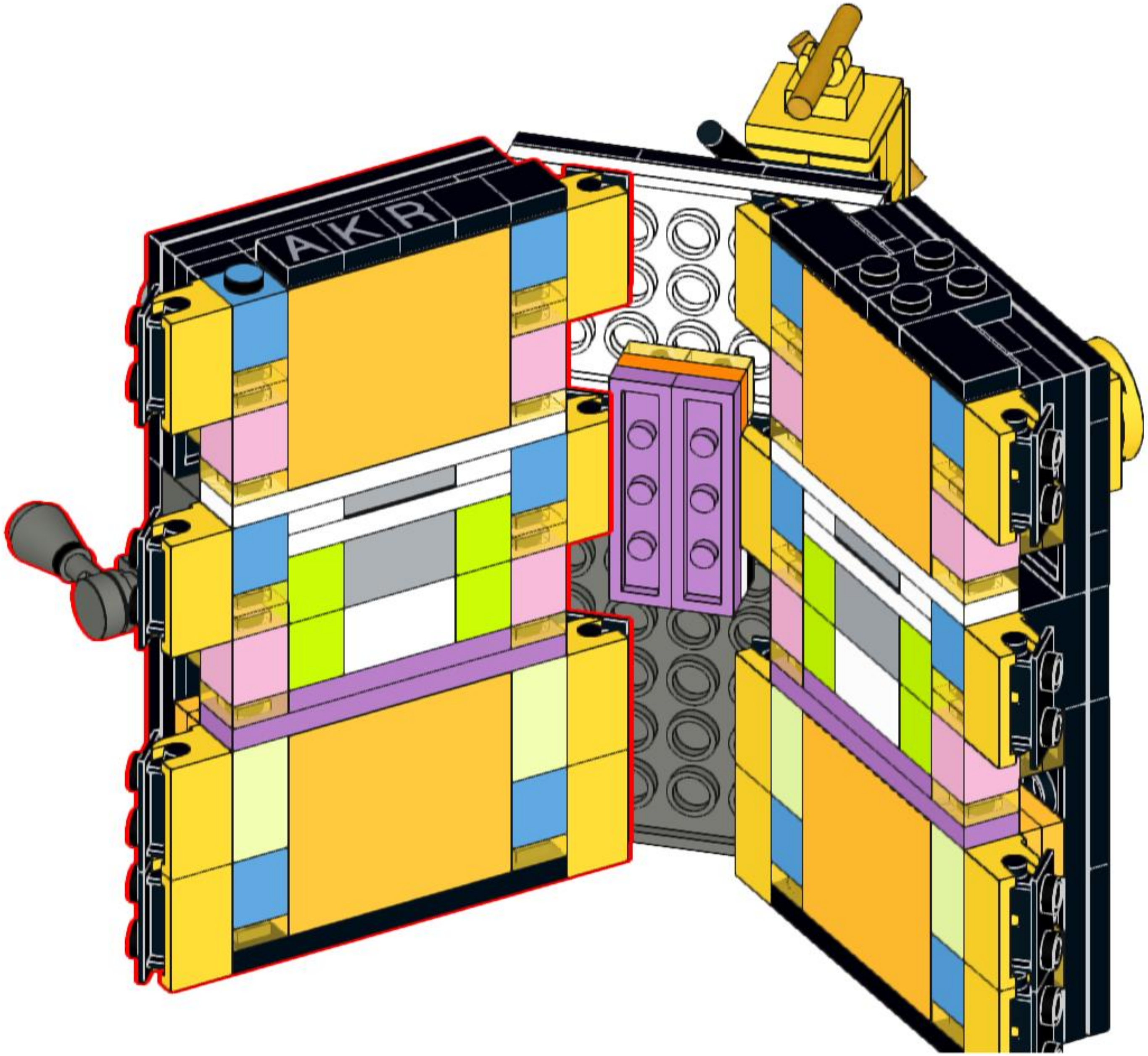

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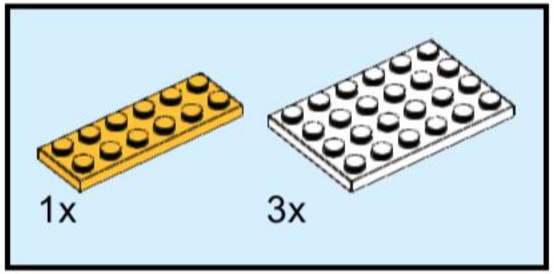

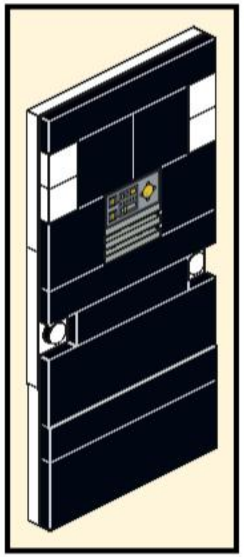

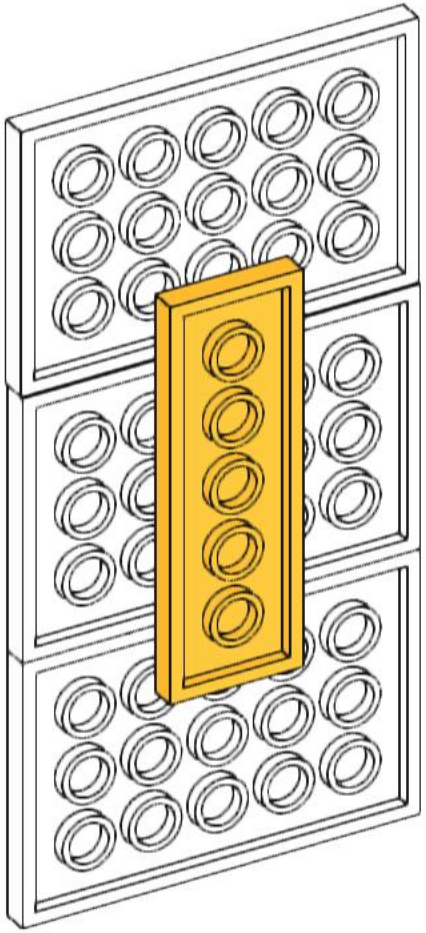

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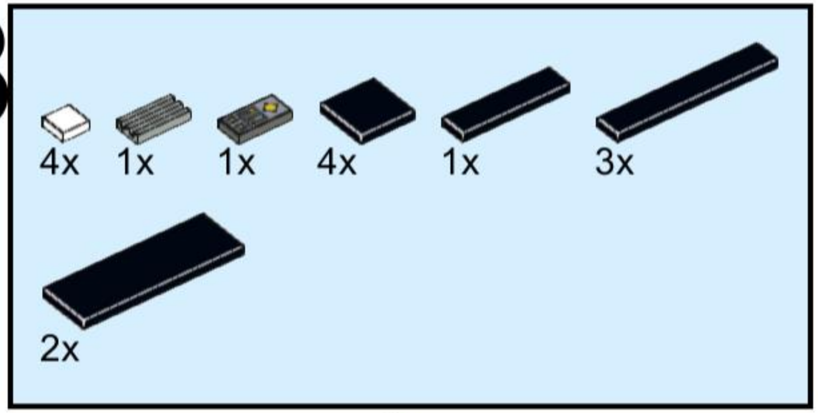

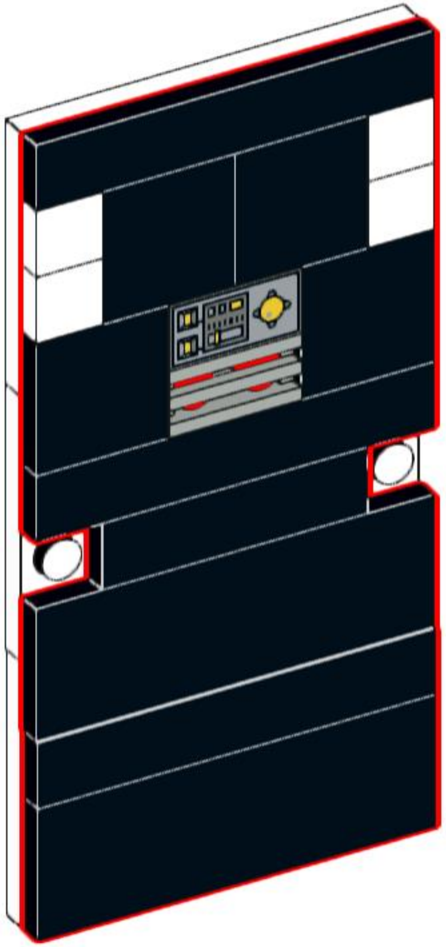

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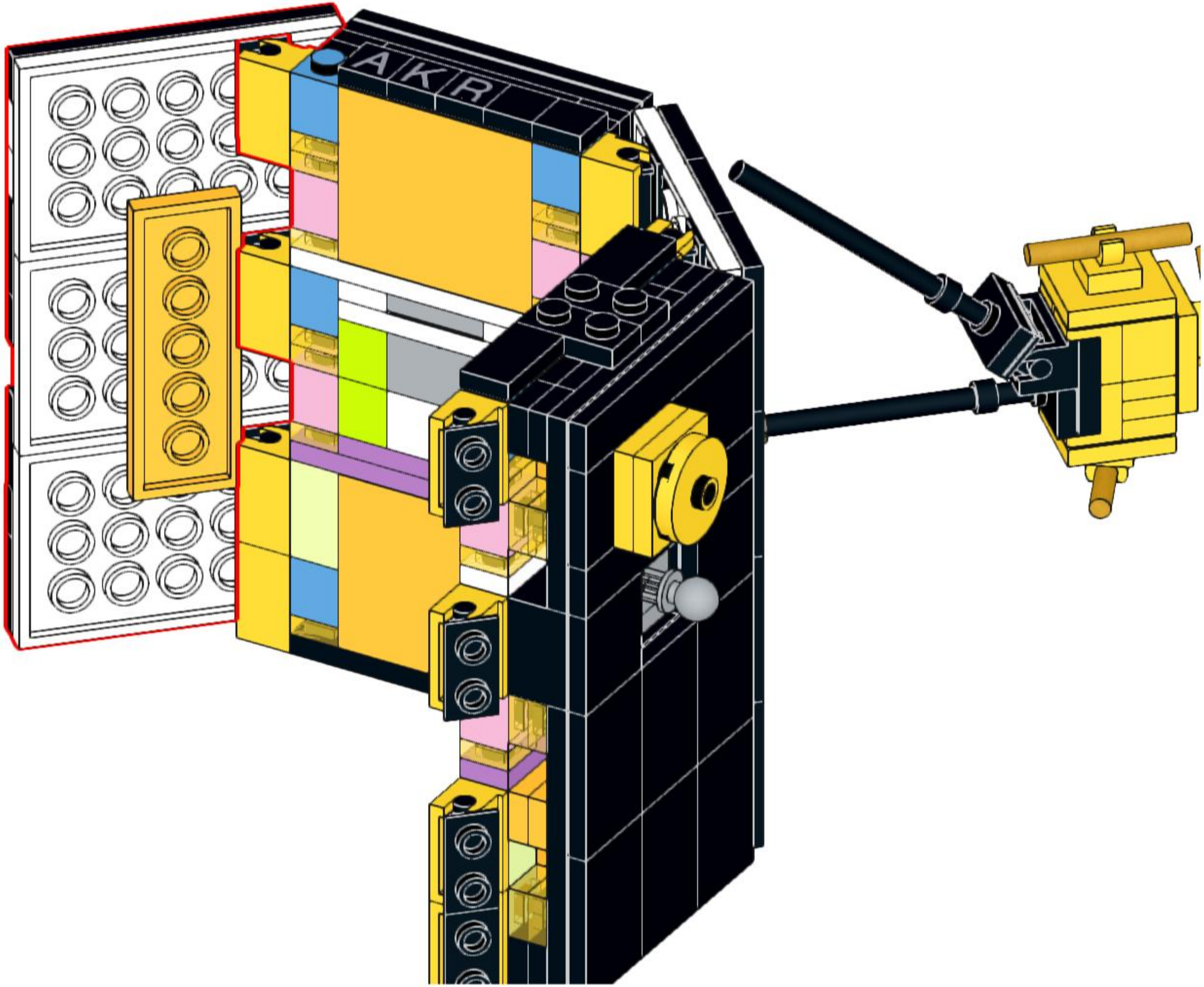
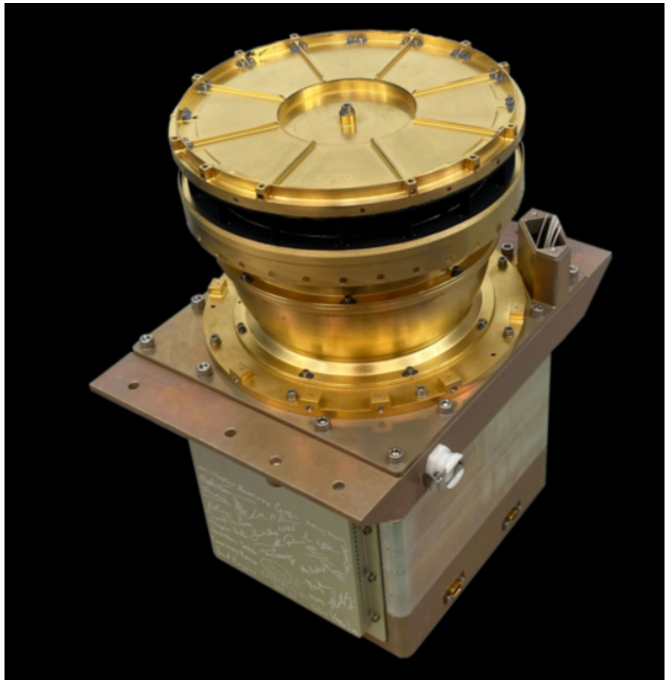
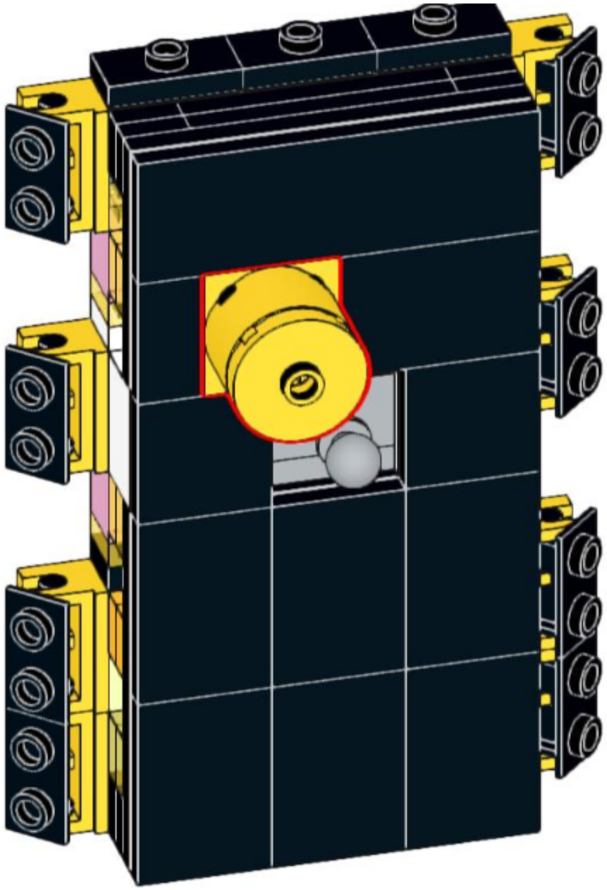


2x
For Model 2

ACI (Analyzer for Cusp Ions)

The ion measurements of the ACI instruments are critical in distinguishing between magnetopause reconnection that is spatially vs. temporally variable. ACI measurements are central to the first two TRACERS science objectives. When flying through the cusp, TRACERS will observe dispersion signatures where the highest energy ions are seen at the lowest latitudes (the equatorward edge of the cusp). This energy dispersion is rarely smooth, often consisting of 'steps' where the ion energy is constant for a short range of latitude and then decreases to the next step. If the steps occur at the same latitude on both spacecraft, then reconnection is spatially variable; if the steps move in latitude (that is, to higher latitude), then reconnection is temporally variable.





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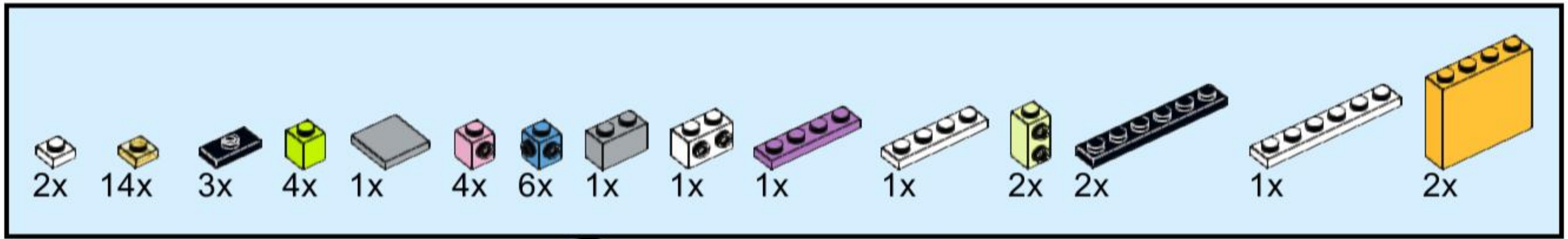

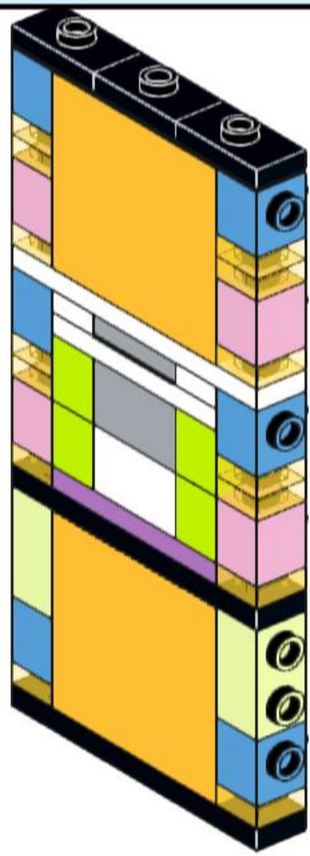

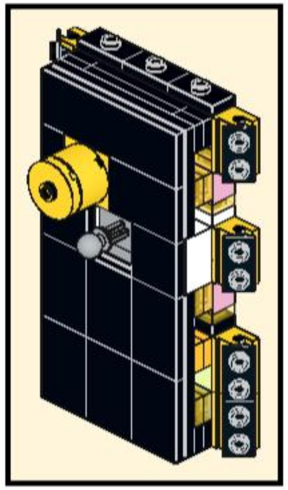

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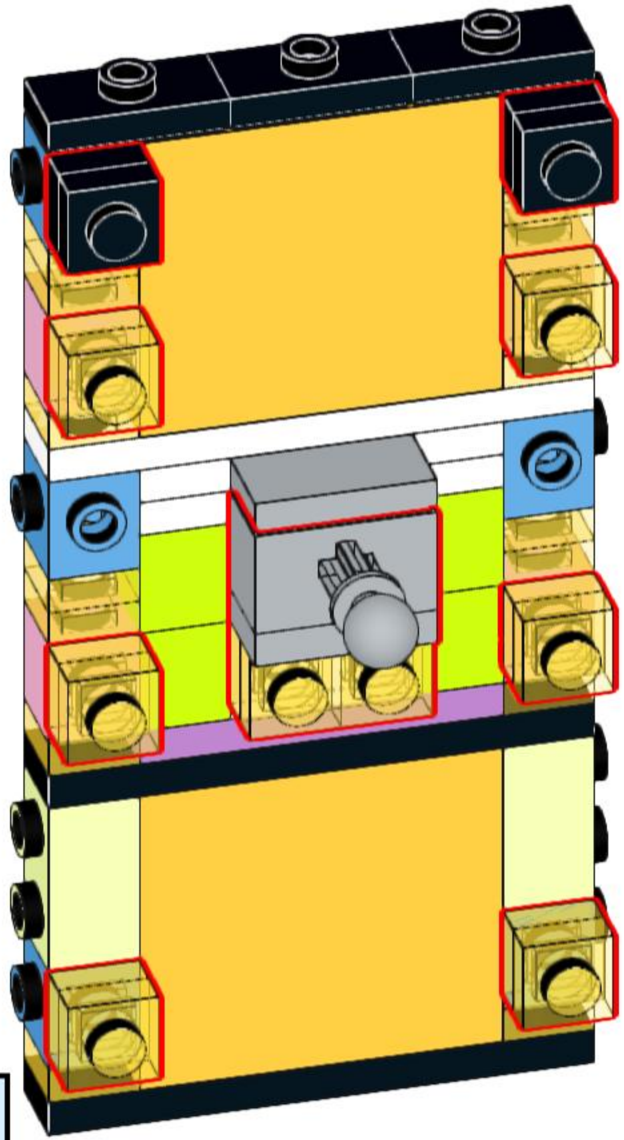

