

The **H-MAC** Heavy Metal Articulating Chassis Construction Guide



The Heavy Metal Chassis is constructed with two identical drive modules built using 10 mechanical sub-assemblies. The drive modules are integrated into a single chassis using a steel truss axle.

Sub Assemblies

1. Bulkhead Assembly	Average assembly time: 2 student about 10-15 minutes
2. Bulkhead Standoffs	Average assembly time: 2 students about 5 minutes
3. Motor and Sprocket	Average assembly time: 2 students about 5 minutes
4. Motor and Bulkhead	Average assembly time: 2 students about 10 minutes
5. Drive Axle	Average assembly time: 2 students about 10-15 minutes
6. Driven Axle	Average assembly time: 2 students about 10-15 minutes
7. Chains and Bulkheads	Average assembly time: 2 students about 15-20 minutes
8. Bulkhead and Chassis	Average assembly time: 2 students about 5 minutes
9. Wheels and Tires	Average assembly time: 2 students about 15-20 minutes
10. Control Box	Average assembly time: 2 students about 5-10 minutes

Total chassis construction time for two students: 1-1/2 - 2 Hours

Necessary Tools

Safety Glasses	3/8 "Wrench
Phillips Head Screwdriver #1 pt. And #2 pt.	Wire Strippers and Crimpers
Allen Wrench or Hex Key (sizes .050, 1/16, 5/64, 3/32, and 1/8)	6" or 8" Smooth File
Dial Calipers or Scale Marked in 1/32" Increments	

Materials

Structural/ Mechanical

Qty

- | | |
|----|---|
| 2 | 3/32" x 1.2" Round End Key |
| 2 | 3/32" x 0.60" Round End Key |
| 16 | 5/16" Diameter x 2" long x #10-32 Aluminum Standoffs |
| 12 | 3/8" I.D. Flanged Bearings |
| 4 | 3/8" Shaft Collars with Set Screws |
| 1 | Loctite™ 680 |
| 2 | 16 Tooth, 25 Pitch Steel Sprockets w 0.250" Bore and 2 Set Screws |
| 6 | 20 Tooth, 25 Pitch Steel Sprockets w 0.375" Bore and 2 Set Screws |
| 12 | #8-32 x 1/8" Set Screw (For Sprocket) |
| 8 | 3/8" "E" Clip |
| 2 | 25 Pitch, 100 Link Assembled Chain |
| 2 | 25 Pitch, 42 Link Assembled Chain |
| 4 | Bulkhead Plates |
| 4 | 7" Diameter High Lug Tires |
| 4 | Wheel Rims |
| 1 | 10-1/2" x 3/8" Diameter Axle |
| 4 | 5" x 3/8" Diameter Steel Axle |
| 1 | Pre-Drilled Project Box w/Cover |
| 4 | 5/16" Bore Threaded Hex Adapter |

Hardware

Qty

- | | |
|----|--|
| 80 | #10-32 x 3/8" Phillip Machine Screws |
| 24 | #10-32 Nylon Lock nuts |
| 24 | #10 Flat Washers |
| 56 | #10 Lock Washers |
| 4 | #10-24 x 1/8" Set Screw |
| 4 | M12 Flat Washer |
| 4 | M12 Jamb Nut |
| 30 | 3/8" Bore x 5/8" OD x 0.125" Nylon Spacer Washers |
| 8 | 3/8" Bore x 5/8" OD x 0.0625" Nylon Spacer Washers |
| 4 | 3/8" Bore x 5/8" OD x 0.625" Nylon Spacer Washers |

Electrical

Qty

- | | |
|---|--|
| 1 | SPST Toggle Switch |
| 2 | Gearhead Motor (12 Volt, 65:1 Standard) |

Note: Maximize the educational benefit to the students and minimize the time on task by allowing the students time to handle and identify all the HMC component. Review this document completely before beginning the assembly of the H-MAC.

** Kits are shipped with a variety of 0.062" or 0.125" thick spacer washers. Use them to achieve the necessary axle spacing as describe in the text.*

Assembly 1

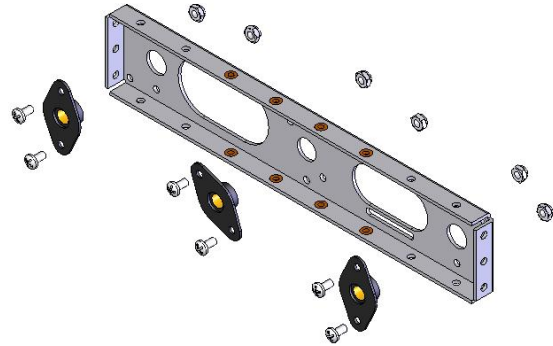
Bulkheads

(4 Assemblies required) (Multiply listed quantities x 4)
(Average assembly time: 2 students about 10-15 minutes)

Components and Tools to Make 1 Assembly

Qty.	Description
6	#10-32 Nylon Locking Nuts
6	#10-32 x 3/8" PH Machine Screws
1	Bulkhead Plate
3	3/8" I.D. Flanged Bearings
1	3/8" Combination Wrench (not shown)
1	#2 Phillip Head Screwdriver (not shown)

4 Assemblies Required

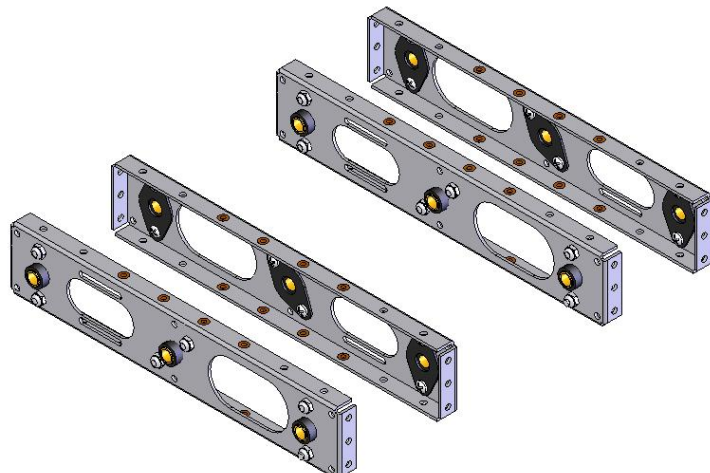


Procedure

1. Place the 3/8" I.D. flanged bearings into the mounting holes on the bulkhead as shown in the illustration on the right. Place the bearings through the bulkhead plates from the inside, to the outside as illustrated.
2. Attach the flanged bearings using (2) #10-32 x 3/8" Phillips head machine screws, and (2) #10-32 nylon locking nuts. Secure the nuts firmly onto the machine screws using a 3/8" wrench and a #2 Phillip head screwdriver. The approximate torque (Tightening) specification is about 22 -26 inch pounds. If this specification is not familiar to you then take a moment to research torque specifications online or ask someone who knows.



3. Repeat the procedure and create 4 identical assemblies. Note the orientation of the assemblies. They are configured as two pairs of bulkheads. The interior bulkheads are oriented in such a way that the slotted openings are at opposite ends. This is necessary to accommodate the motor placement. While it is not necessary to reverse the outer bulkheads, it is highly advisable as it makes adjusting the motor/drive chain easier.



Assembly 2

Bulkhead Standoffs

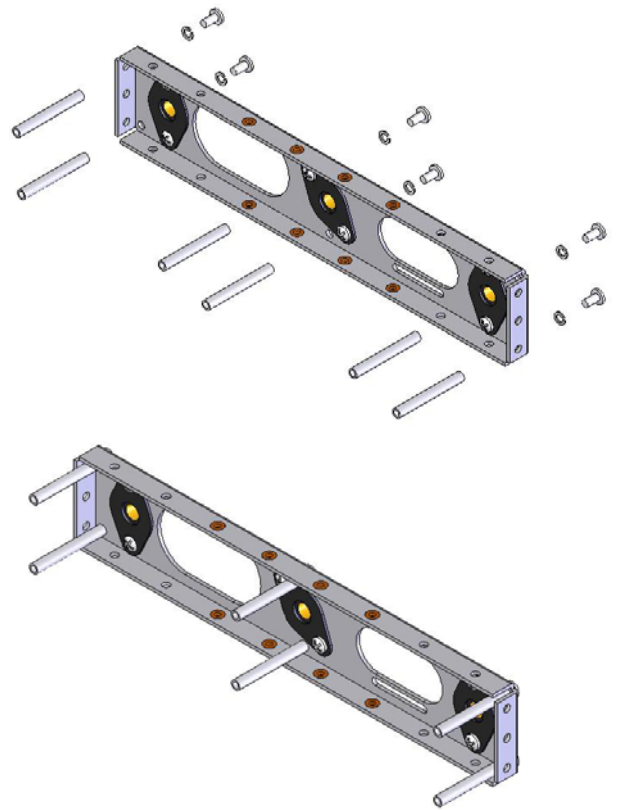
(2 Assemblies required) (Multiply listed quantities x 2)
(Average assembly time: 2 students about 5 minutes)

Components and Tools for 1 Assembly

Qty.	Description
6	5/16" Diameter x 2" long x #10-32 Aluminum Standoffs
6	#10-32 x 3/8" PH Machine Screw
6	#10 Lock Washer

Procedure

1. Fasten the 6 aluminum standoffs to the inside of the bulkhead as shown on the right.
2. Create (2) Assemblies of this type.



Assembly 3

Motor and Sprocket

(2 Assemblies required) (Multiply listed quantities x 2)
(Average assembly time: 2 students about 5 minutes)

Components and Tools for 1 Assembly

Qty.	Description
1	Gearhead Motor (12 Volt, 65:1 Standard)
1	25 Pitch Sprockets w 0.250" Bore and 2 Set Screws

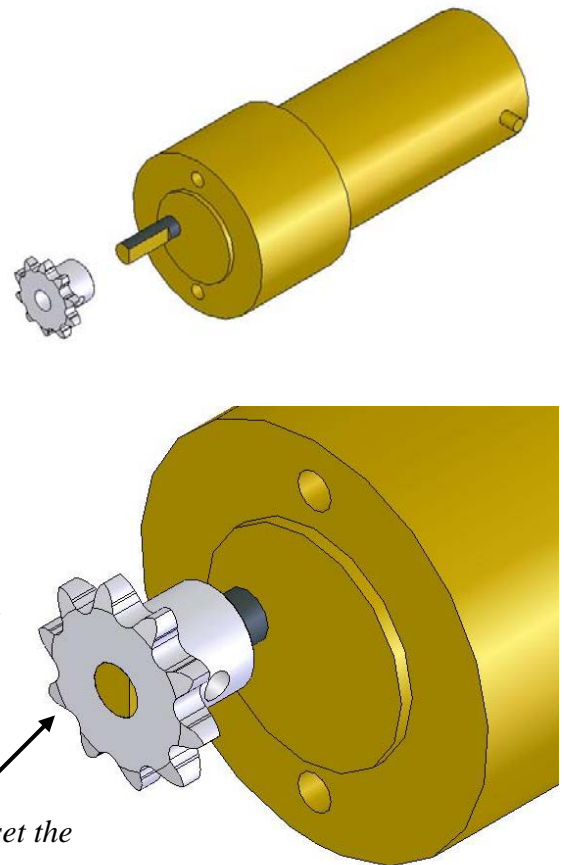
Note: 16 Tooth sprockets are standard. The image(s) Below are shown with optional 10 tooth sprocket.

Procedure

1. Fasten the (16) tooth sprocket to the end of the motor shaft as shown in the illustration on the right. Align the face of the sprocket, flush with the end of the motor shaft. Secure the sprocket in place by tightening the set screw on the flat of the motor shaft.

Sprocket face is flush with motor shaft end

Note: After the final assembly it is advisable to reset the set screws using red Loctite™



Assembly 4

Motor and Bulkhead

(2 Assemblies required) (Multiply listed quantities x 2)
(Average assembly time: 2 students about 10 minutes)

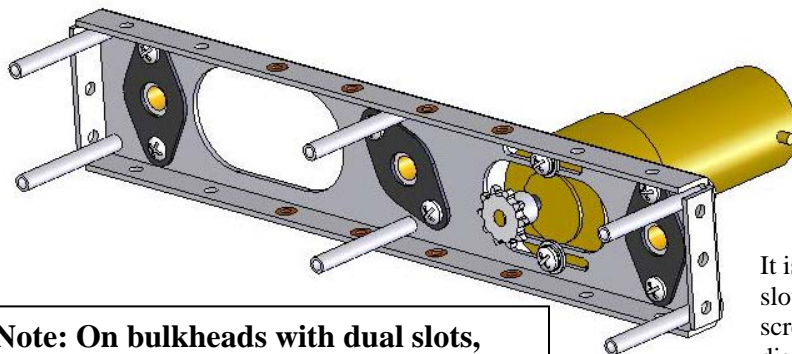
Components and Tools for 1 Assembly

Qty.	Description
1	Gearhead Motor and Sprocket Assembly
2	#10-32 x 3/8" PH Machine Screw
2	#10 Lock Washers
2	#10 Flat Washers

Procedure

1. Fasten the gearhead motor and sprocket assembly to the bulkhead. The #10-32 machine screws pass through the slots in the bulkhead. The motor pilot slides along the large oval slot. Thread the screws and washers through the bulkhead and into the motor but do not tighten them at this time. The motor assembly should slide easily along the slots.