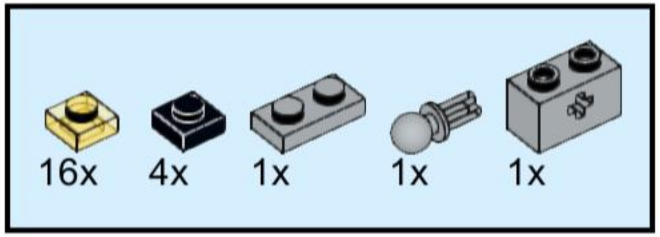

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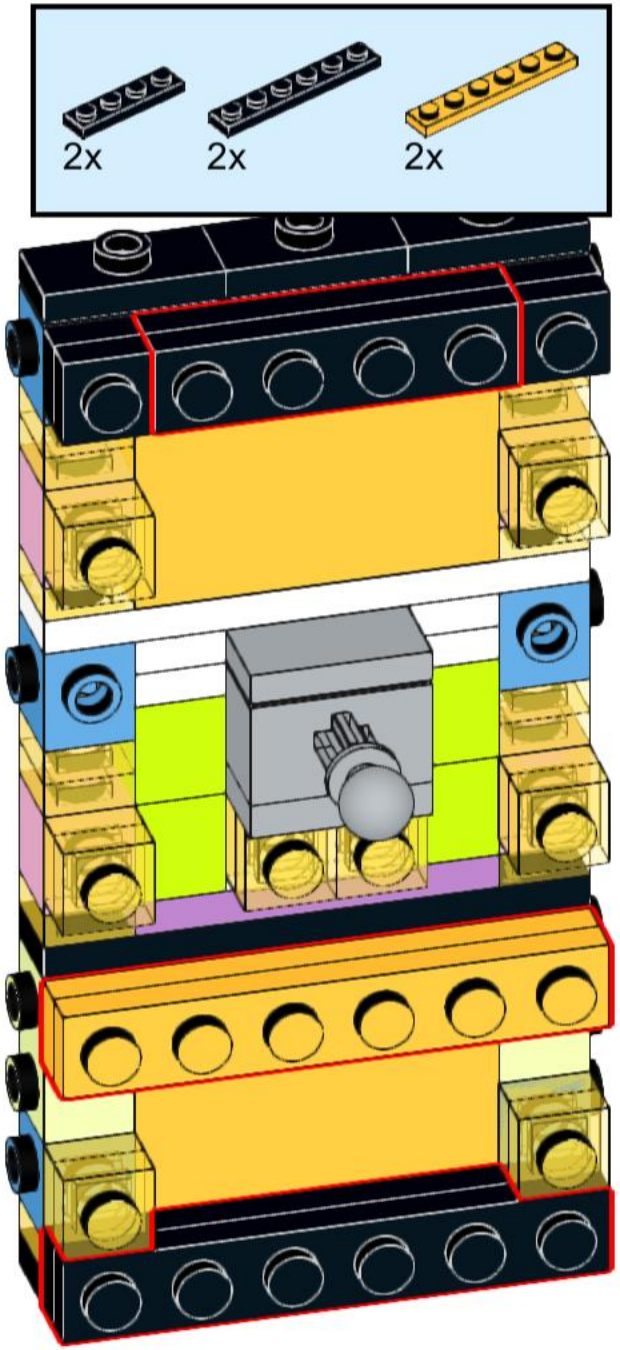

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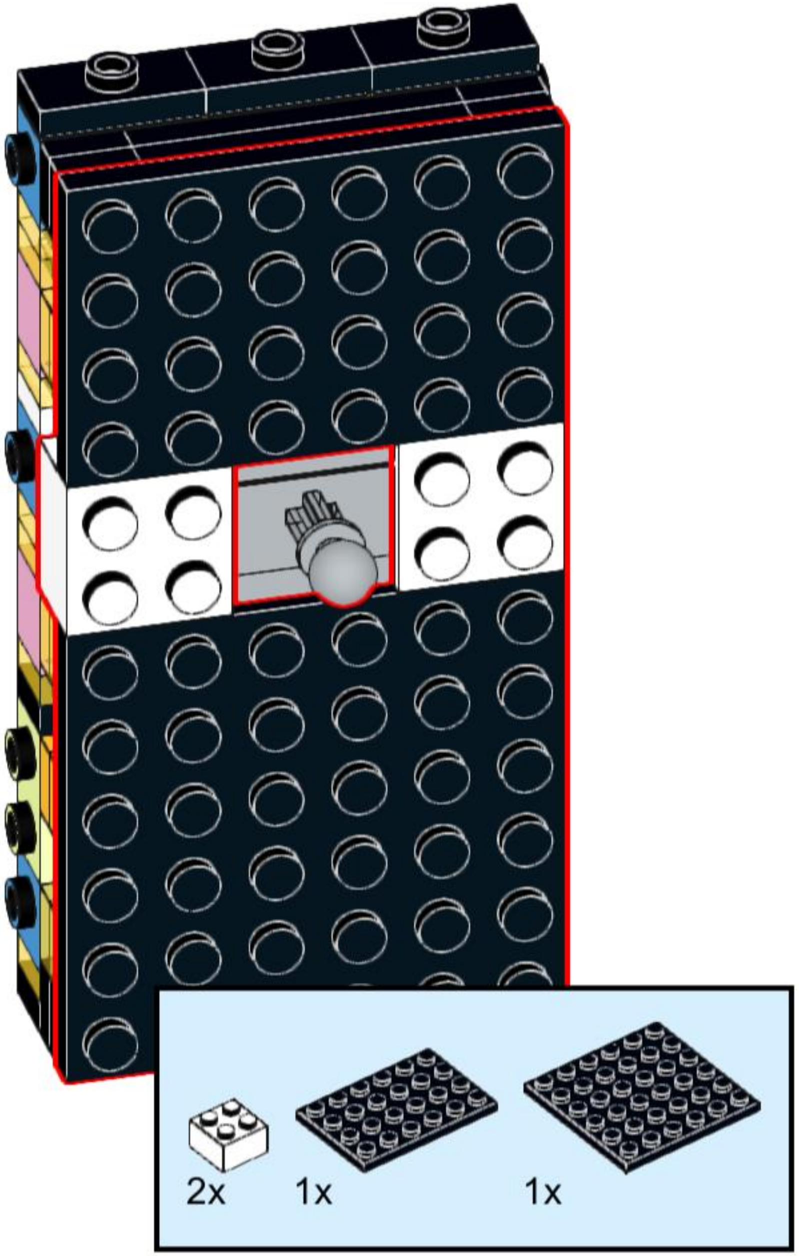

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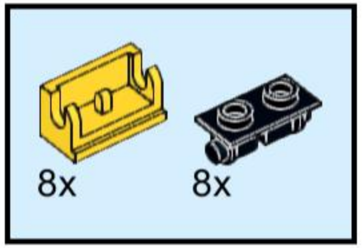

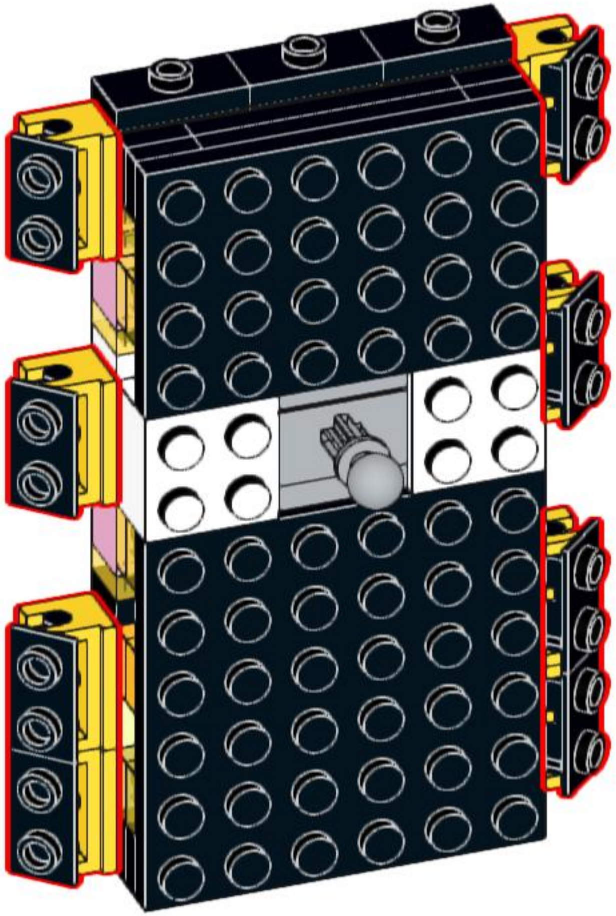

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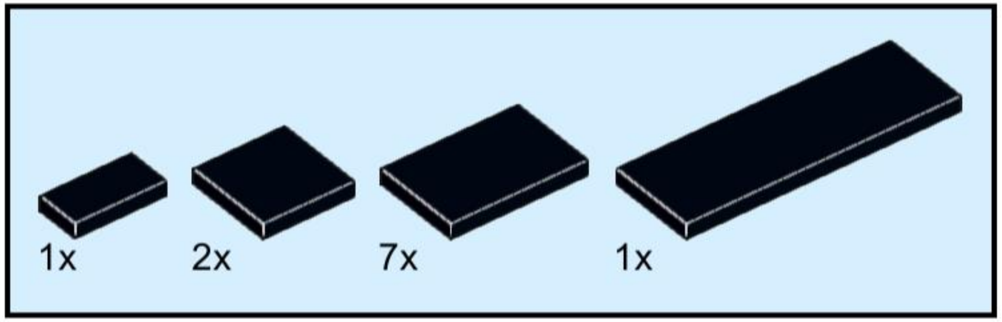

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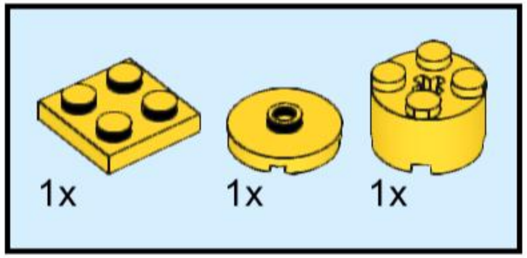

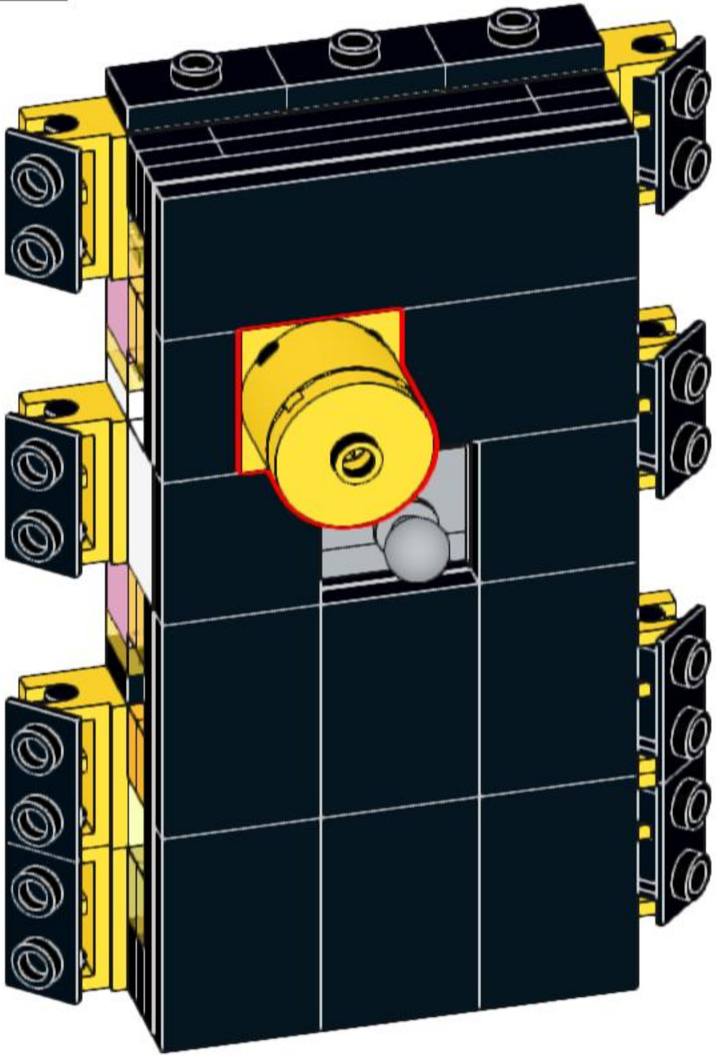

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For Model 2

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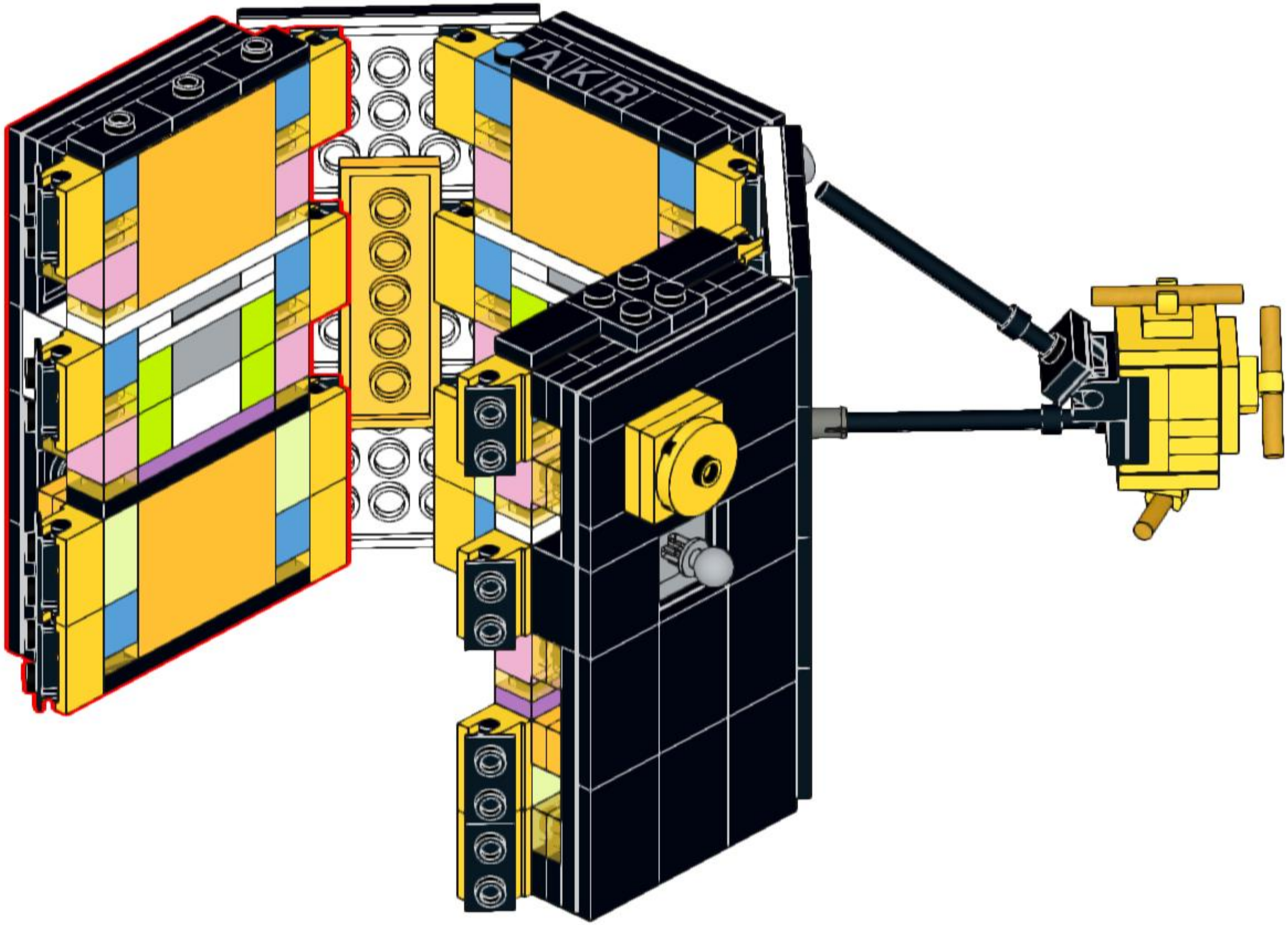
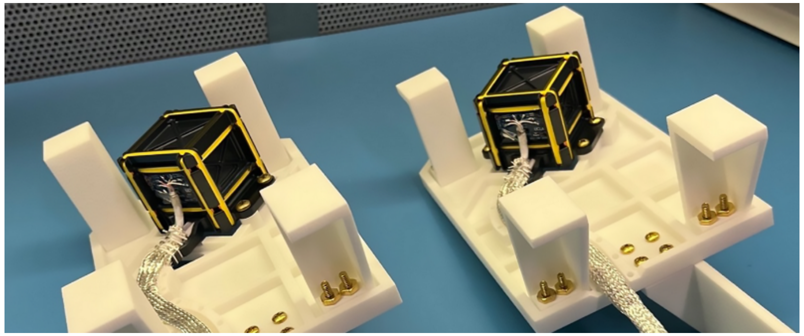
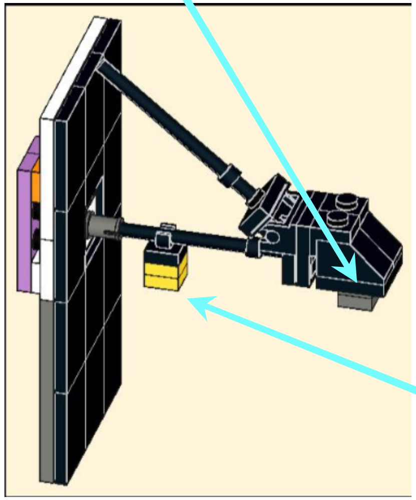


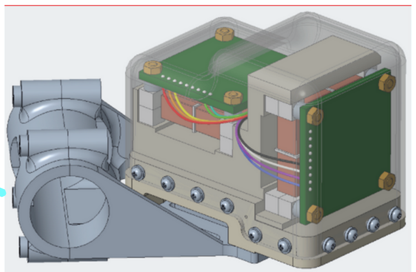
MAG (Fluxgate Magnetometer)

The MAG instruments, with their measurements of the background magnetic field of plasma, are important in understanding the causes of particle (electrons and ions) signatures within the funnel-shaped cusp region. Fluxgate magnetometers have flown on a high percentage of all space science missions and space weather missions to provide high-fidelity measurements of the local magnetic field. Fluxgate magnetometers deliver a magnetic field measurement through modulating (gating) the local magnetic field. This is done by periodically saturating a piece of ferromagnetic core material and sensing this modulated magnetic field using a coil of wire. Fluxgate performance is limited by the intrinsic magnetic noise of the core as it enters magnetic saturation.



(MAG)

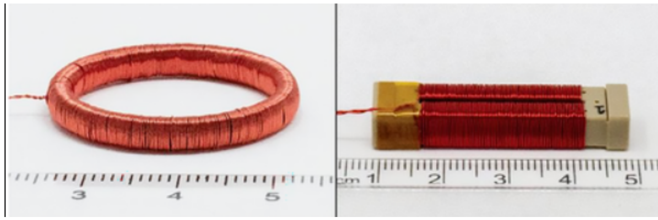




(MAGIC)

MAGIC (Magnetometers for Innovation and Capability)

Many of the best fluxgates worldwide use what are known as S1000 cores that were developed in the 1960s and have been out of production since 1996. These cores were produced using 6-81 Permalloy (6% Molybdenum, 81.3% Nickel, remainder Iron). Incredibly, the manufacturing process to create these high performing cores is lost to history. With the stockpiles dwindling, many researchers are going to great lengths to recycle S1000 cores from previously made fluxgate magnetometers. It was an unsustainable problem. So, University of Iowa is resurrecting and refining fluxgate technology to produce new high-quality cores. the MAGIC team has revealed potential optimizations that could enable lower noise sensors, miniature sensors for nanosatellites, and efficient high-volume production for constellation missions. In its test phase, the MAGIC instrument will be riding along on TRACERS to show it can survive liftoff and operate in orbit without impacting the other instruments. This allows the team to test two designs, one on each spacecraft. T1, the leading TRACERS satellite, will host a MAGIC instrument with a 'Tesseract' sensor design and T2 will host a MAGIC instrument with a more traditional 'ringcore' sensor design.