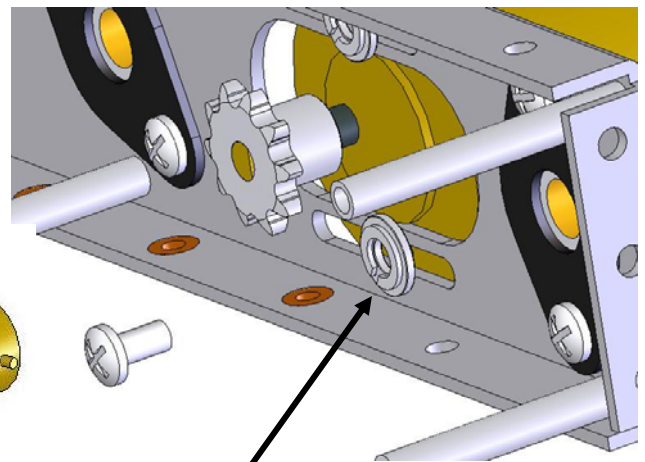
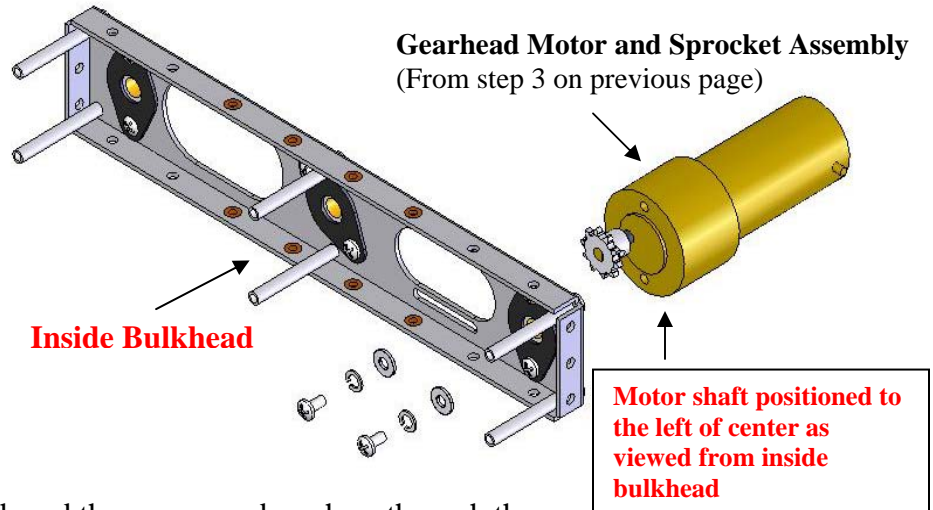
The completed assembly is shown below. 2 Assemblies are required.



Note: On bulkheads with dual slots, position the motor mounting screws in the slot nearest the center of the bulkhead and in the orientation shown on the following page

Note: If the bulkhead has dual slots; position the motor mounting screws in the slot nearest the center of the bulkhead and in the orientation shown below.

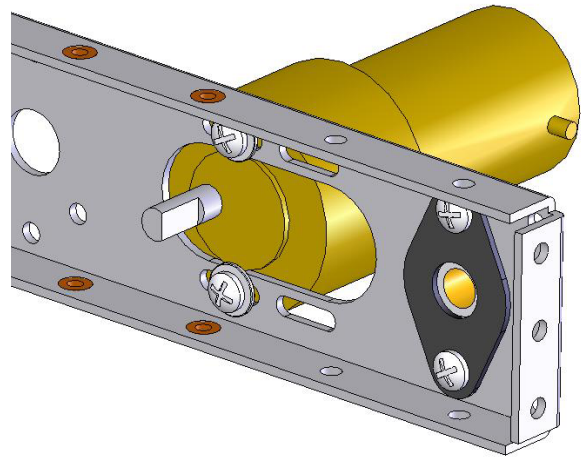
Gearhead Motor and Sprocket Assembly
(From step 3 on previous page)



It is important that the flat washers be positioned against the slots and that the locking washers be positioned between the screw head and the flat washer. This arrangement will distribute the clamping force needed to hold the motor in place as well as protect the fasteners from vibrating loose.

Assembly 4 continued

The illustration on the right shows the correct orientation of the motor with respect to the dual slotted bulkheads.

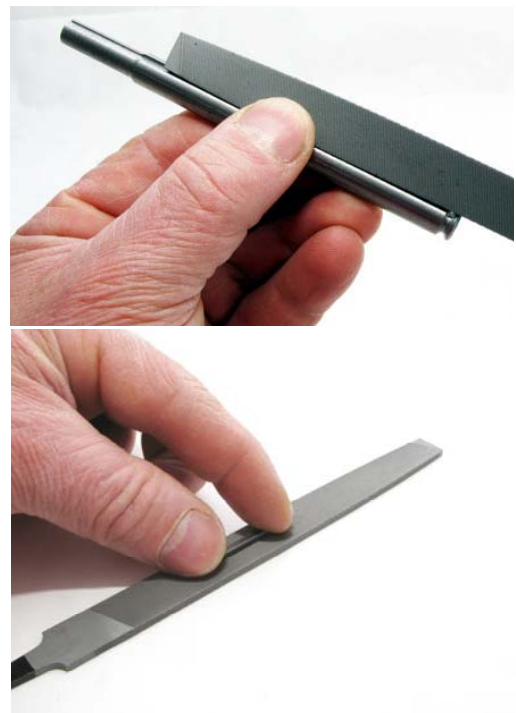


Assembly 5 Drive Axle

(2 Assemblies required) (Multiply listed quantities x 2)
(Average assembly time: 2 students about 10-15 minutes)

Components and Tools for Assembly

Qty.	Description
1	5" x 3/8" Diameter Steel Axle
1	5/16" Bore Threaded Hex Adapter
1	#10-24 x 1/8" Set Screw (For threaded. Hex adapter)
1	M12 Flat Washer
1	M12 Jamb Nut
10	3/8" Bore x 5/8" OD x 0.0625" Nylon Spacer Washers
1	3/32" x 1.2" Round Ended Key Stock
2	20 Tooth, 25 Pitch Steel Sprockets
4	#8-32 x 1/8" Set Screw (For Sprocket)
1	3/8" "E" Clip

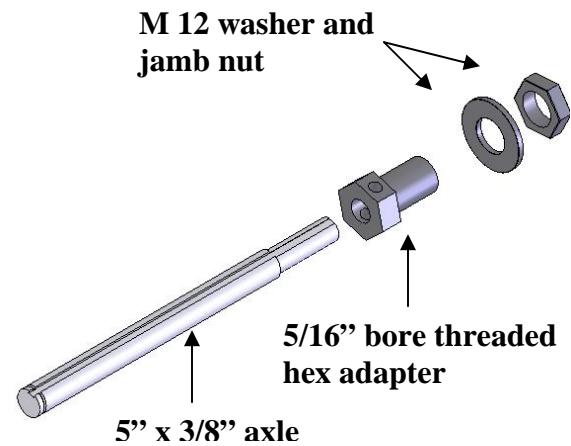


Procedure

1. Use a 6" or 8" smooth flat file to break the edges of the key slot along the entire length of the 3/8" dia. x 5" long machined axle. This will help ensure there are no burred metal edges on the axle key slot. This will allow the key stock to slide smoothly in the axle key slot. If necessary, rub the key stock along the file on two sides to remove a few 0.0001" to allow for a slip fit in the key way. This only needs to be done the first time the axle is assembled. Take the time to fit the key stock so that it slides smoothly in the axle key slot.