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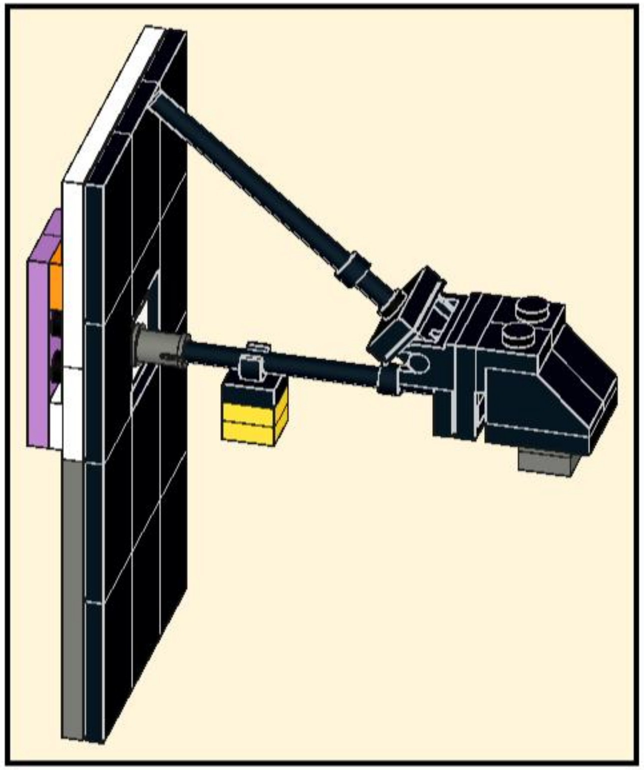

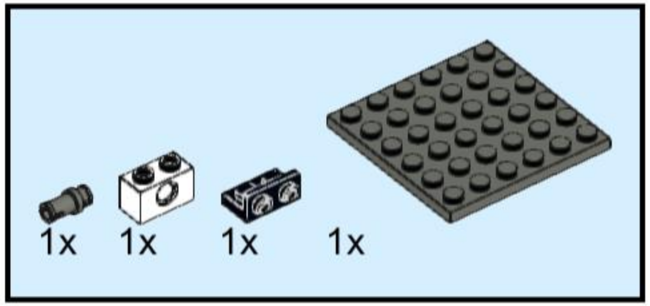

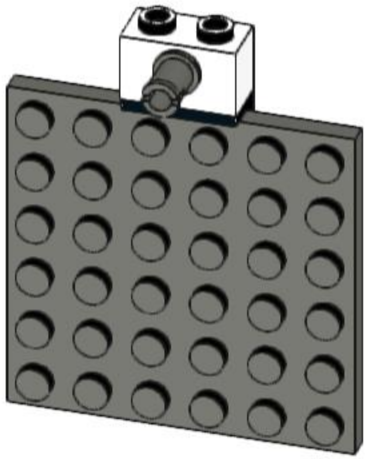

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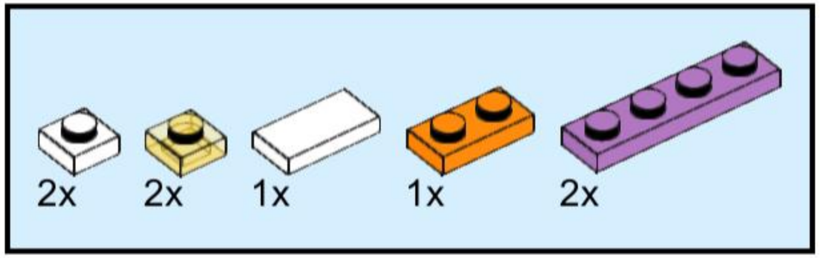

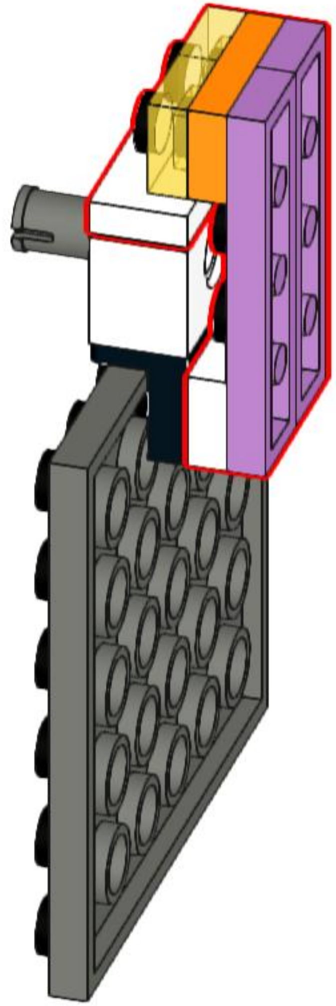

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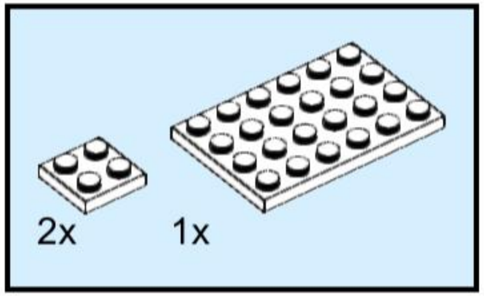

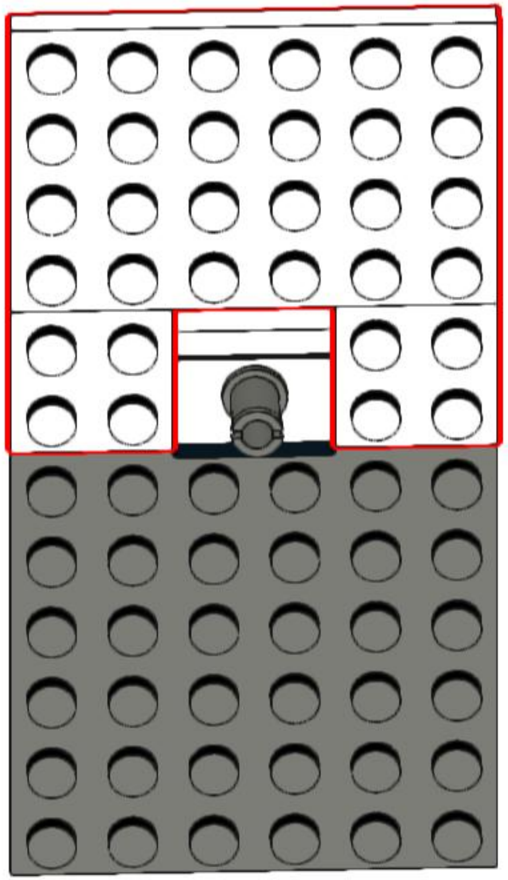

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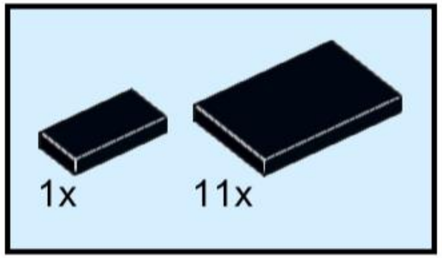
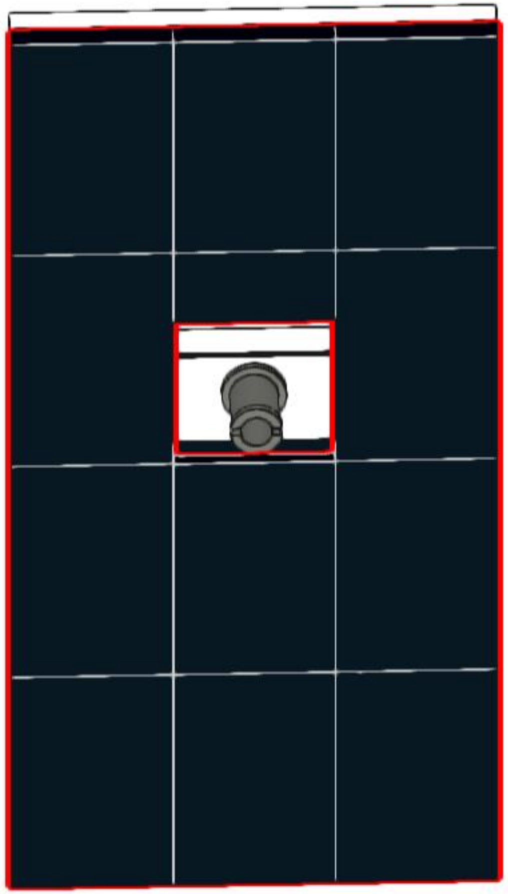
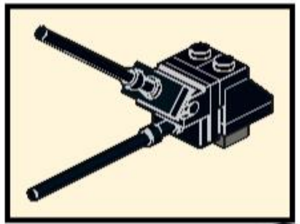
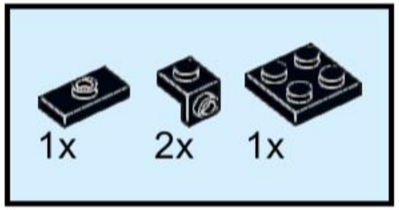


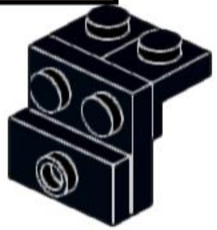


The white 4x4's will be held in place by the black tiles.

62







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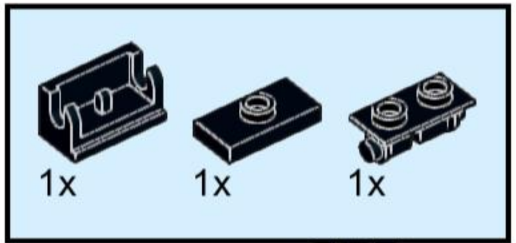

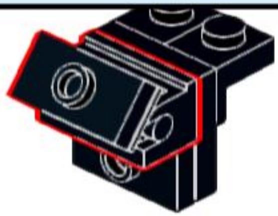

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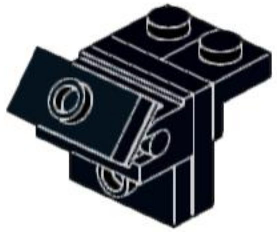

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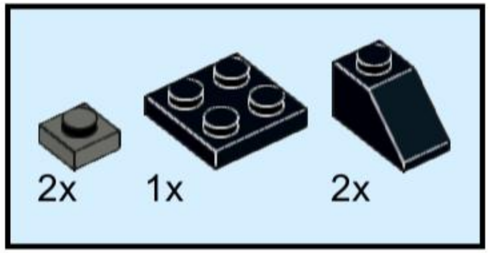

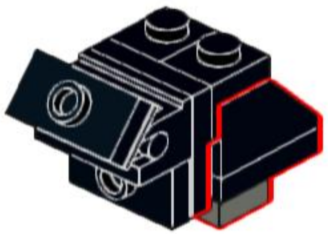

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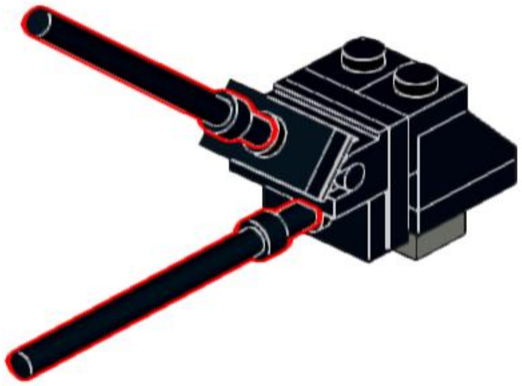

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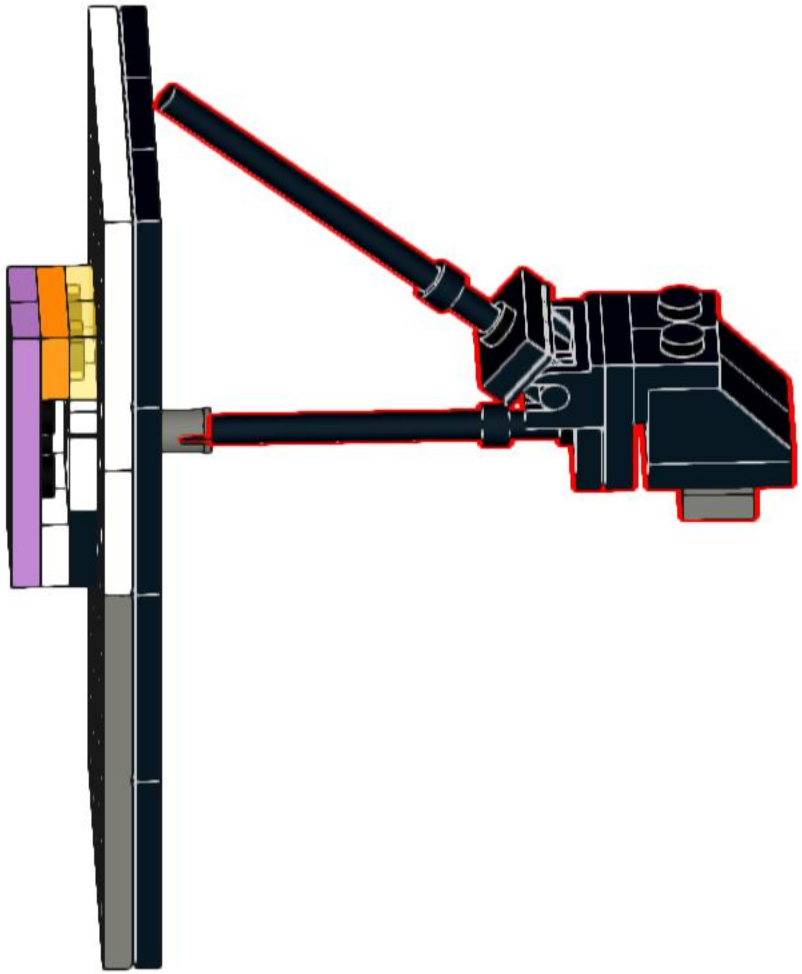

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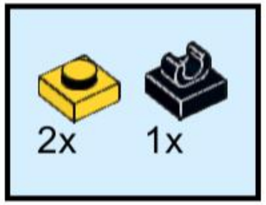

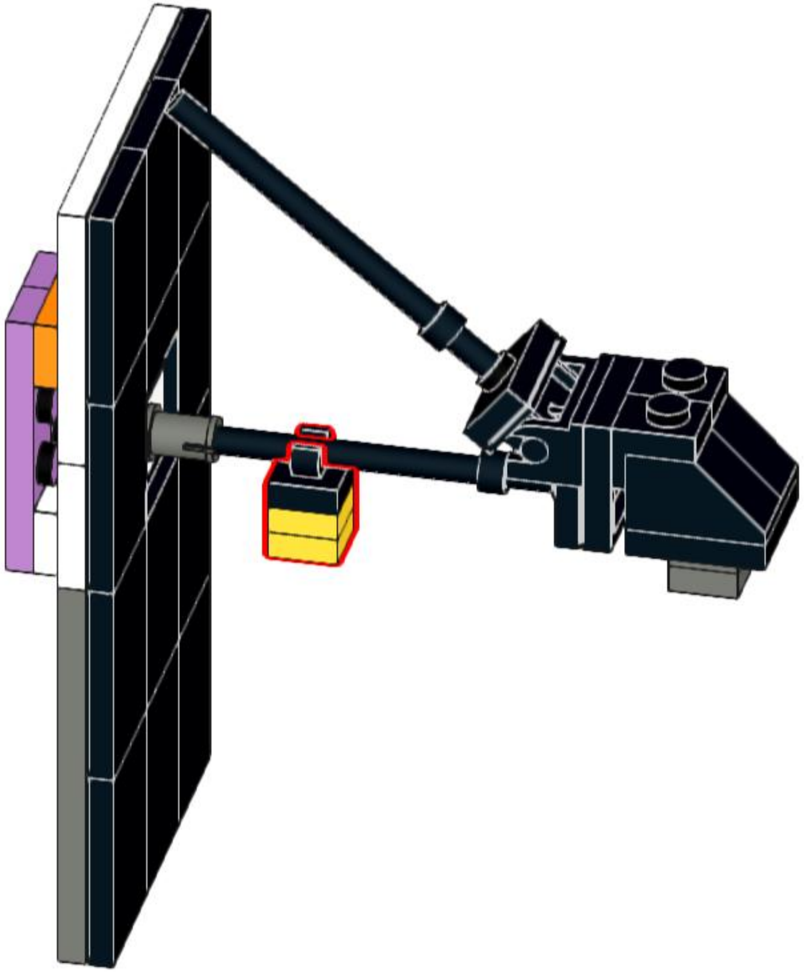

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For Model 2

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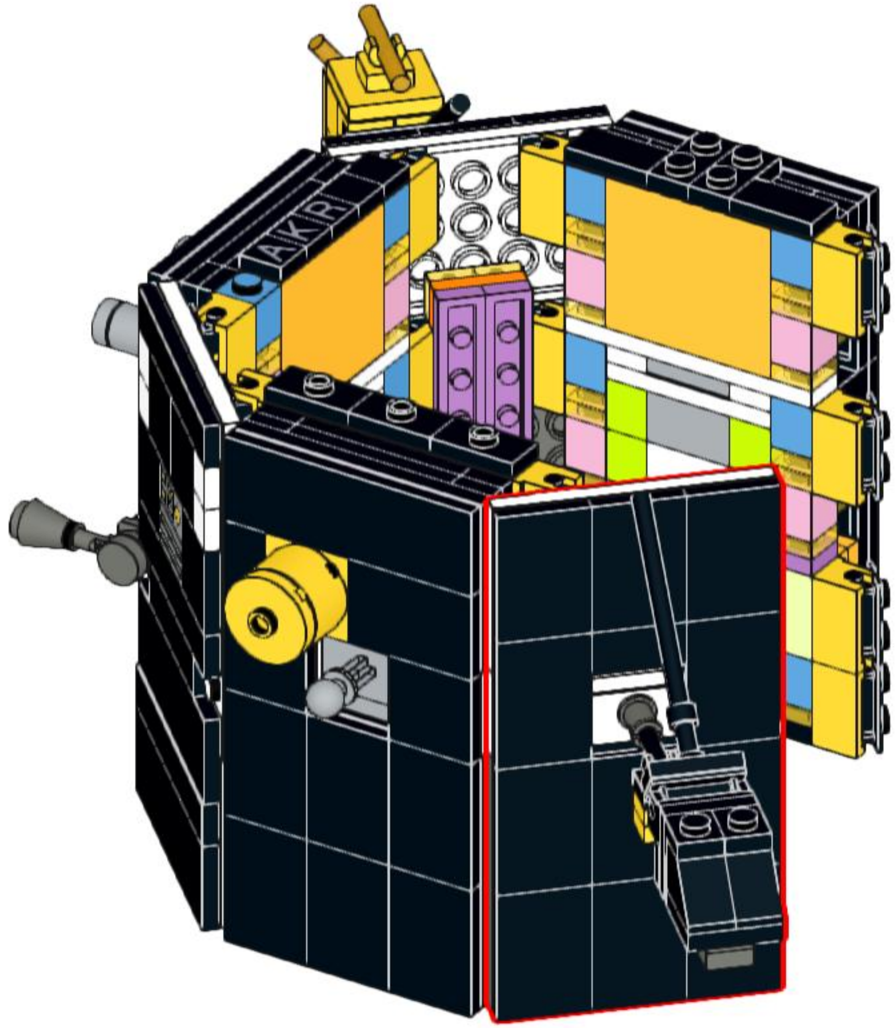

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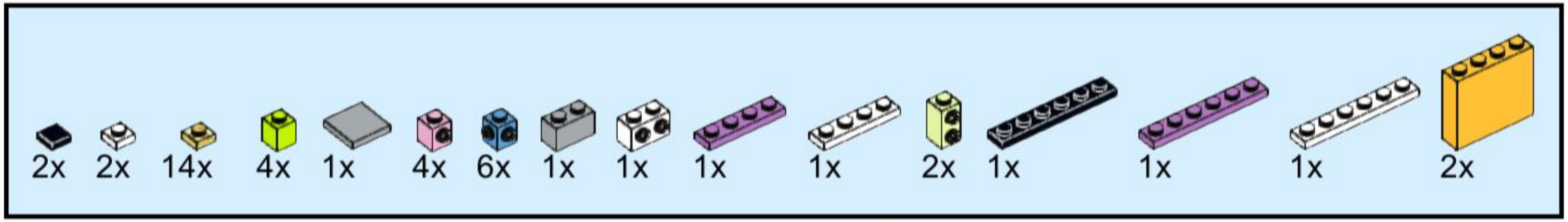

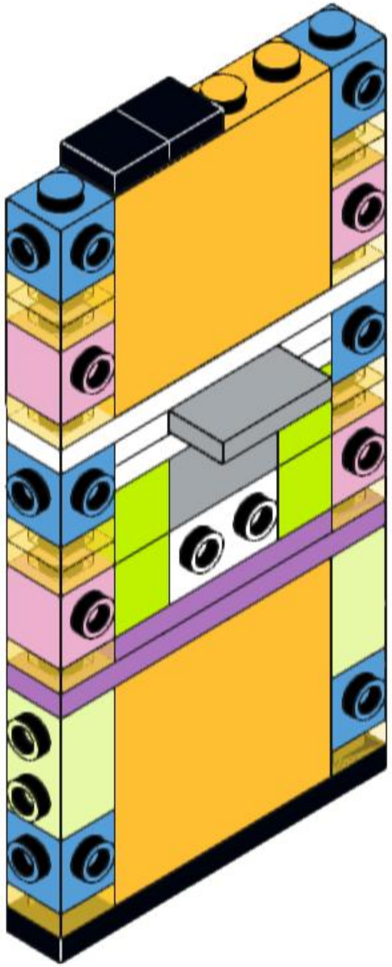

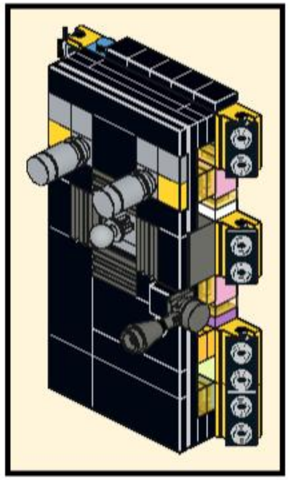

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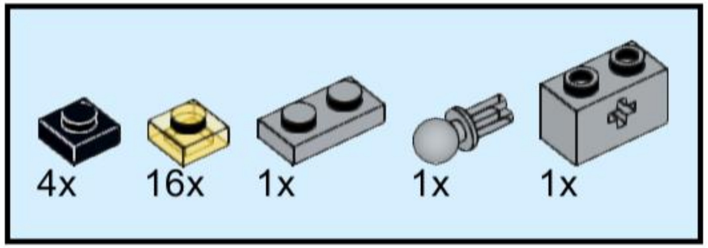

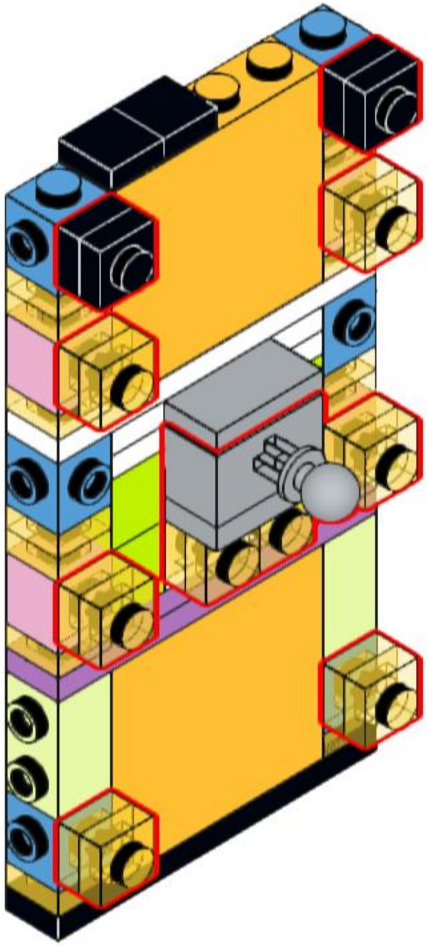

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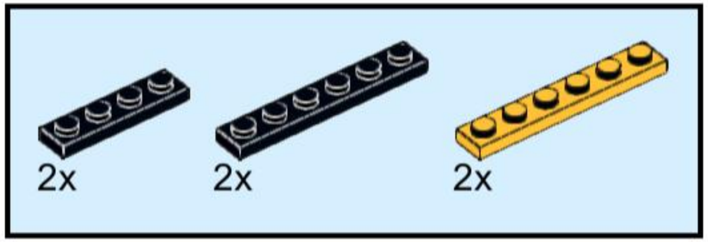