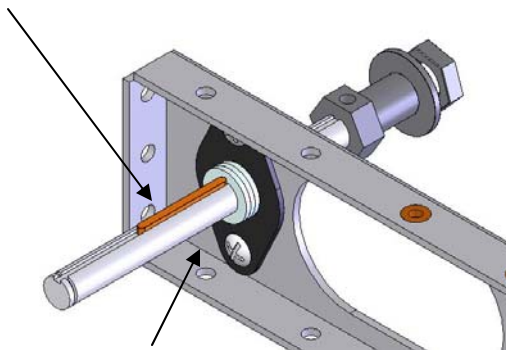
Assembly 5 continued

- Secure the 5/16" bore threaded hex adapter onto the stepped down end of the 3/8" dia. x 5" axle. Make this a permanent connection. Use Loctite™ 680 to join the hex adapter to the axle. Hold the assembly together with the set screw fastened against the flat of the axle key groove.



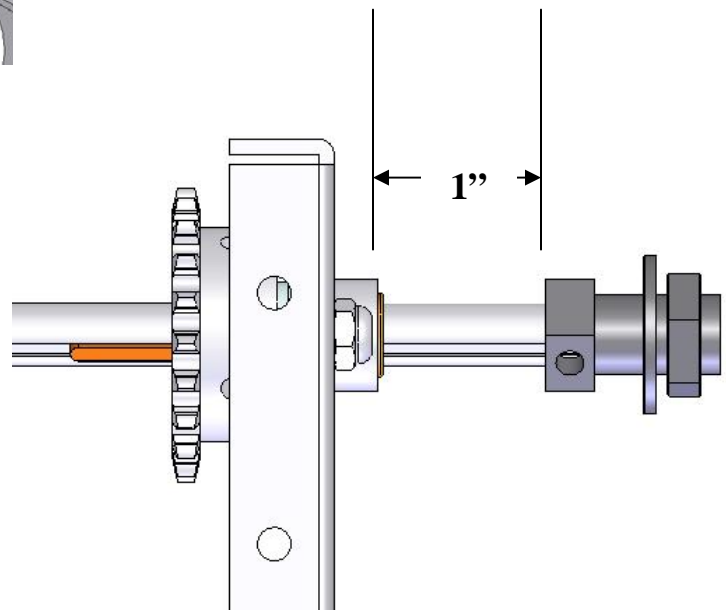
- Slide the 3/8" axle into the flanged bearing on the (non slotted) end of the bulkhead. Refer to illustration on the top of page 6.
- Slide (3) three 3/8"x 0.0625" nylon spacer washers onto the axle.
- Slide the 3/32" x 1.2" round end key stock onto the axle key way. See illustration below left.

3/32" x 1.2" Key



3 Nylon Spacers

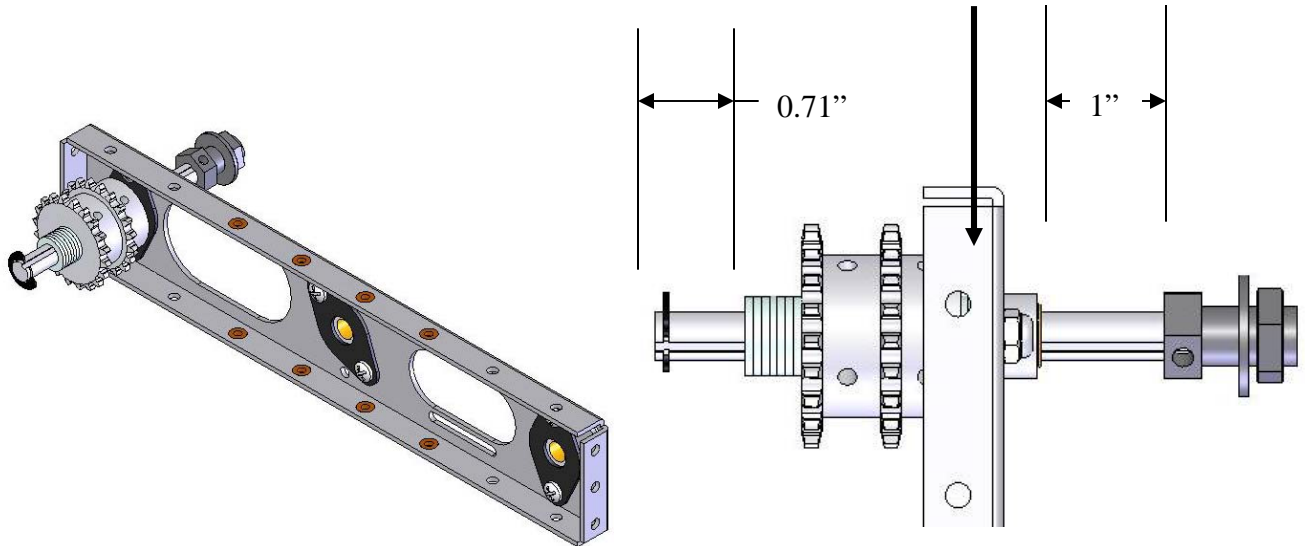
- Slide a 20 tooth sprocket onto the axle and coincident with the nylon spacer washer.
- With the sprocket pressed against the nylon washer, position the axle assembly at the distance illustrated in the graphic below. Gently tighten the set screws on the sprocket.



- With the axle positioned correctly and the 20 tooth sprocket tightened in position, slide the second 20 tooth sprocket onto the shaft, adjacent to the first one.
- Slide 7 nylon washers onto the shaft. Snap the "E" clip onto the axle end groove to hold the assembly together.
- See illustrations on the next page for clarification.

Assembly 5 continued

Remember to position the face of the sprocket hub adjacent to the three (3) spacer washers between the sprocket and the flange



Completed Drive Axle Assembly

Complete the preliminary set up of the drive axle assembly by checking that the axle, threaded hex adapter, sprockets and spacer washers can be positioned at the distances shown above. These measurements are preliminary and adjustments will need to be made during final assembly

Assembly 6 Driven Axle

(2 Assemblies required) (Multiply listed quantities x 2)
(Average assembly time: 2 students about 10-15 minutes)

Components and Tools for 1Assembly

Qty.	Description
1	5" x 3/8" Diameter Steel Axle
1	5/16" Bore Threaded Hex Adapter
1	#10-24 x 1/8" Set Screw (For threaded. Hex adapter)
1	M12 Flat Washer
1	M12 Jamb Nut
20	3/8" Bore x 5/8" OD x 0.0625" Nylon Spacer Washers
2	3/8" Bore x 5/8" OD x 0.625" Nylon Spacer Washers
1	3/32" x 0.60" Round Ended Key Stock
1	20 Tooth, 25 Pitch Steel Sprockets
4	#8-32 x 1/8" Set Screw (For Sprocket)
1	3/8" "E" Clip

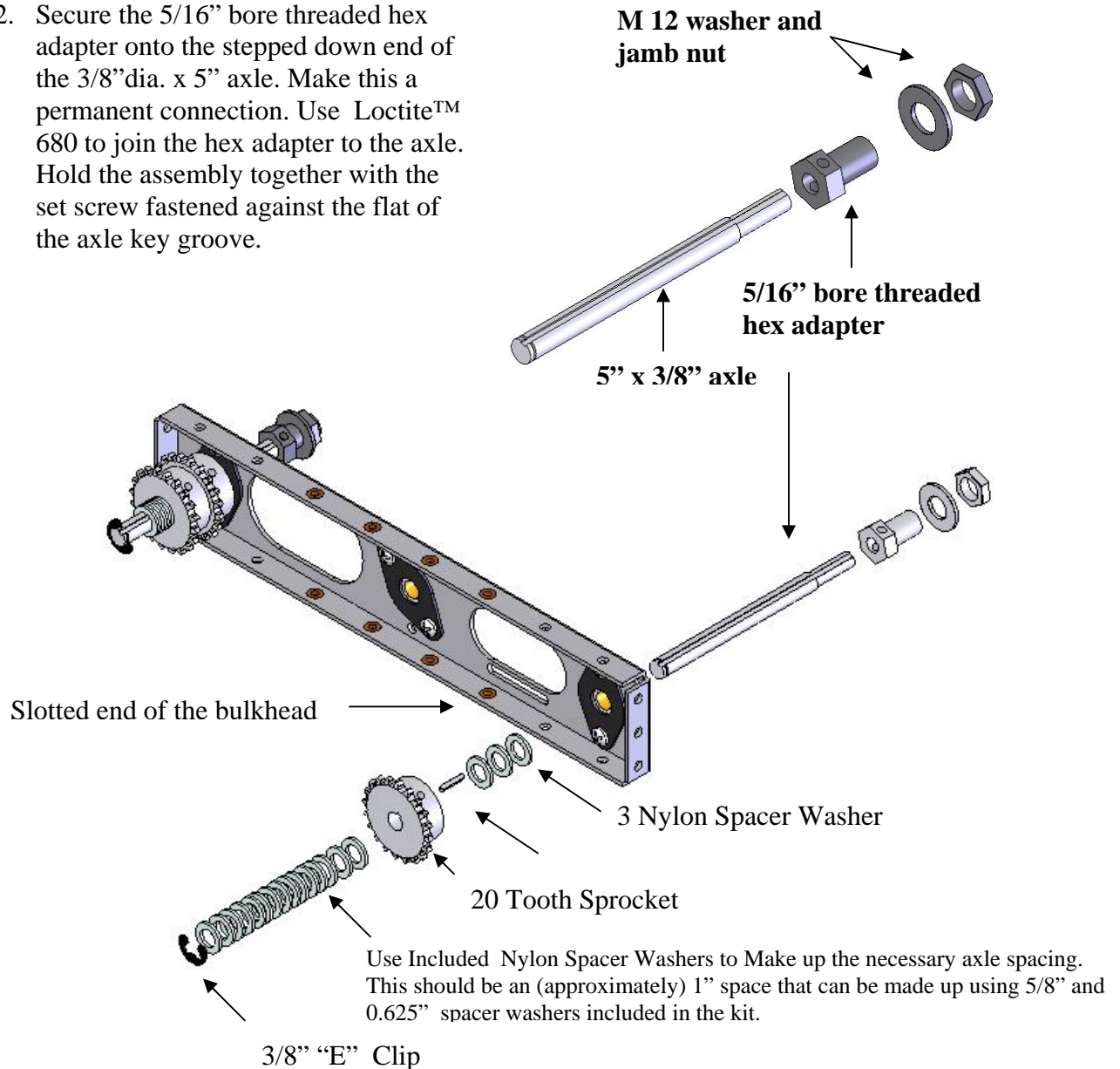


Procedure

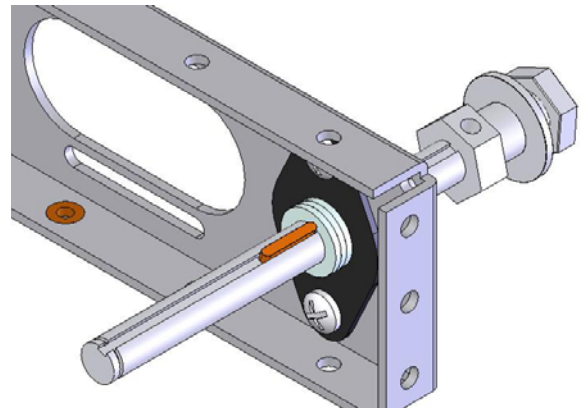
1. Use a 6" or 8" smooth flat file to break the edges of the key slot along the entire length of the 3/8" dia. x 5" long machined axle. This will help ensure there are no burred metal edges on the axle key slot, and will allow the key stock to slide smoothly in the axle key slot. If necessary, rub the key stock along the file on two sides to remove a few 0.0001" to allow for a slip fit in the key way. This only needs to be done the first time the axle is assembled.

Assembly 6 continued

- Secure the 5/16" bore threaded hex adapter onto the stepped down end of the 3/8" dia. x 5" axle. Make this a permanent connection. Use Loctite™ 680 to join the hex adapter to the axle. Hold the assembly together with the set screw fastened against the flat of the axle key groove.