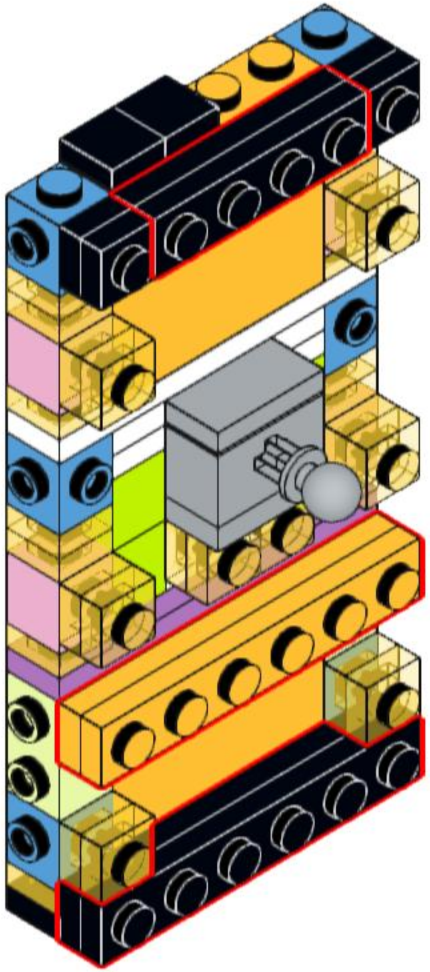

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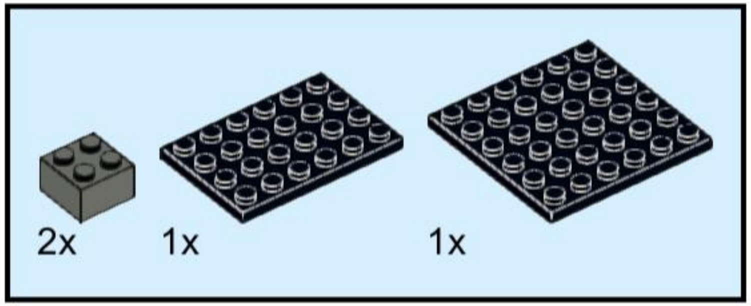

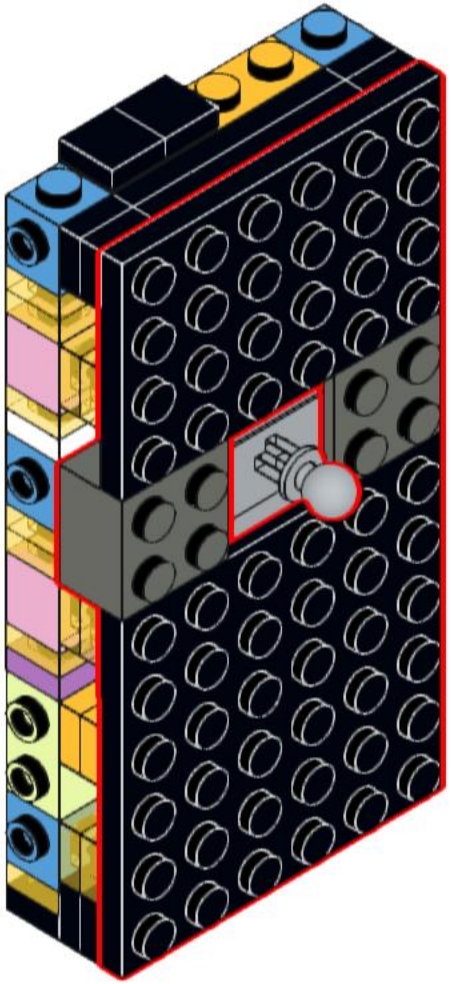

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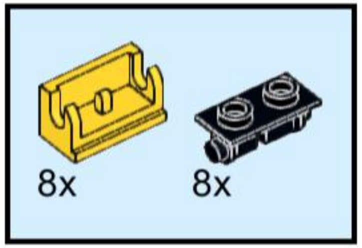

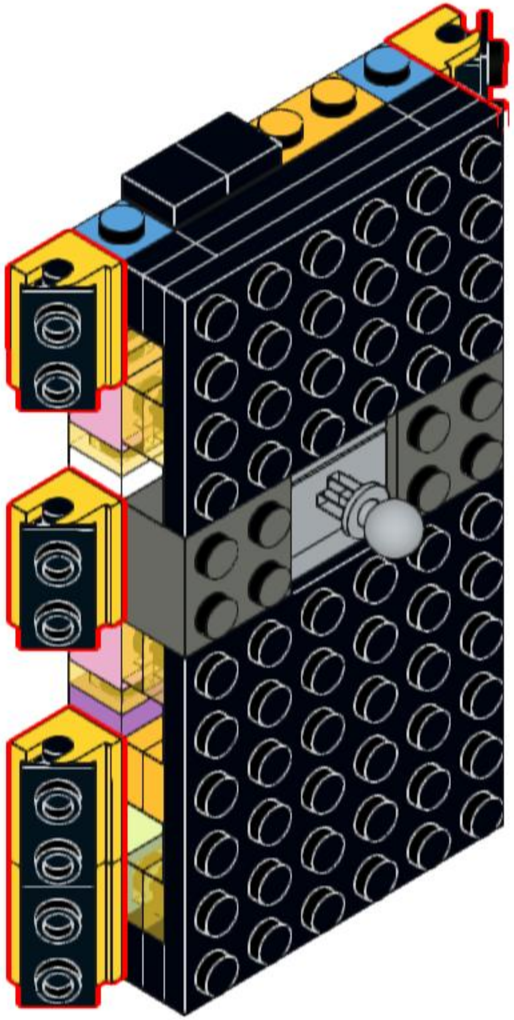

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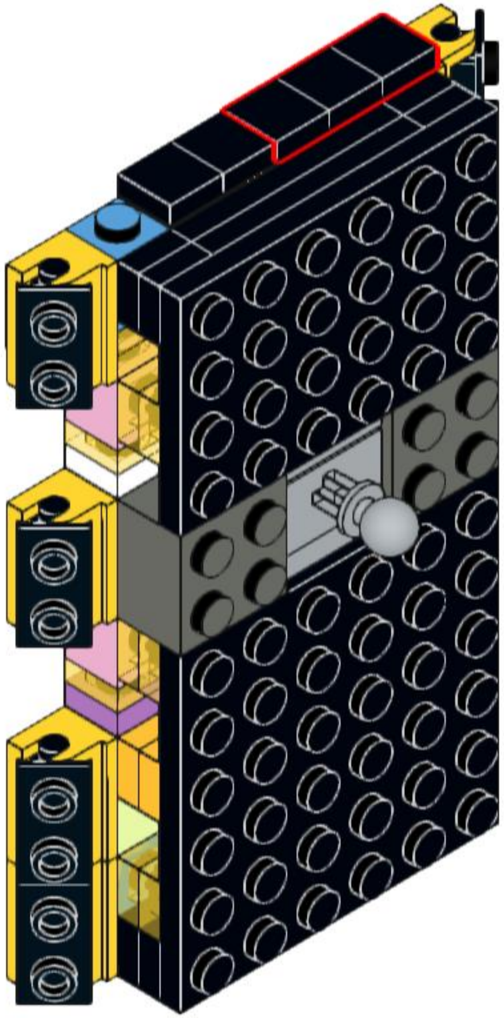

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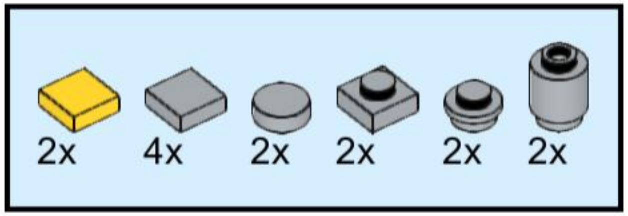

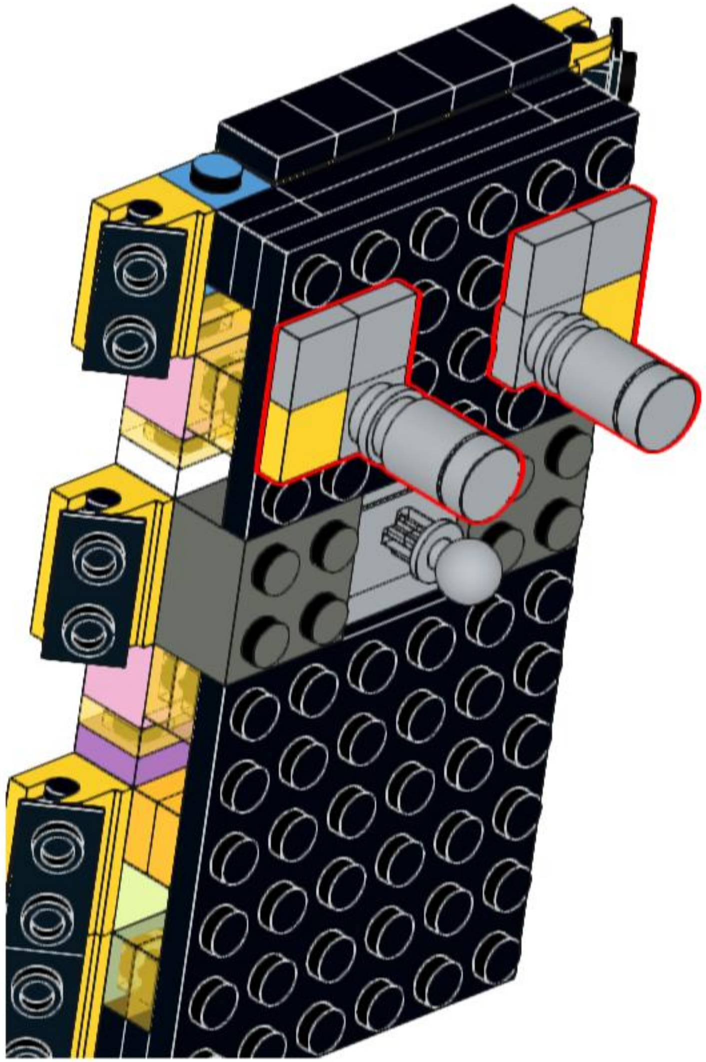

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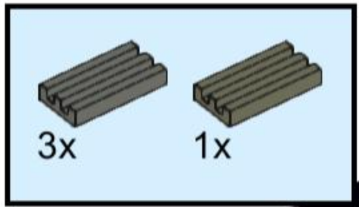

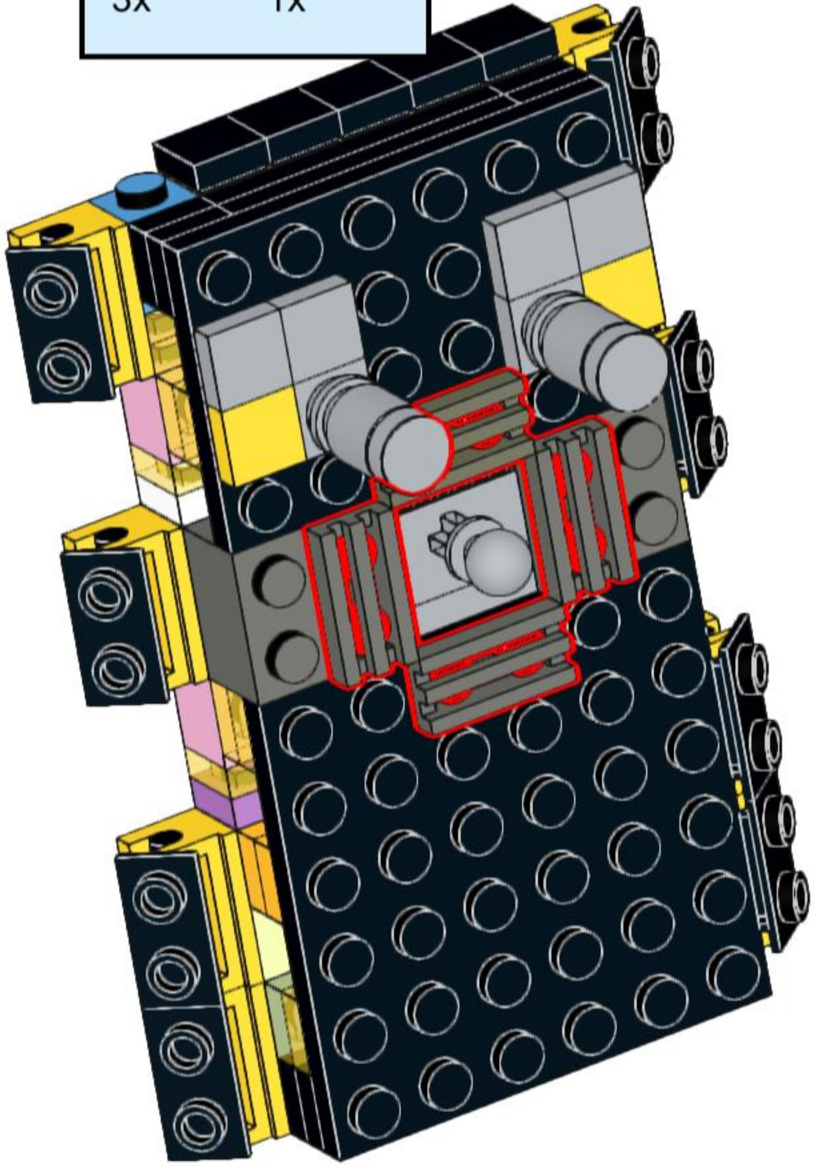

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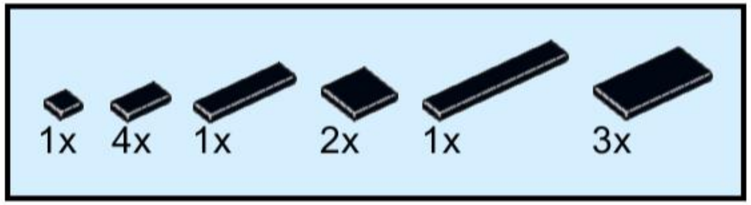

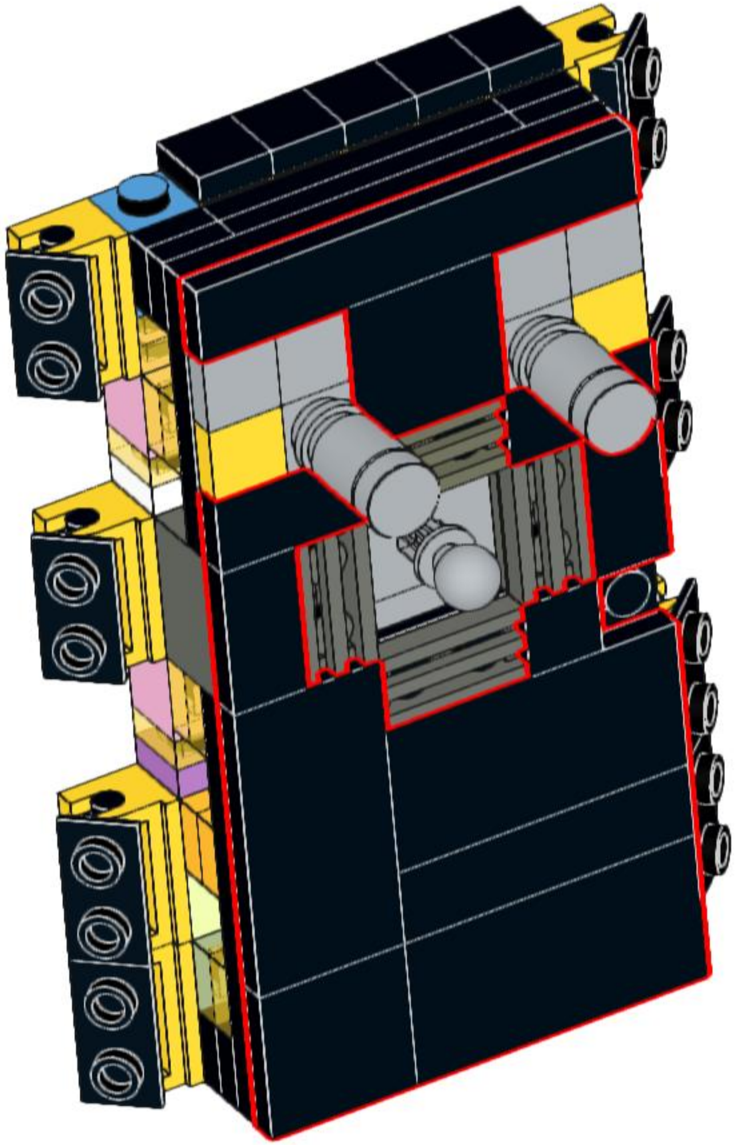

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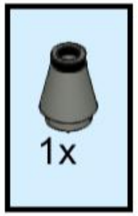

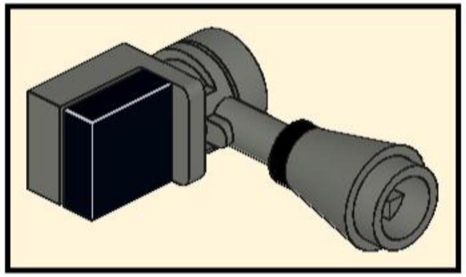

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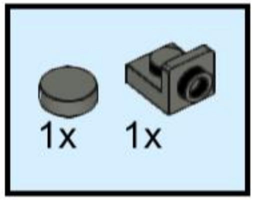

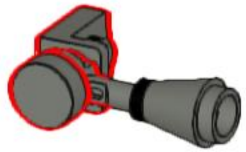

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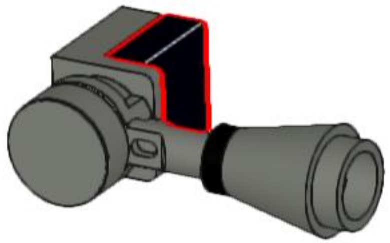