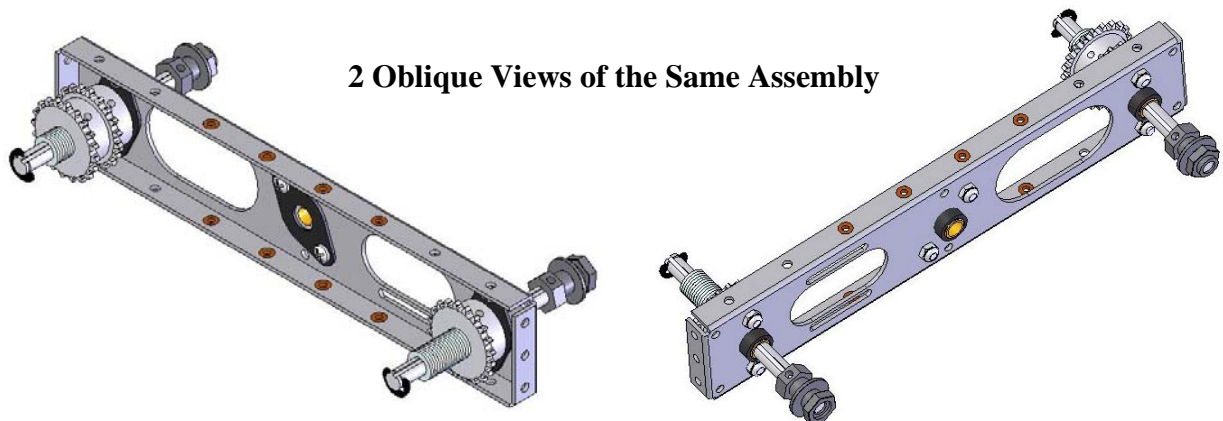
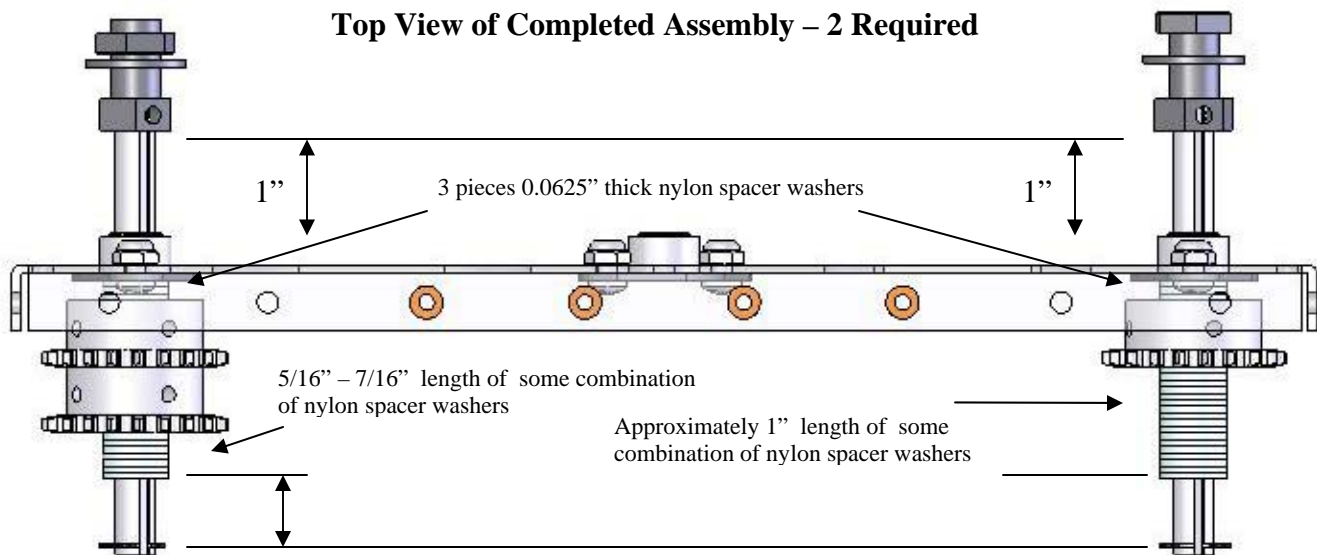
- Slide the 3/8" axle into the flanged bearing on the (slotted) end of the bulkhead. Refer to illustration on right.
- Slide (3) three 3/8"x 0.0625" nylon spacer washers onto the axle.
- Slide the 3/32" x 0.60" round end key stock onto the axle key way. See illustration on the right.



Assembly 6 continued

12. Slide a 20 tooth sprocket onto the axle and coincident with the nylon spacer washer.
13. With the sprocket pressed against the nylon washer, position the axle assembly at the distance illustrated in the graphic below. Gently tighten the set screws on the sprocket..
14. Slide the remaining (15-17), 0.0625" thick nylon washers onto the shaft. Snap the "E" clip onto the axle end groove to hold the assembly together. *Note: Depending on how the components align, may be necessary to remove or add spacer washers in order to insure that the axles turn freely, but without excessive side play.*
15. Refer to the illustration, below, for clarification.

The illustration above is a top view of a completed assembly. The bulkhead has been rendered transparent to allow viewing of all the components. Check your completed assembly against this view to ensure that all components are positioned.



Assembly 7

Fitting the Chains and Bulkheads

(2 Assemblies required) (Multiply listed quantities x 2)

(Average assembly time: 2 students about 15 - 20 minutes)

Components and Tools for 1 Assembly

Qty.	Description
1	25 Pitch, 100 Link Assembled Chain
1	25 Pitch, 42 Link Assembled Chain
1	Completed Axle and Bulkhead Assembly. (Assembly 6)
1	Completed Motor and Bulkhead Assembly. (Assembly 2)
18	#10-32 x 3/8" Phillip Head Machine Screws
18	#10 Lock Washers
8	#10 Flat Washers
1	#1 pt Phillip Head Screw Driver, 8" or Longer
1	5/64" Hex Key Wrench
2	3/8" "E" Clip

Procedure

1. Lay out the axle and bulk head assembly as shown in the picture on the right. Remove the "E" clips, the jamb nuts and the washers from the ends of the axles.
2. The axles pass through self aligning bearings. This allows the axles to have a small angular range of motion. It is necessary to take advantage of this small range of motion in order to fit the 100 link chain to the sprockets. Begin by gently bending the axles in toward each other.



3. Fit the 100 link chain around the (2) inner most sprockets.
4. After fitting the 100 link chain, wrap the 42 link chain over the second sprocket on the drive axle (Assembly 5)

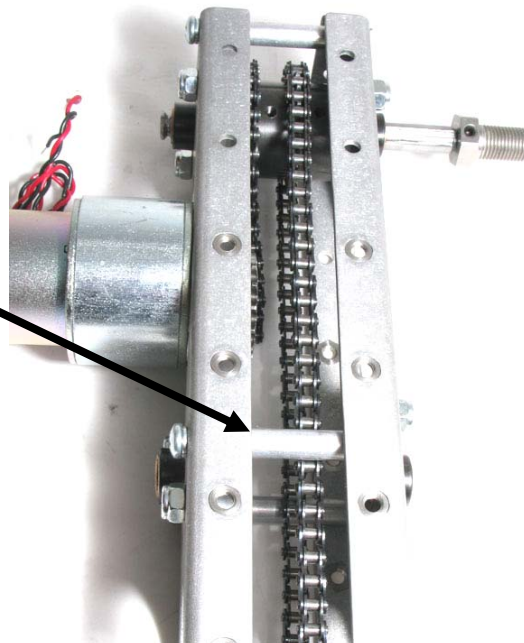
Assembly 7 continued

5. Check to see that the two assemblies are complete. Loosen all the set screws on all the sprockets. Check to see that the axles slide easily back and forth through the sprocket bores.
6. Check to see that the motor mounting screws are loose and that the motor slides easily within the slots. Slide the motor as close towards the nearest end of the bulkhead as possible.
7. Bring the axle and motor bulkhead assemblies together. Take special care to ensure that the 100 link chain fits INSIDE of the two (2) CENTER aluminum standoffs. *Note: It will be necessary to move the axles into position to align them with the bearings on the axle bulkhead.*
8. After fitting the bulkheads together, reach inside the axle bulkhead assembly to wrap the 42 link chain around the motor sprocket.