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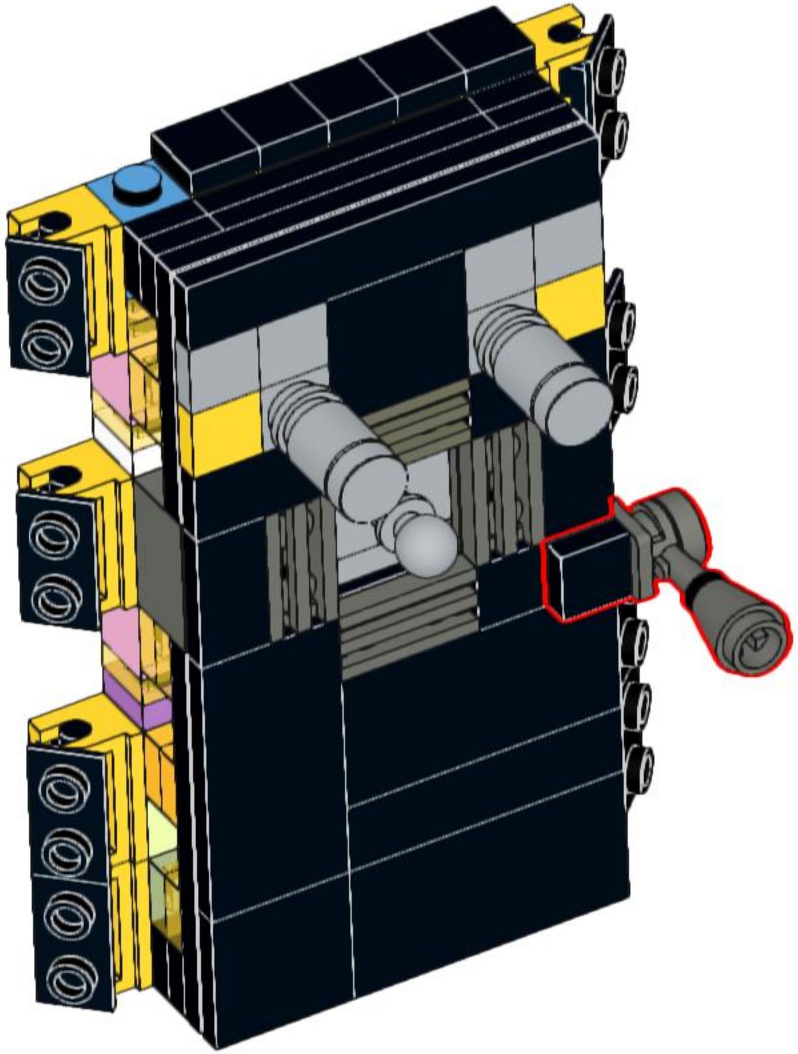
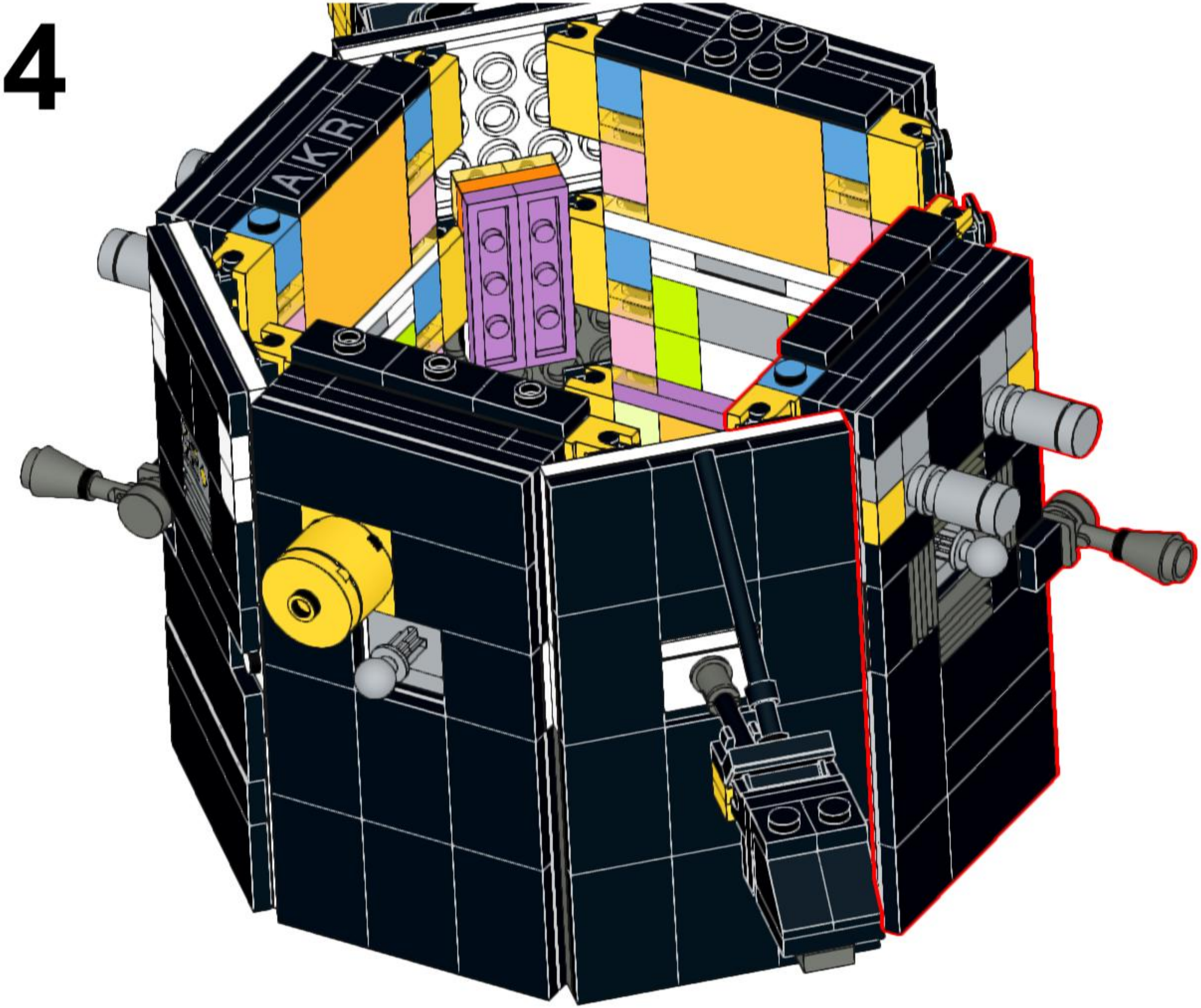


2x

For Model 2

84



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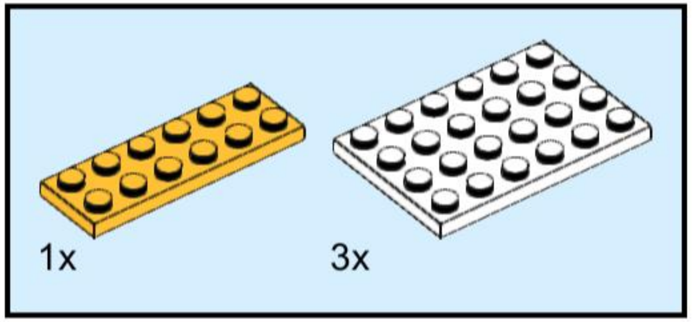

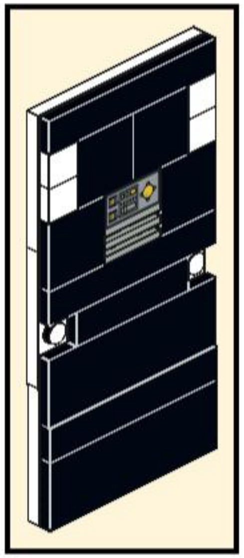

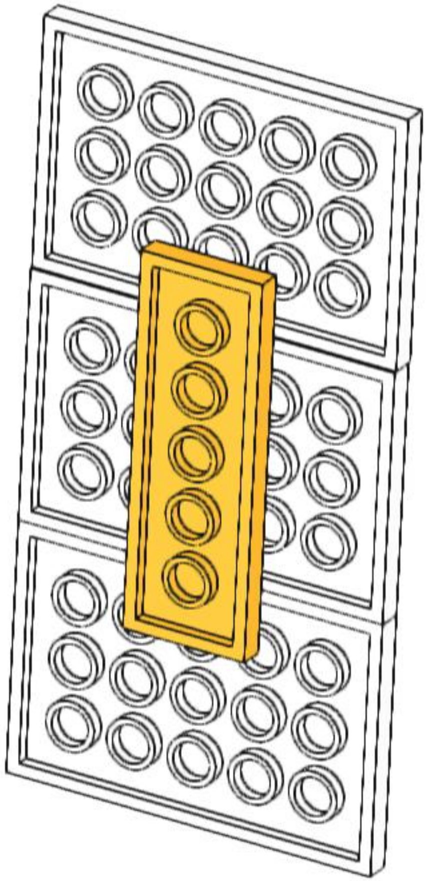

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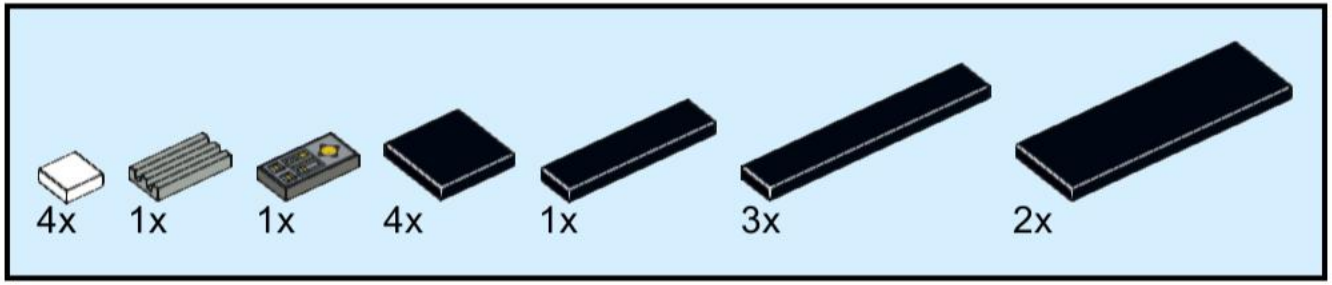
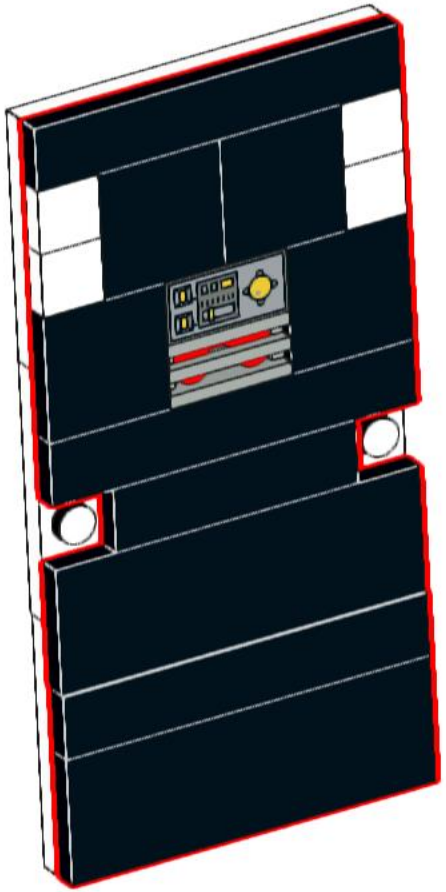
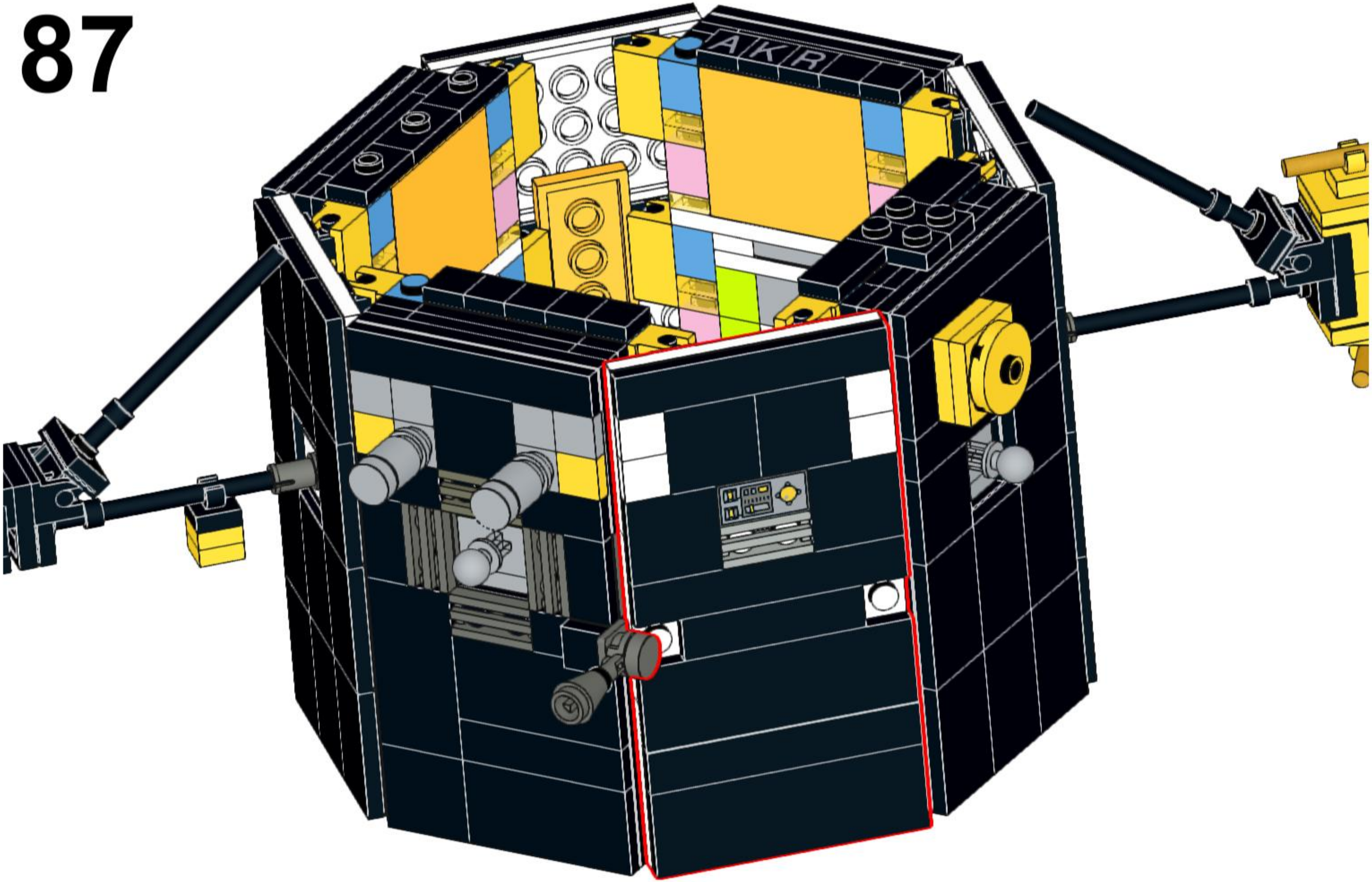




2x
For Model 2

87



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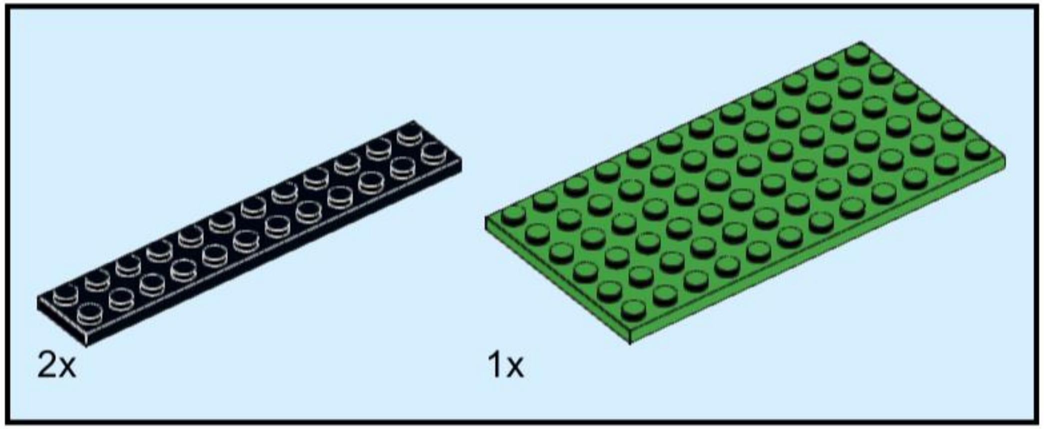
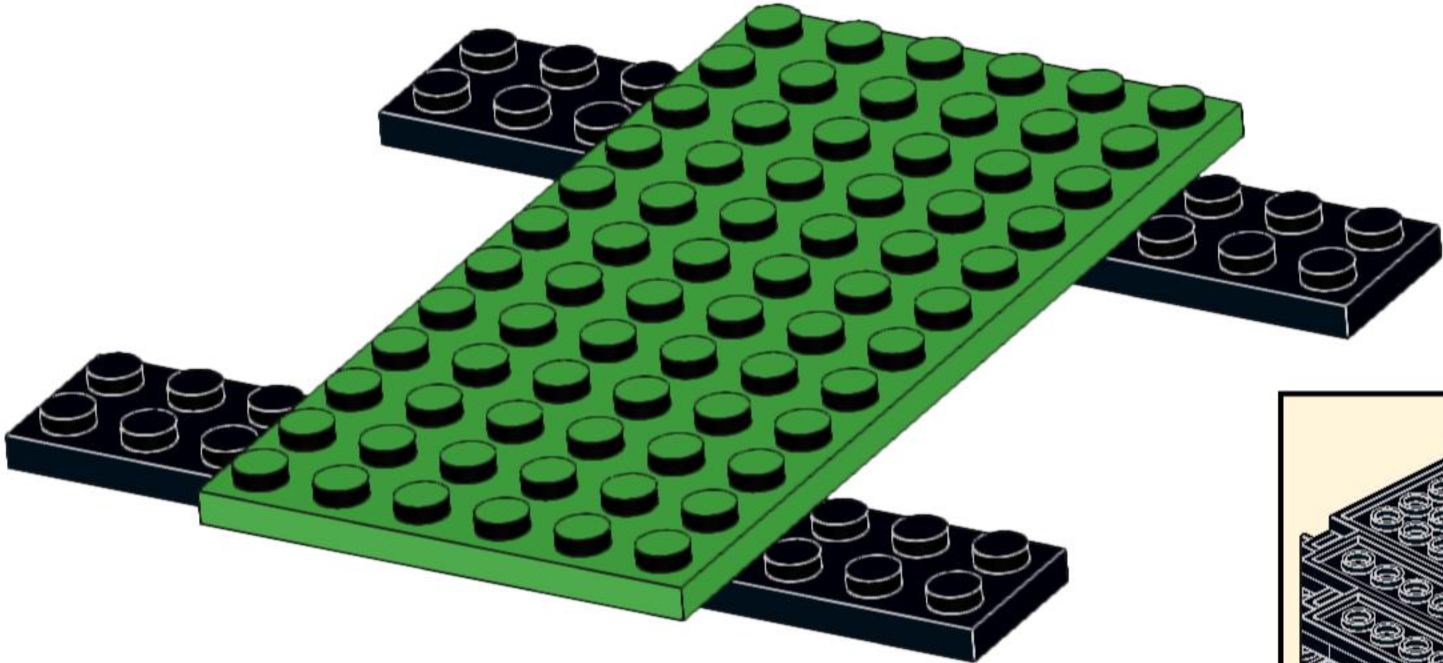
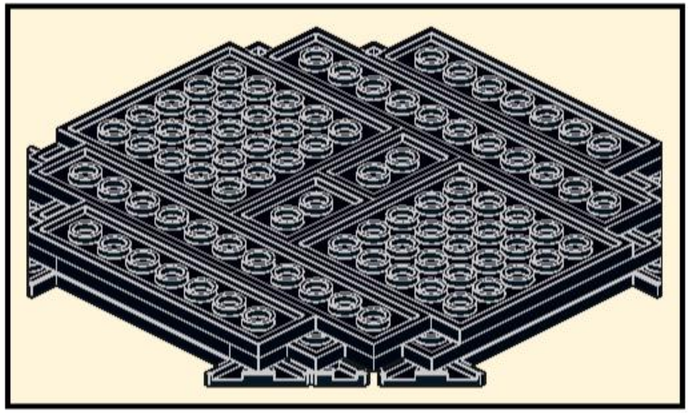
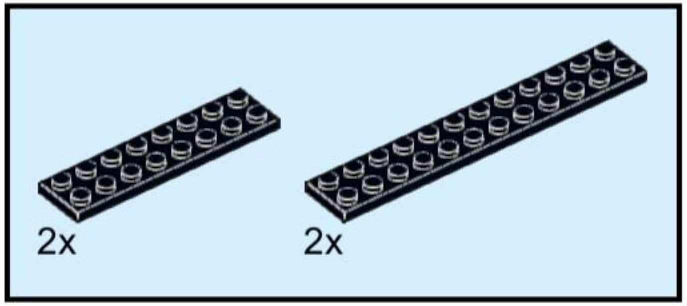




FLOOR



89



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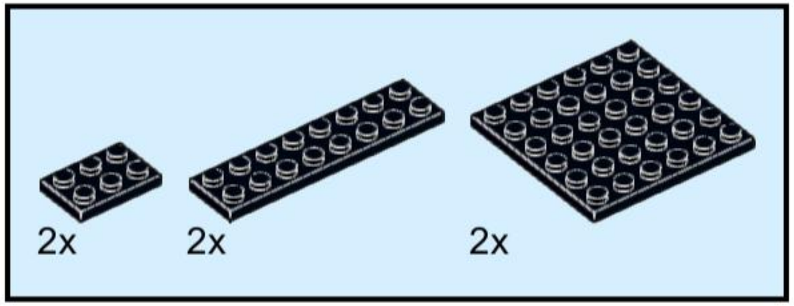

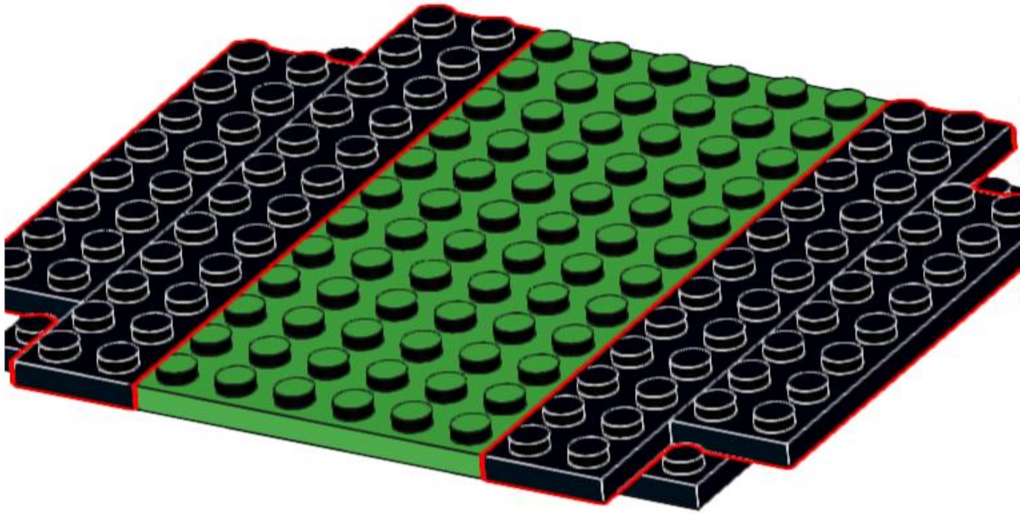

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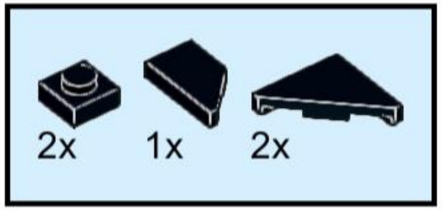
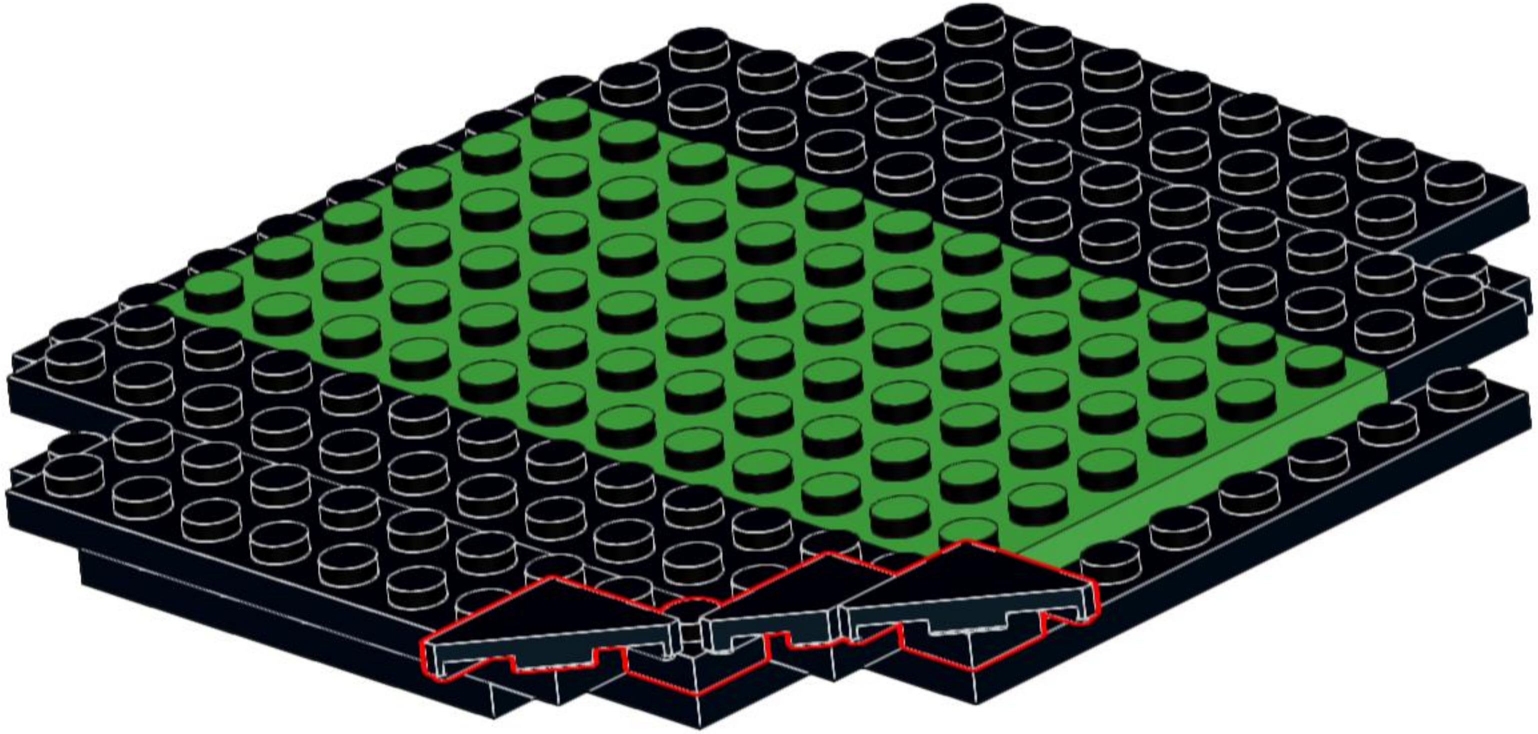
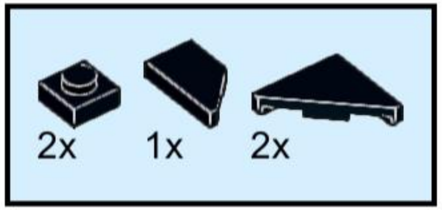
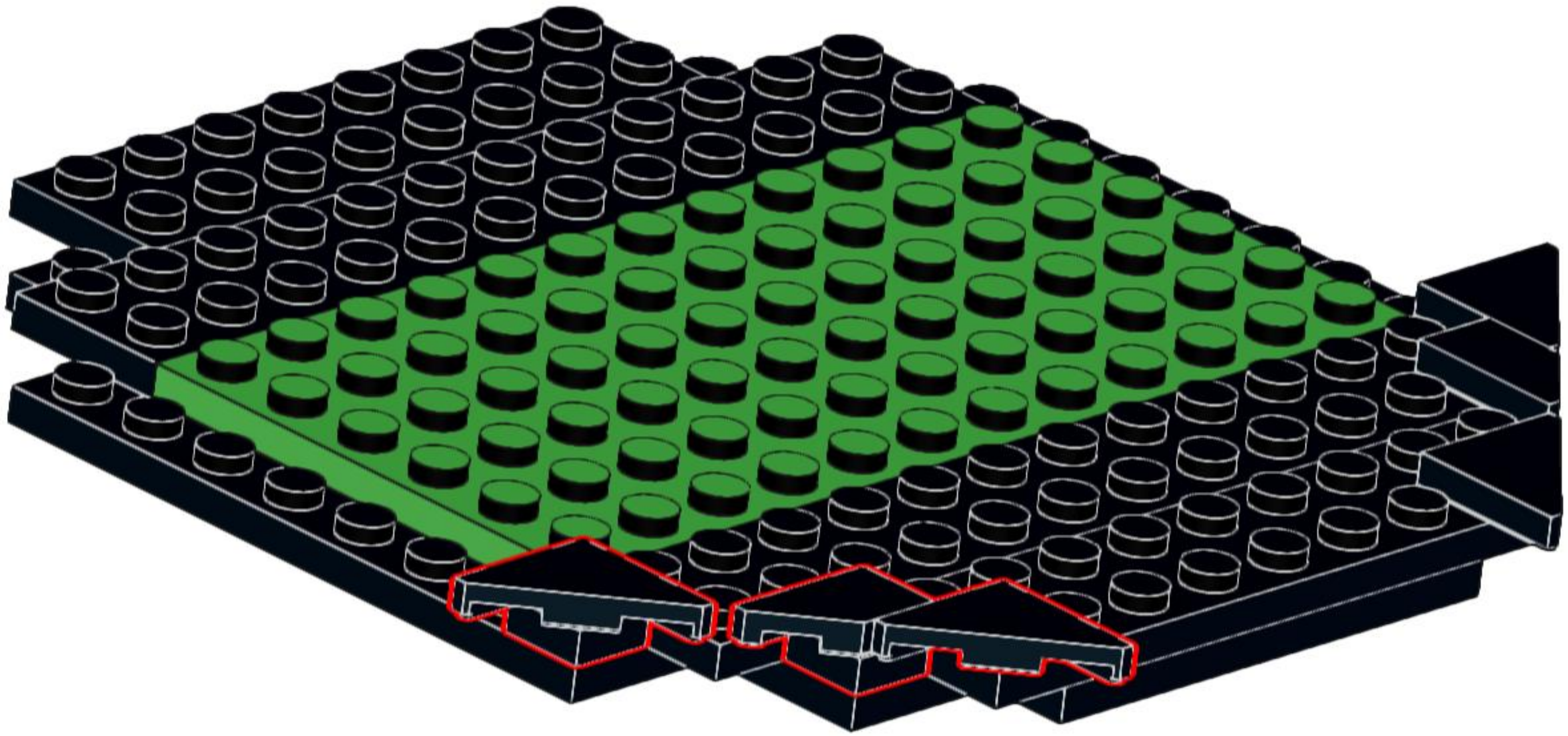


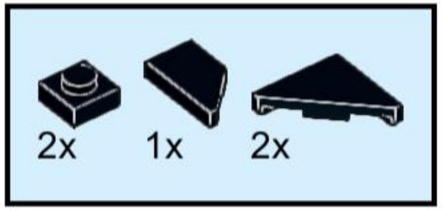


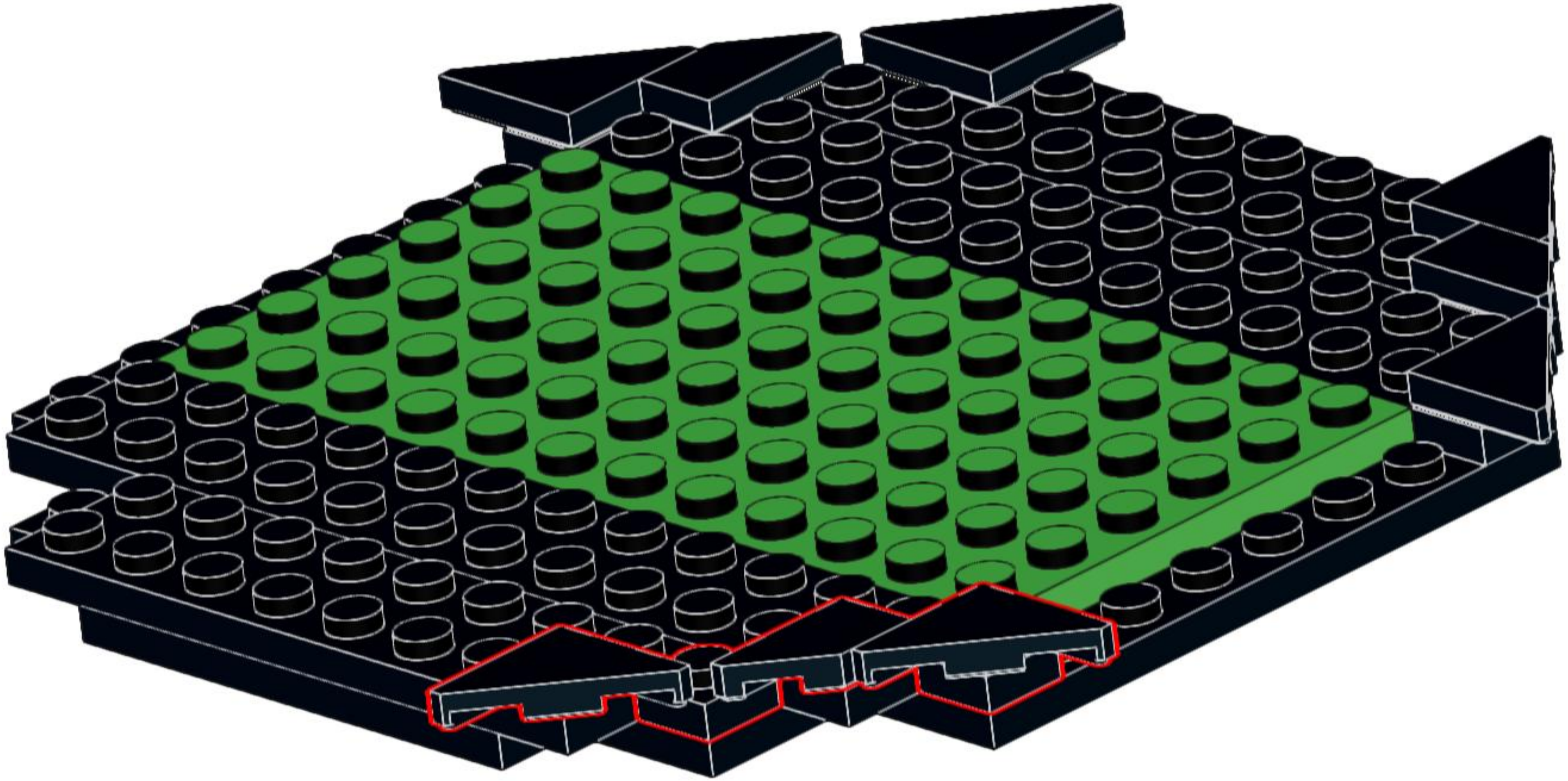
92



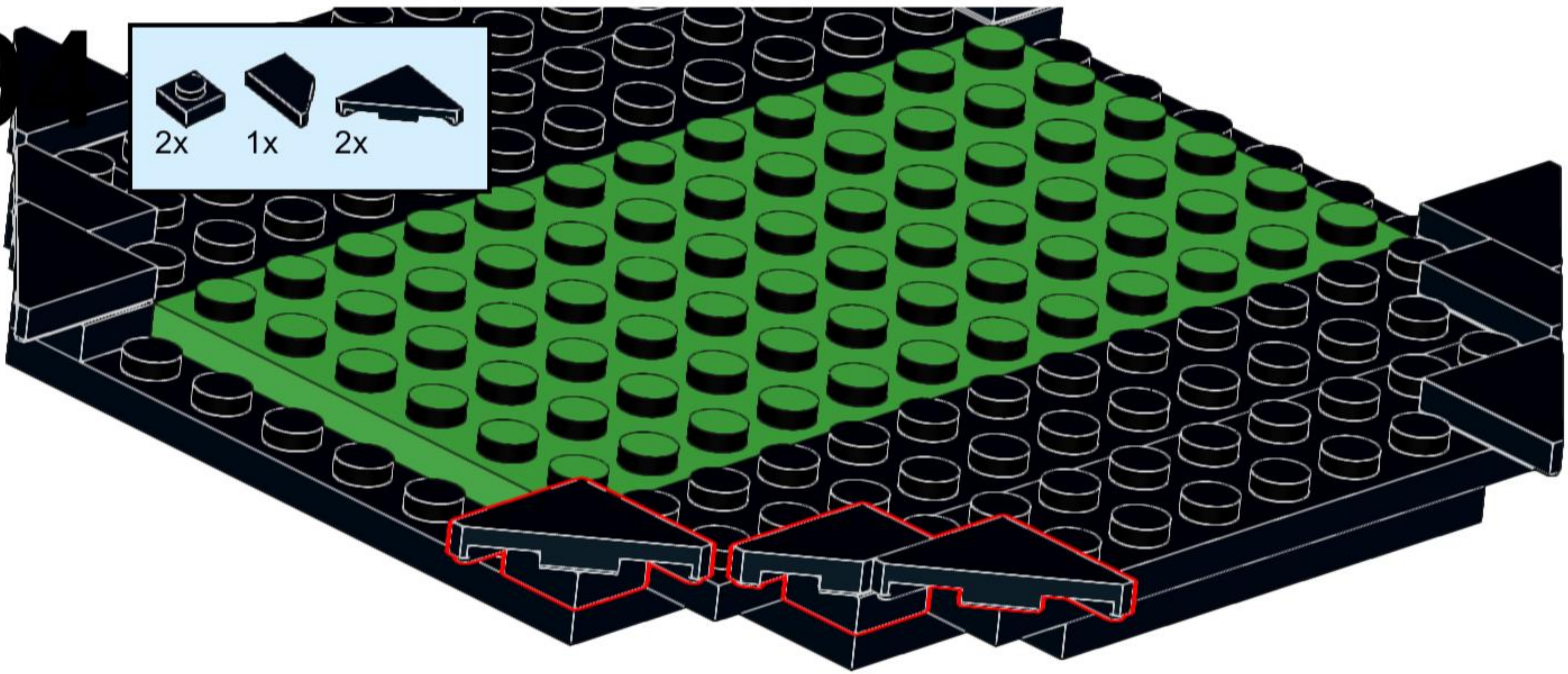


93





94



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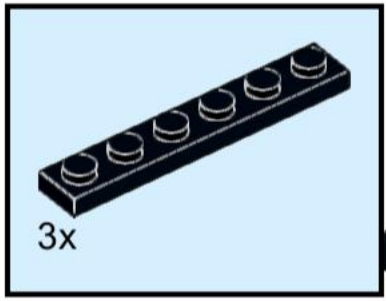

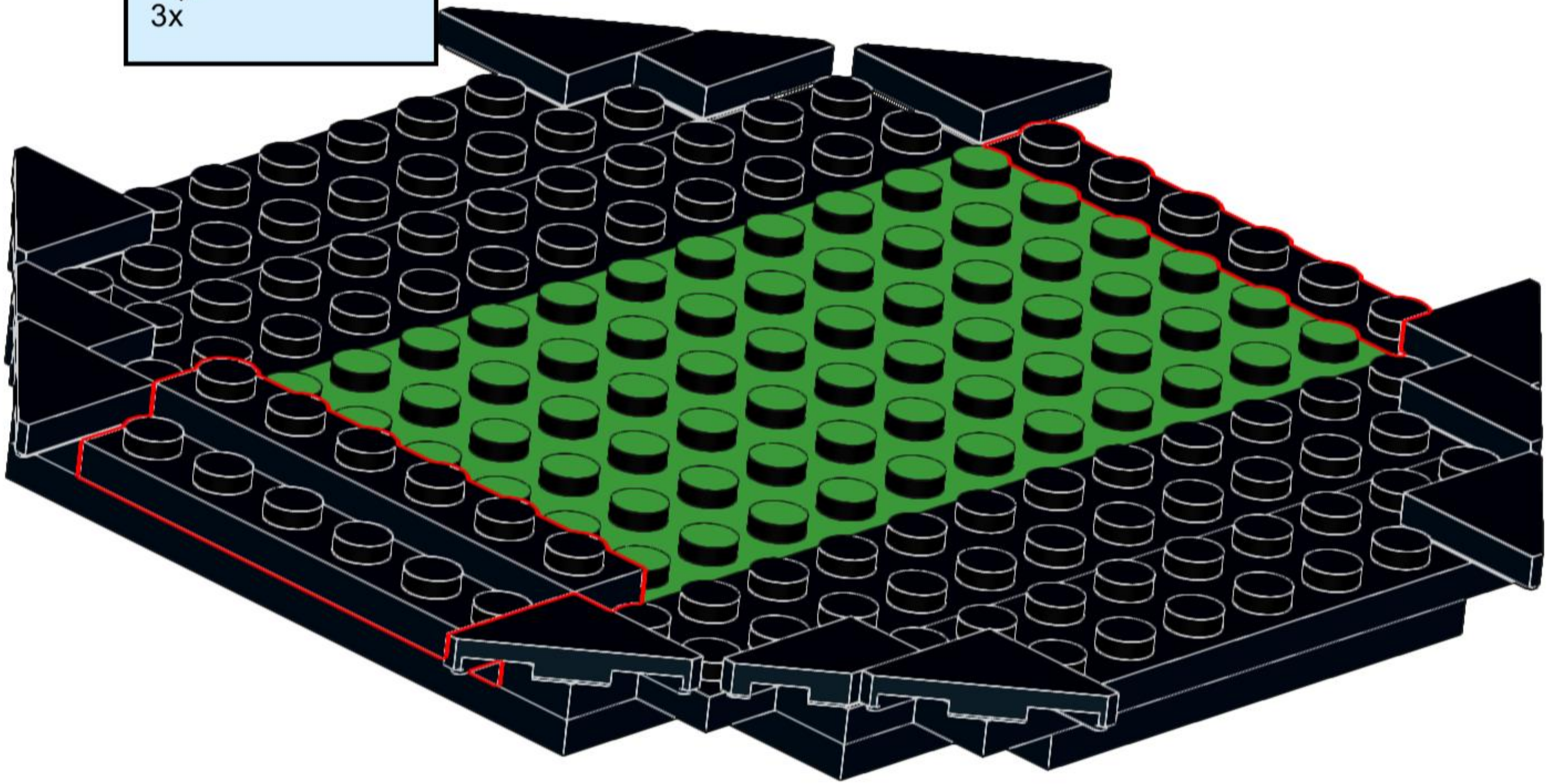

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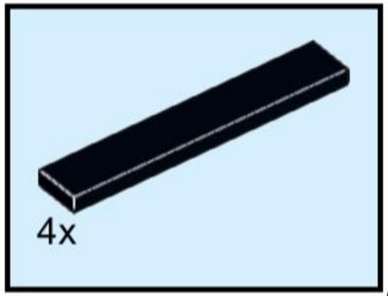