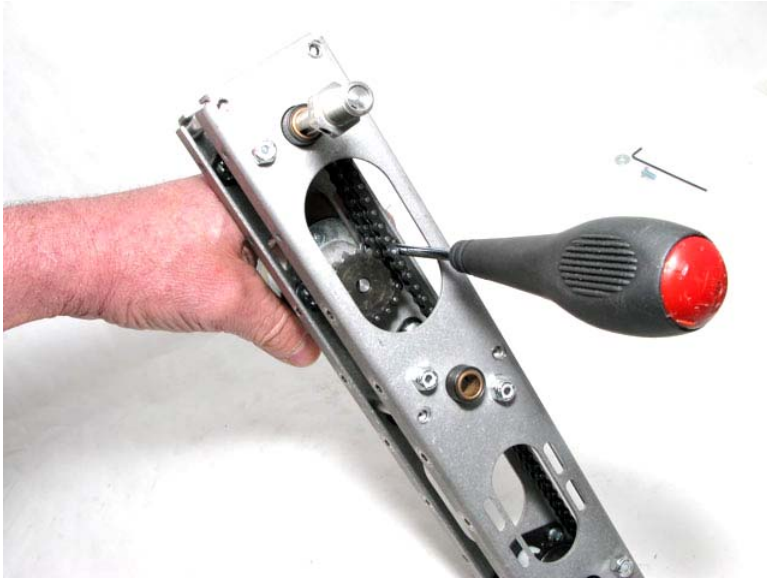
Slide the motor towards the axle in order to bring the two sprockets closer together. Wrap the chain completely around the motor sprocket

Make certain that the 100 link chain rests completely inside both of the aluminum standoffs as shown in the photograph on the right.



Assembly 7 continued

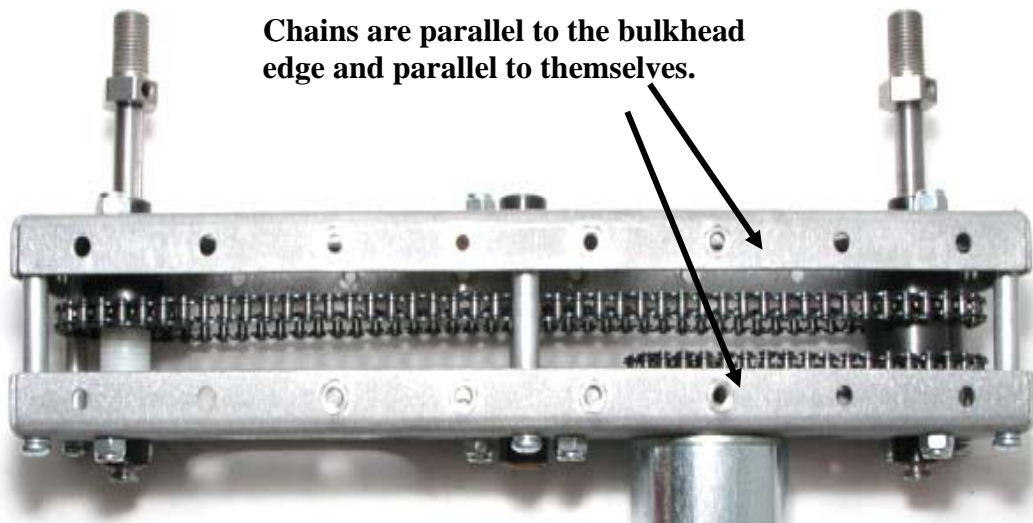
9. Grab the motor by the motor housing and force it firmly downward to tighten the chain. With the motor held in place, tighten the motor mounting screws using a #1 point Phillip head screwdriver. Make certain there are flat washers on the motor mounting screws before tightening them in place. Failure to do this will separate the mounting slots and cause the motor mount to fail.



10. Check to see that the chains and axles are aligned. An easy way to do this is to check that the chains are parallel, or very close to parallel with the edges of the bulkheads.

11. Fasten the bulkheads together using six (6) #10-32 x 3/8" Phillip head machine screws. **Adjust the axles so that the "E" clip slots extend just past the flanged bearings. When the axles are in position tighten the all the sprocket set screws.**

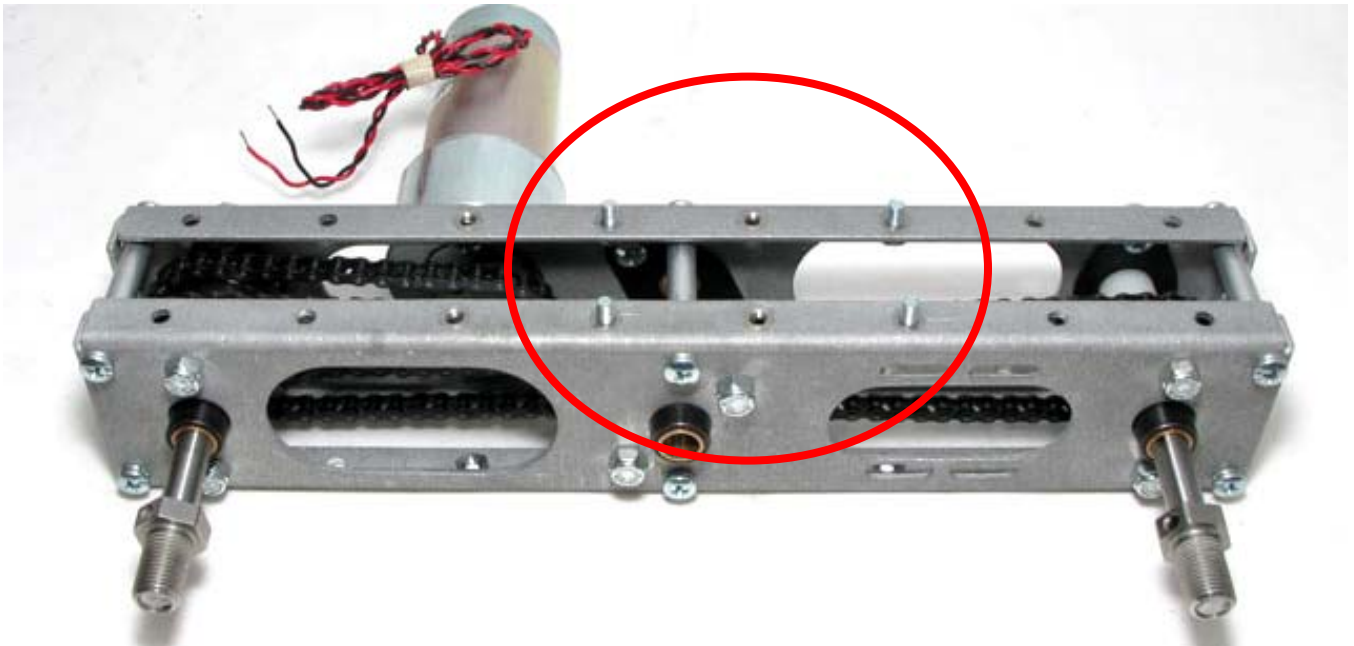
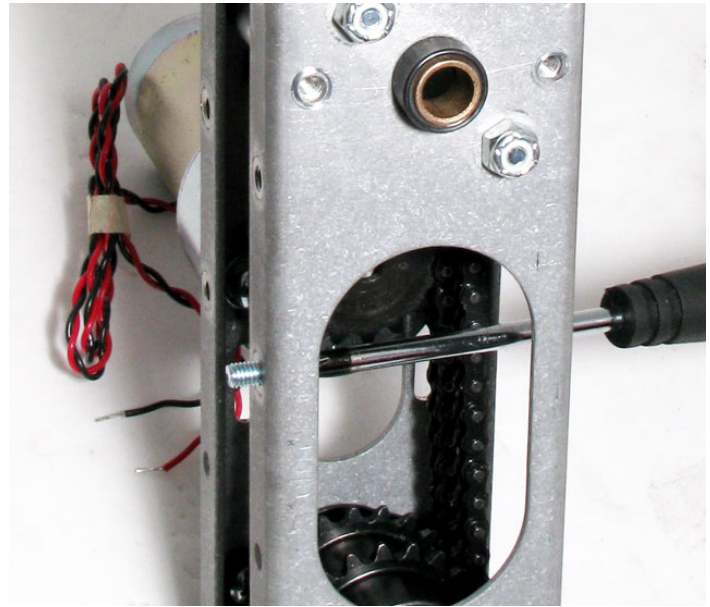
12. After completing steps 1 through 11 above check the chain drive system. Place the assembled unit on a bench and power the motor leads using a 12 volt battery. Listen for smooth running in both directions. There will be light clicking as the chain passes over the standoff. If there are any untoward noises. Stop and check the assembly.