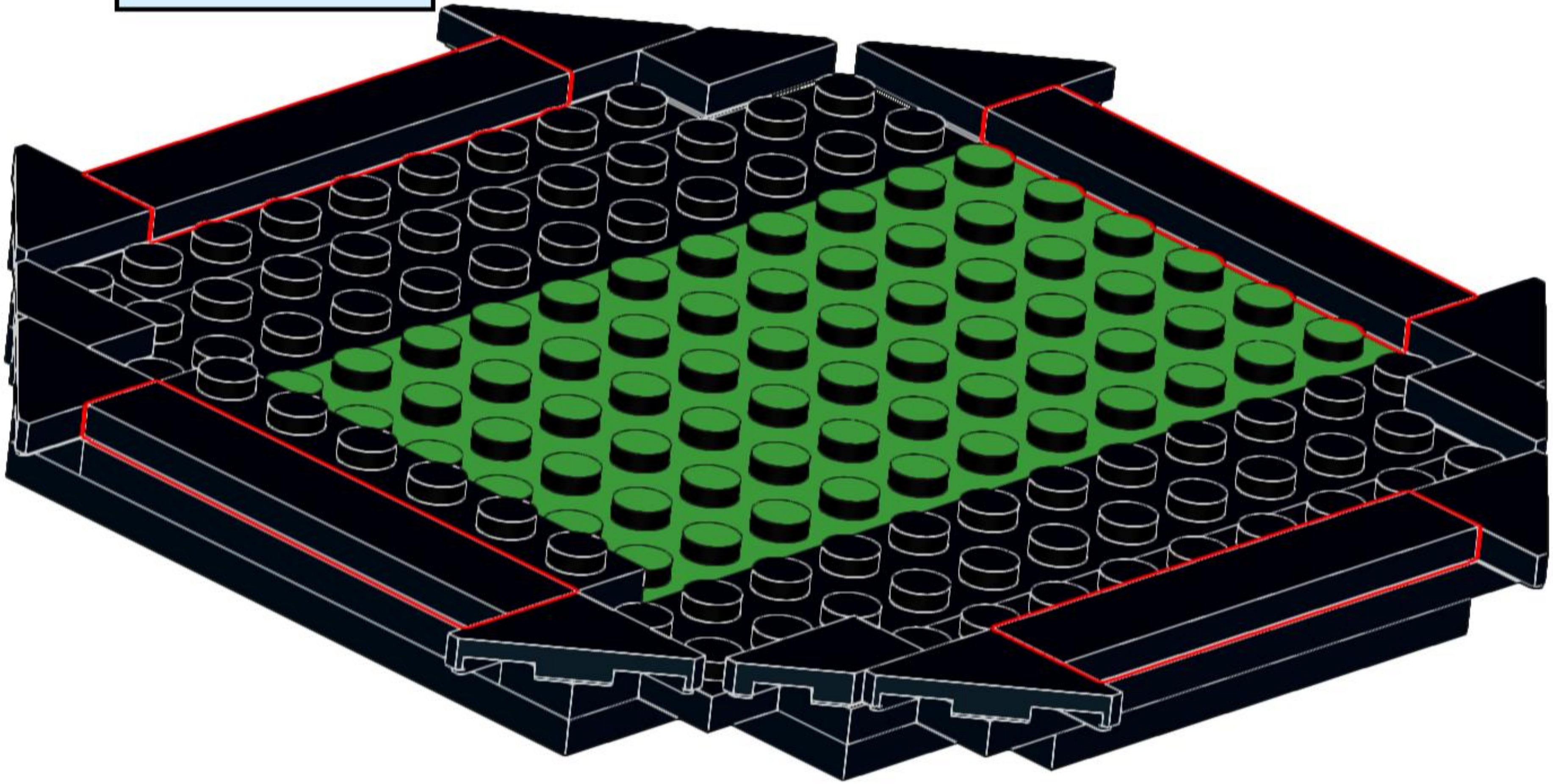

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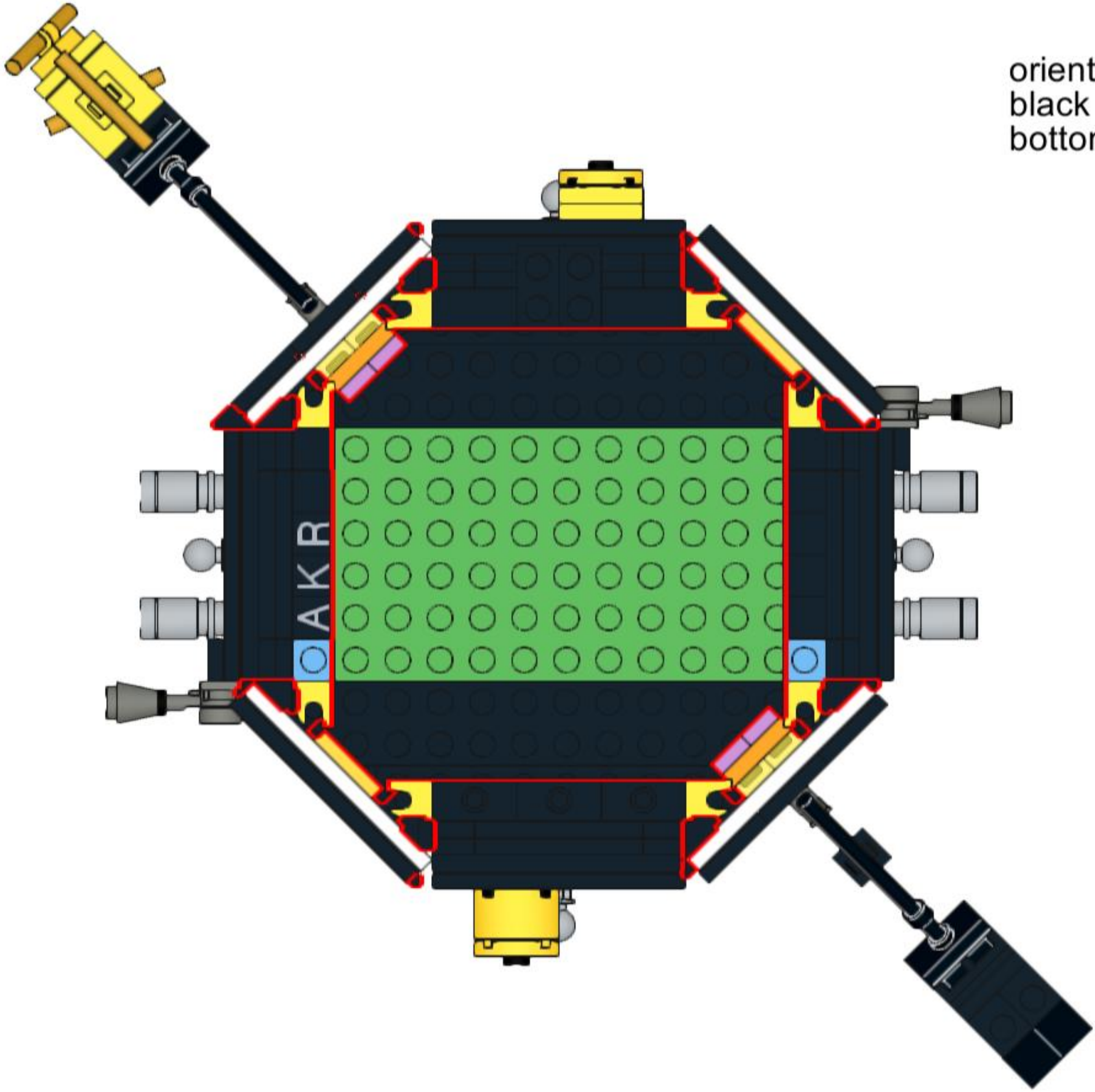
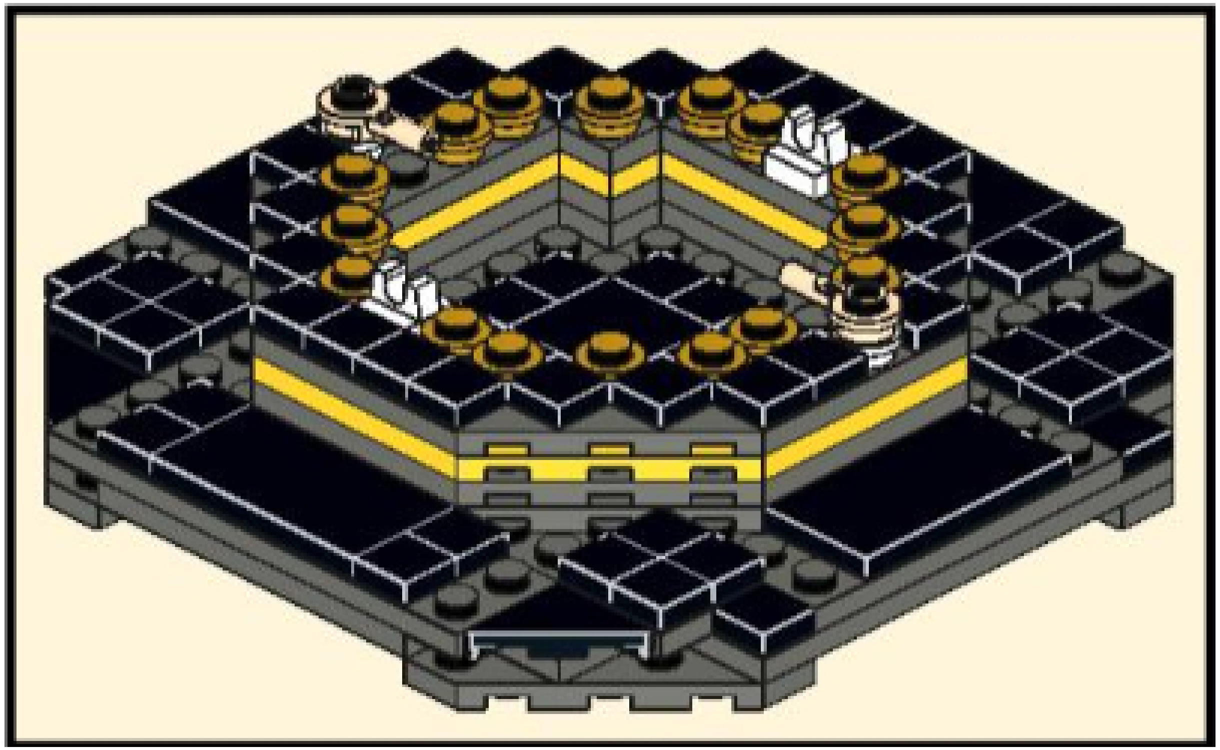


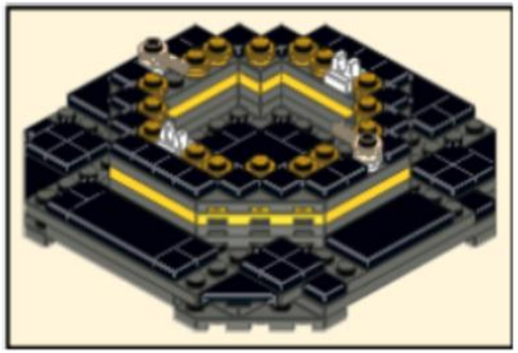
orient the floor so the exposed
black 1x6 is attatched to the
bottom of the AKR panel

2x
For Model 2

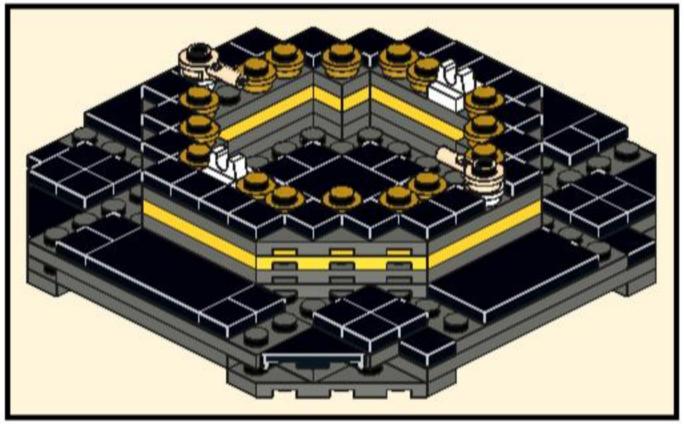
98

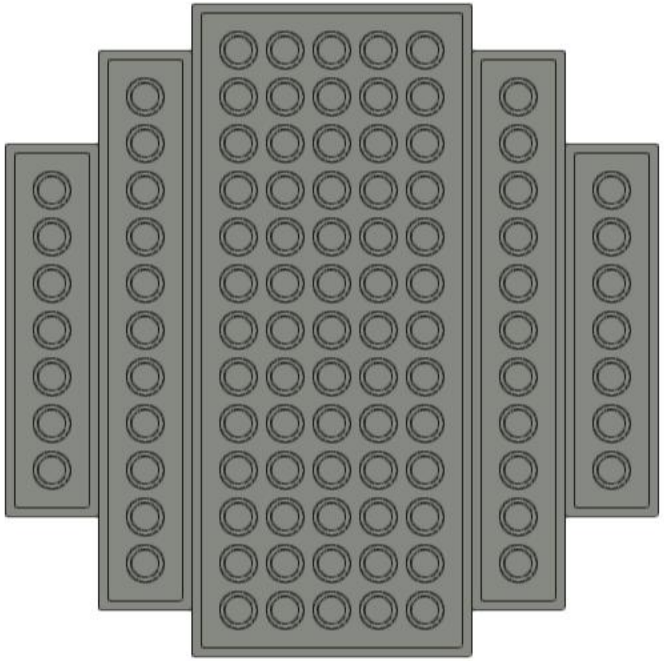


Z-deck

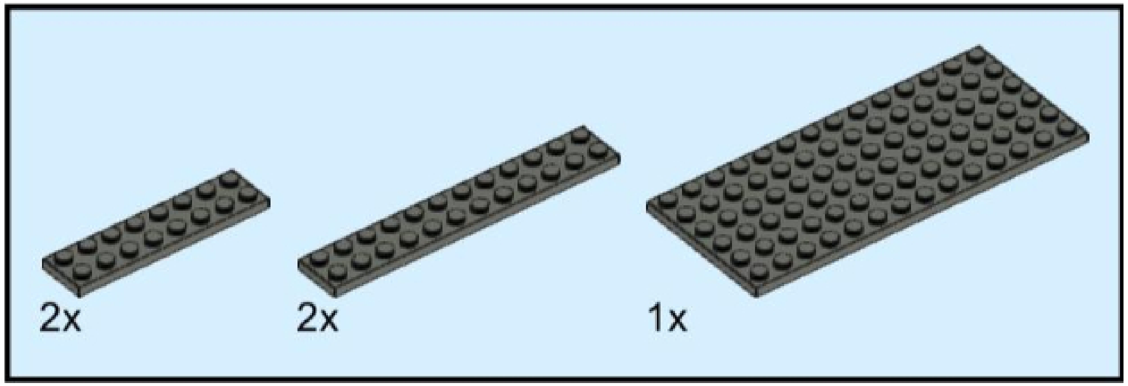


99

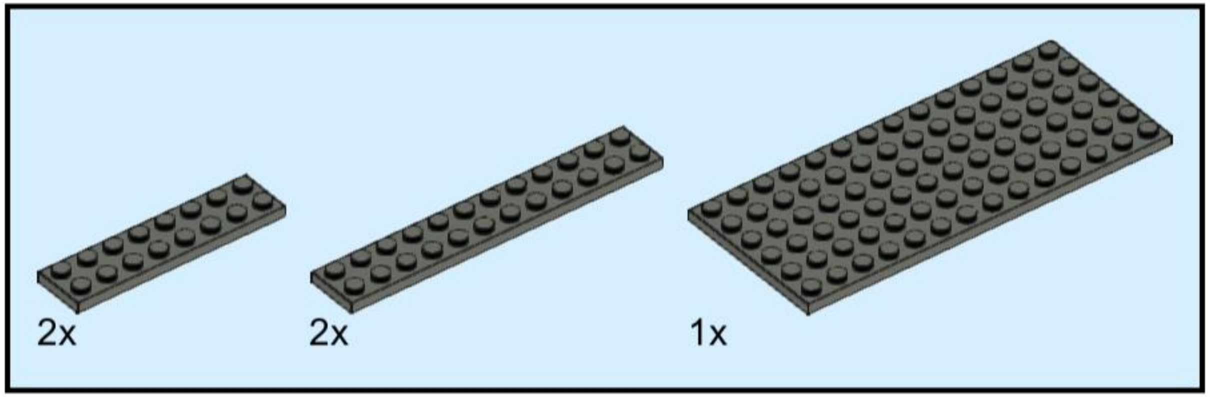


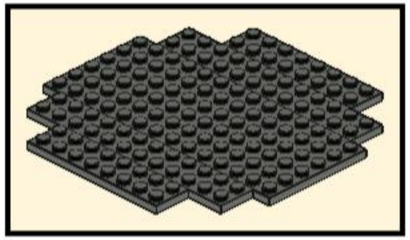


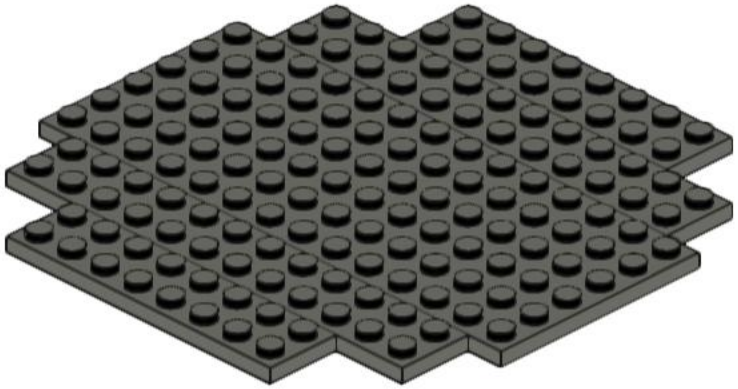
The pieces will not hold together
(as they are side by side) until step
100-101. Make the same shape twice,
rotate one of them 90 degrees, and
snap on top of the other, as shown in
step 101.



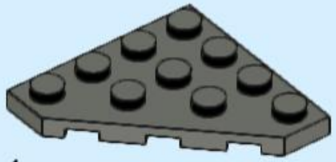
100



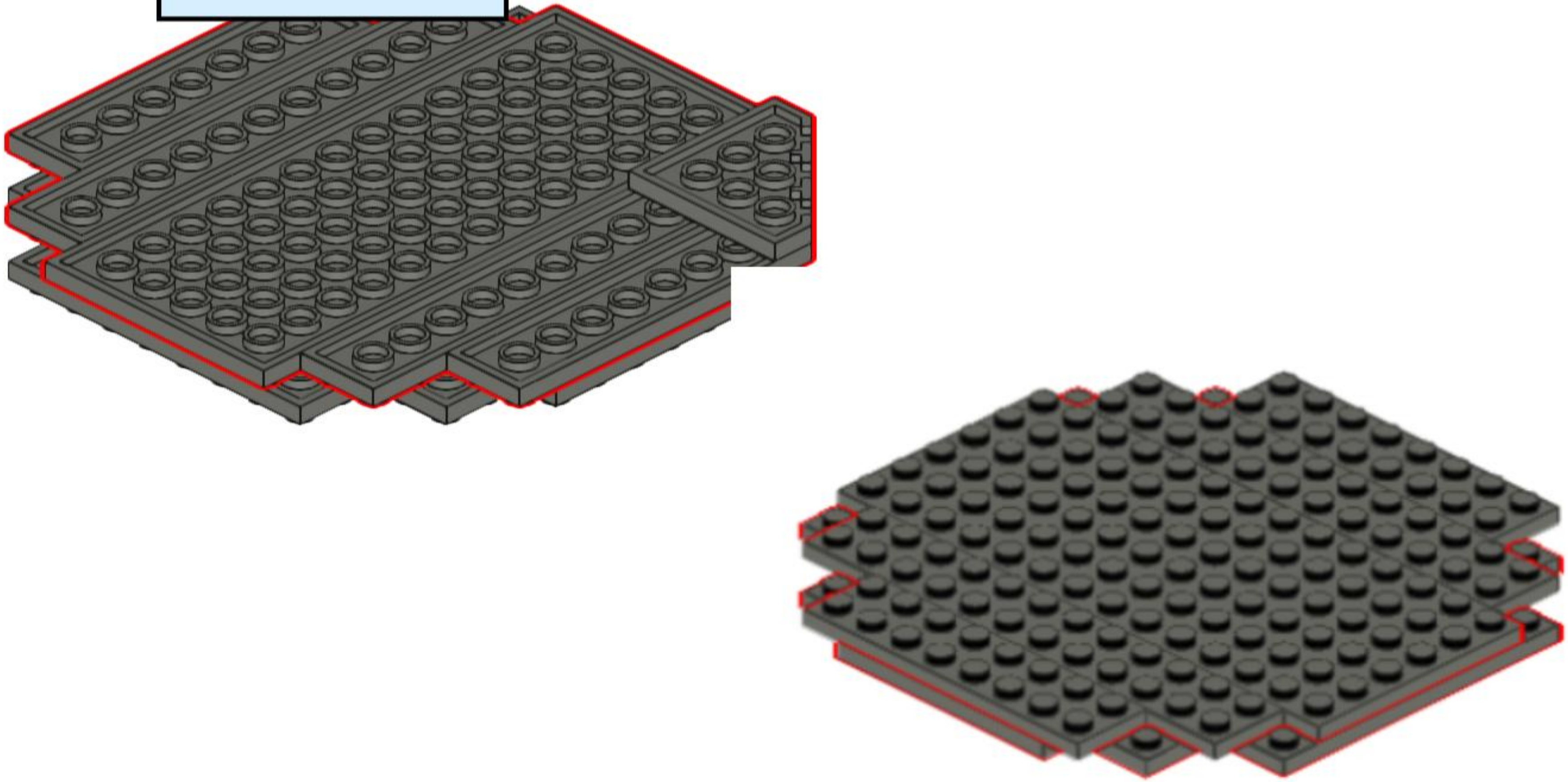




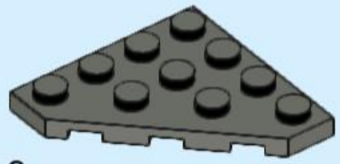
101

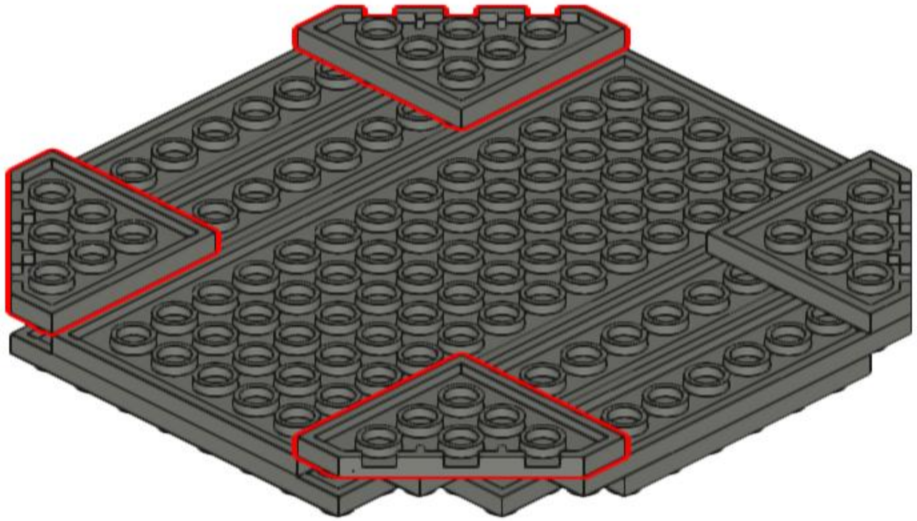


1x

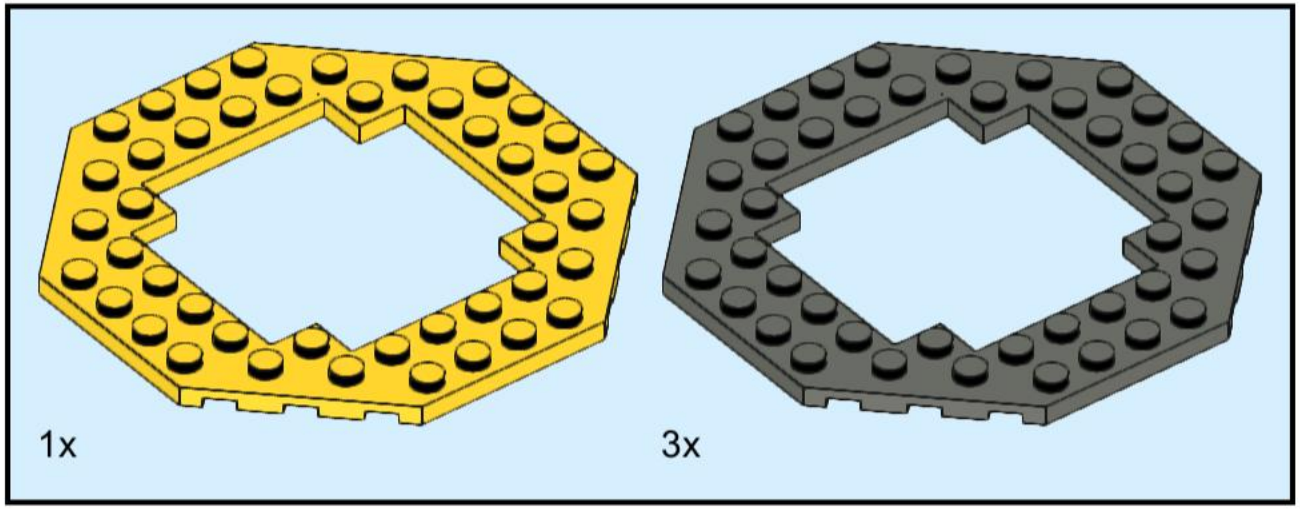


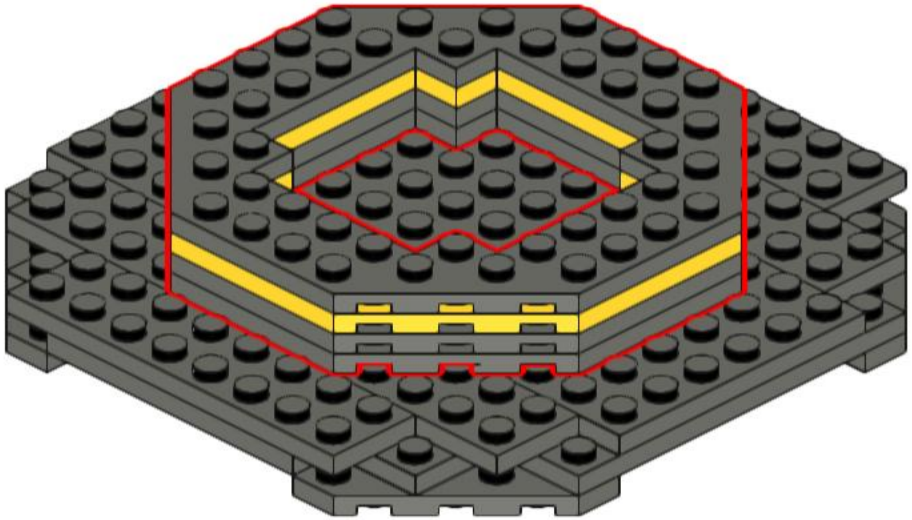
102


3x

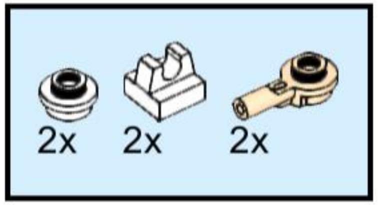


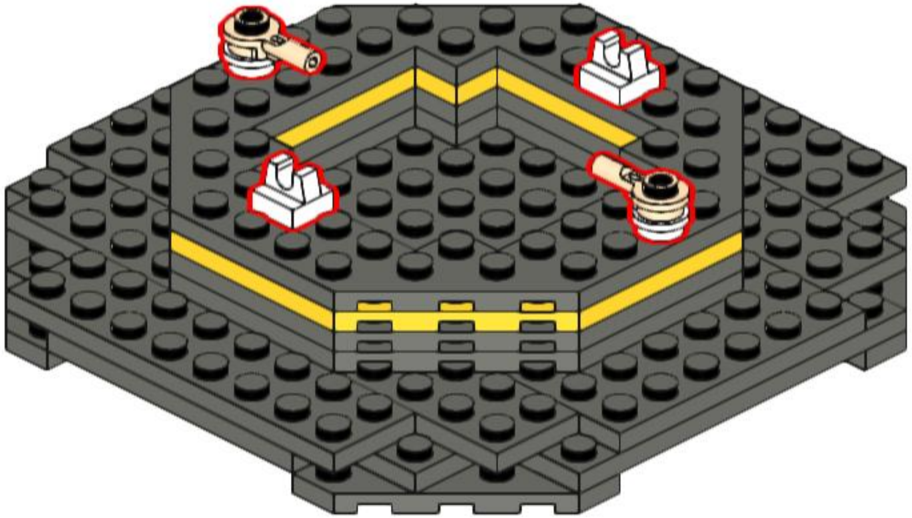
103



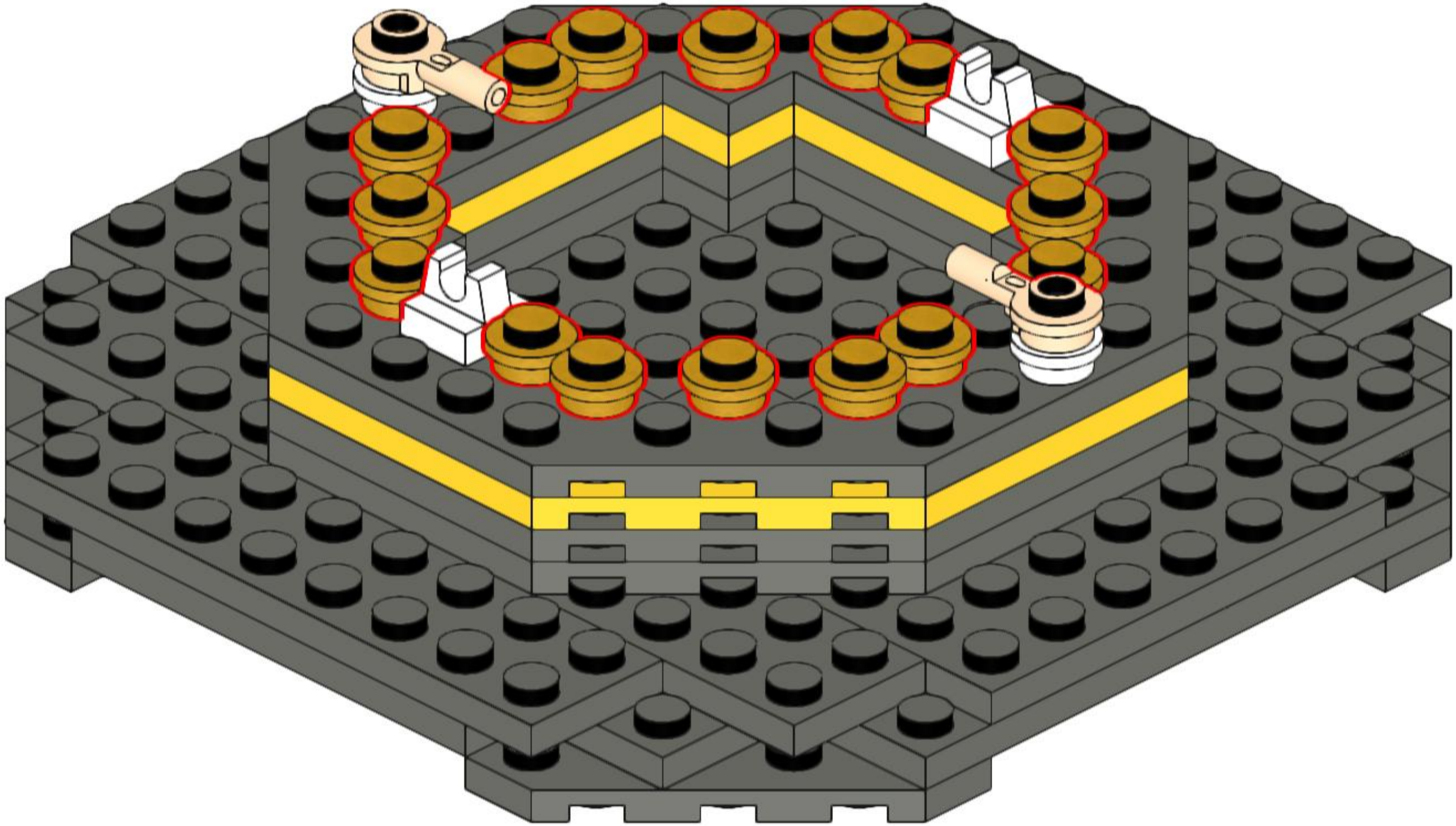


104

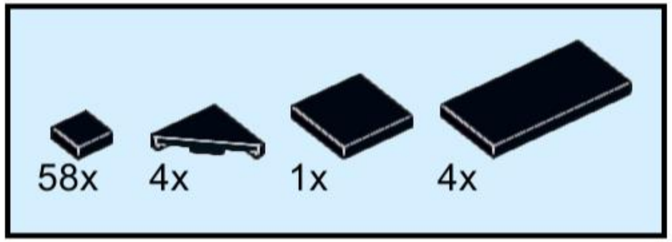


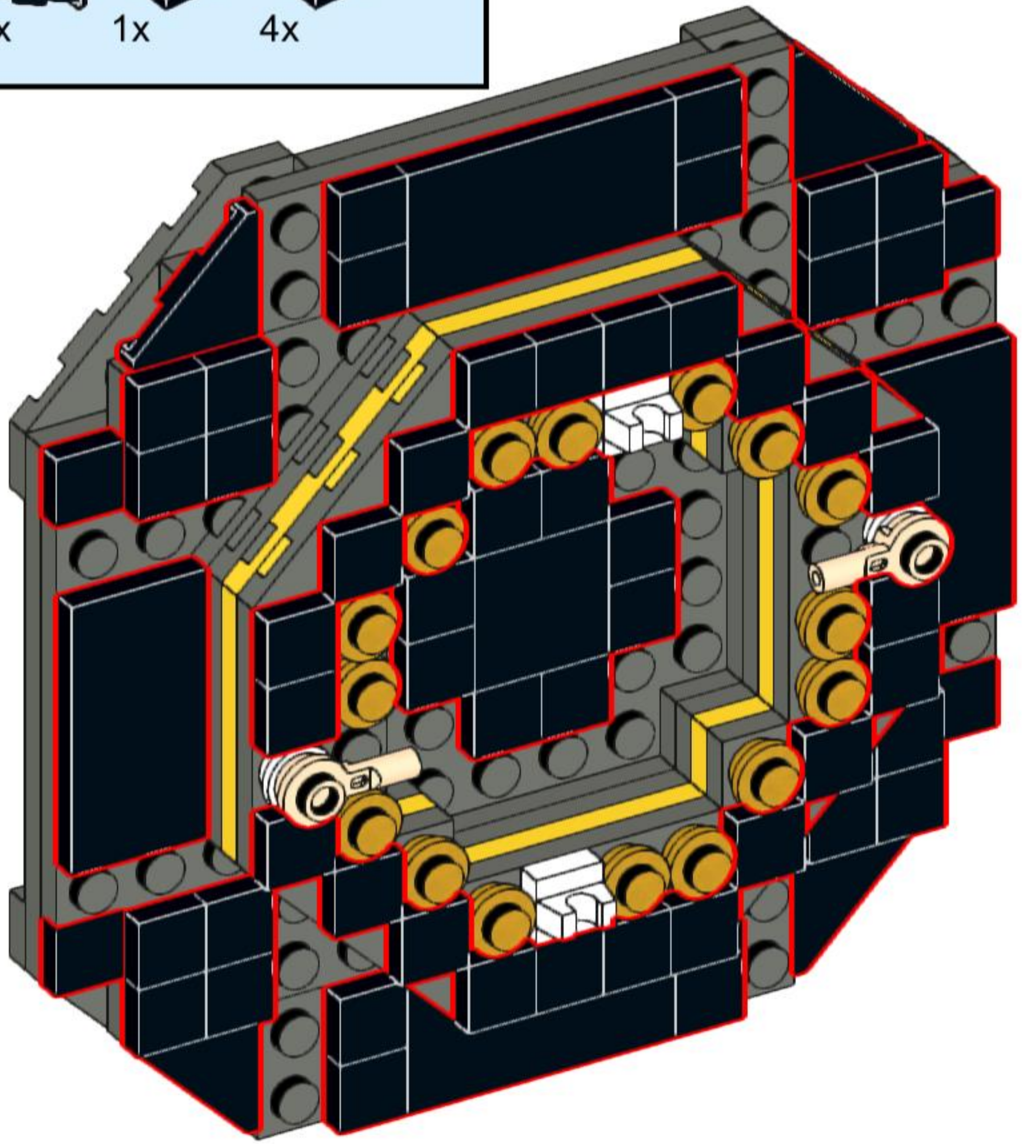


105



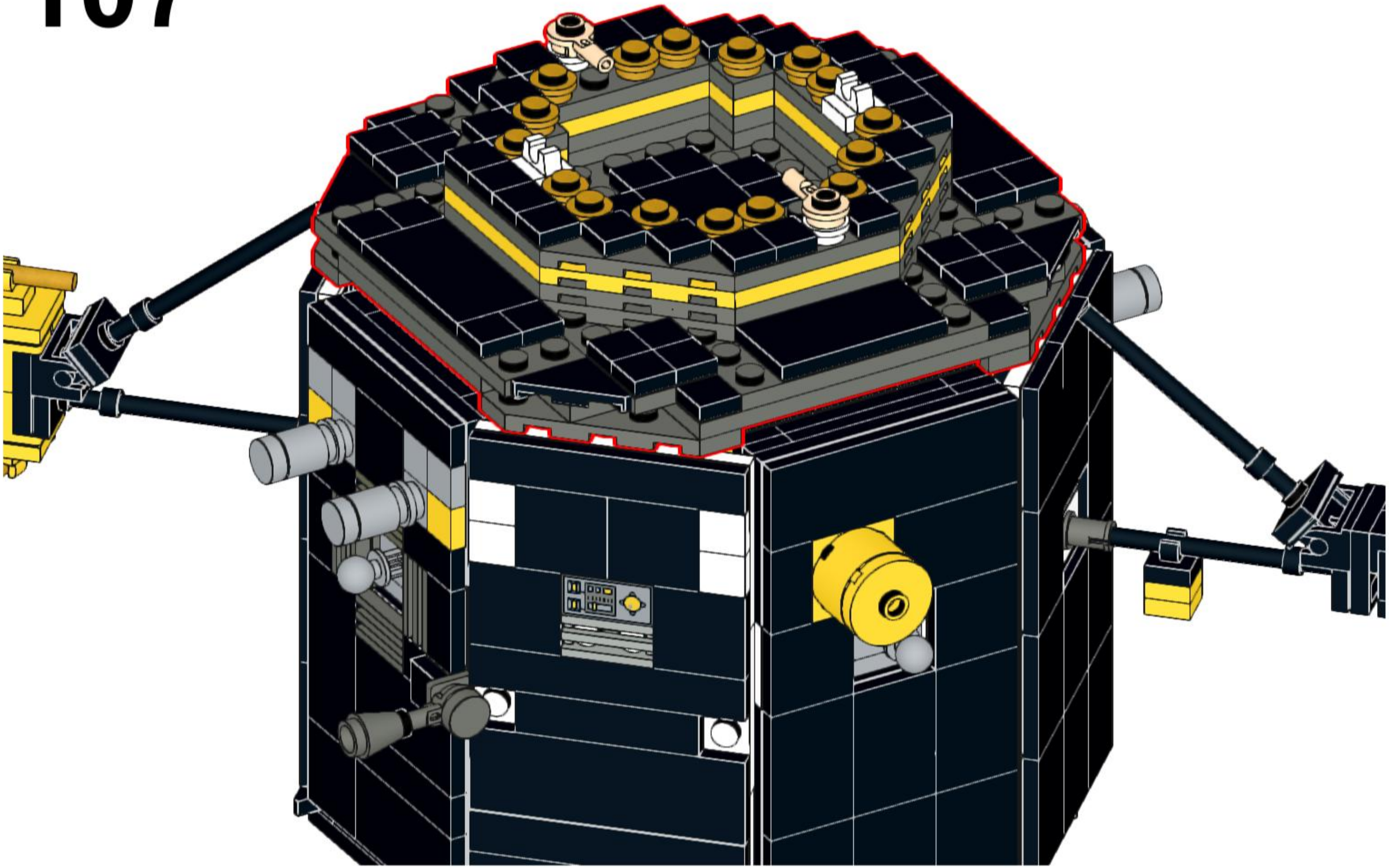
106





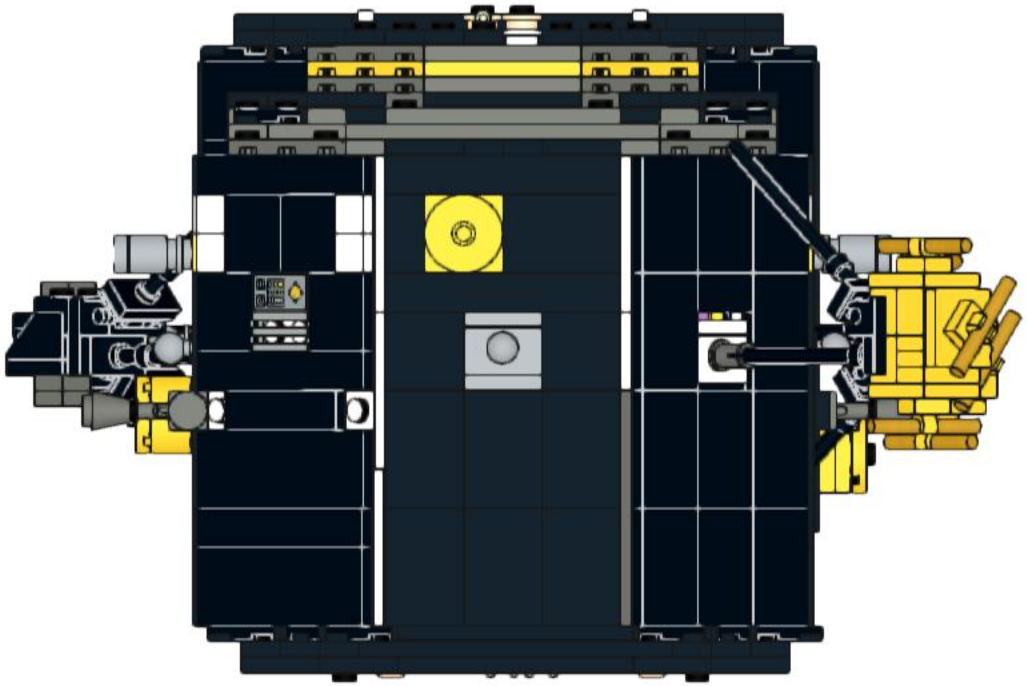
2x
For Model 2

107

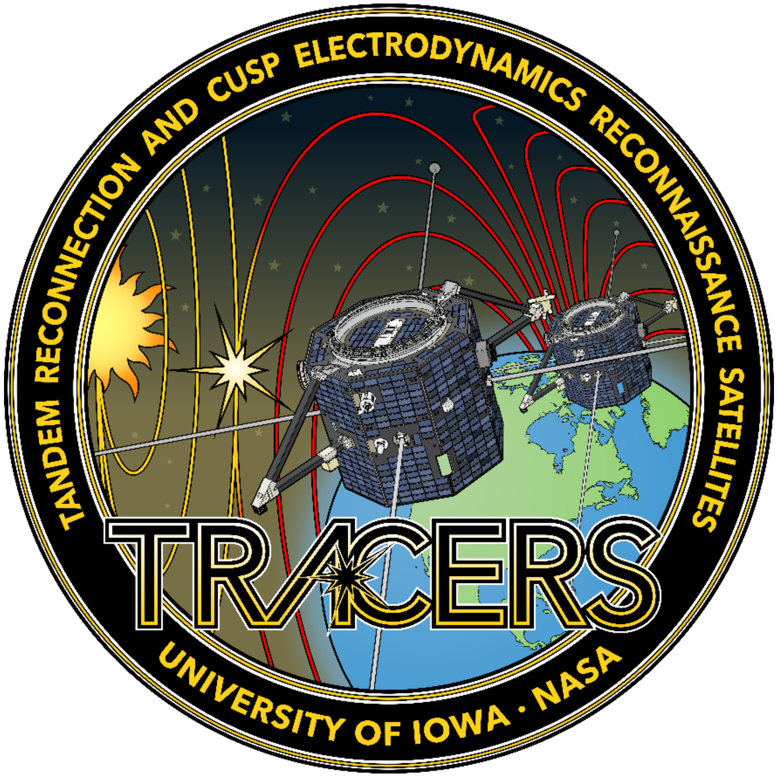


108

Snap together the two sattelites to complete the model. Rotate the hexagon on one of the roofs so the allignment of the two snapped together is correct.



This is the tracers launch configuration. Once the satellites reach orbit, they will disconnect and properly align themselves, the EFI stacer booms will extend, and TRACERS scientists will start unlocking the secrets in Earth's magnetic field.



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This model was designed in 2024-2025 on BrickLink Studio software, a free, open use, all-encompassing software for designing and assembling Lego sets, with many features similar to other 3D modeling software and a handy price estimation tool. This model was designed for the TRACERS team at the University of Iowa. The model was designed, instructions written, built once, re-designed, and built a couple times more by University of Iowa Mechanical Engineering Student Ava Reed. This set is for all who have worked hard on TRACERS. This set is to inspire the future astrophysicists learning about space for the first time. This set is for Craig Kletzing, whose questions remain the foundation of the TRACERS mission.

Thanks for building! - AKR