Chains are parallel to the bulkhead edge and parallel to themselves.

Assembly 7 continued

13. Thread 4, #10-32 x 3/8" long Phillip head machine screws into the top of one of the bulkhead assemblies. These will be needed as mounts for the aluminum standoffs that will support the control box. It will be necessary to use a #10 lock washer on each machine screw to ensure that they do not vibrate loose. Carefully thread these screws into the threaded inserts pressed into the bulkhead flanges. The screws should thread in easily. If there is any resistance **STOP threading them.** Examine the threaded ends and if they are not damaged attempt to thread them again. **Attempting to force them into the pressed in inserts will damage the insert threads.** Two machine screws on each bulk head are the minimum necessary to support the project box. The placement should be every other hole (Two on each bulkhead). Refer to the photograph below.



Assembly 8

Bulkhead and Chassis

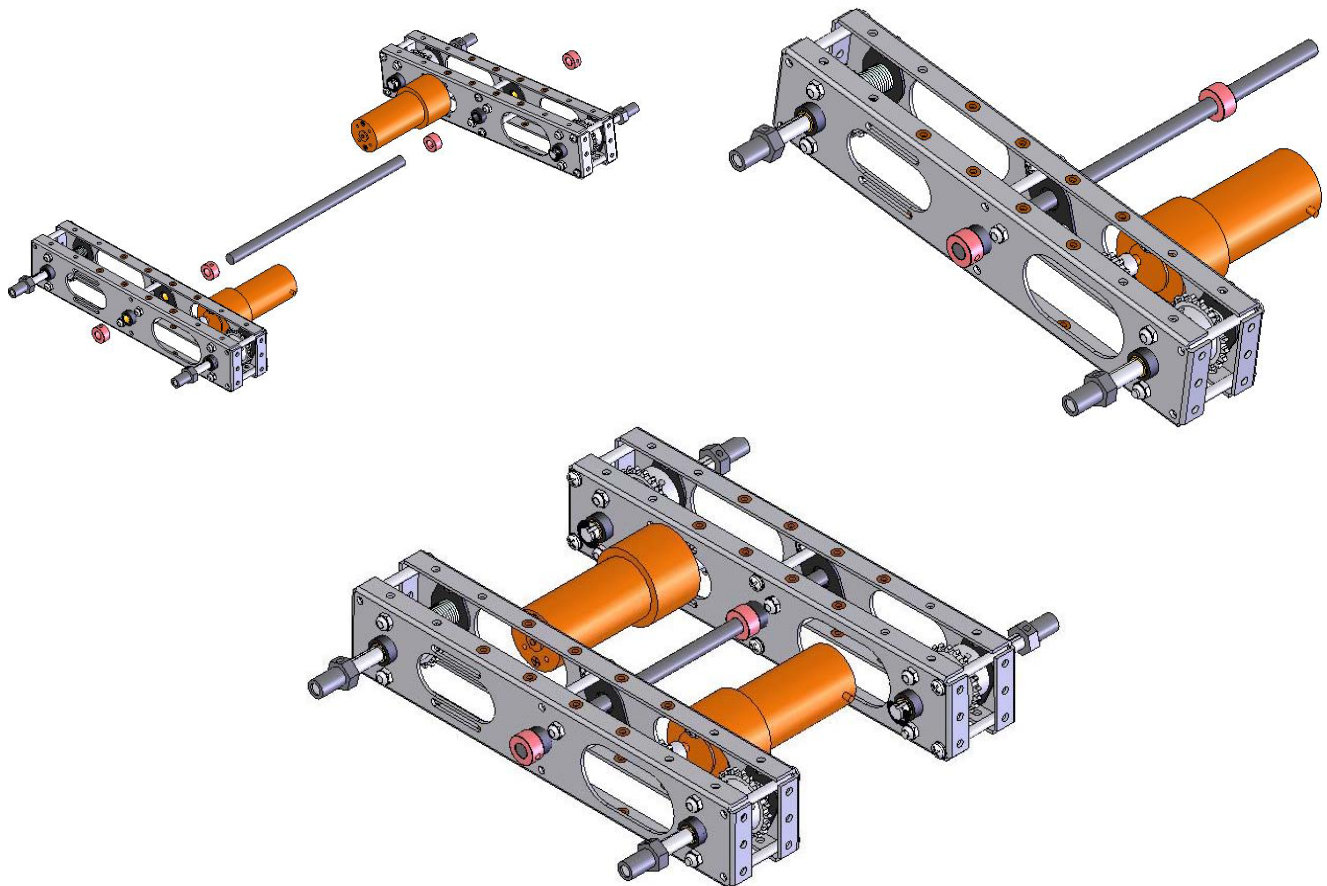
(1 Assembly required) (Multiply listed quantities x 1)
(Average assembly time: 2 students about 5 minutes)

Components and Tools for Assembly

Qty.	Description
1	10-1/2" x 3/8" Diameter Steel or Aluminum Axle
4	3/8" Shaft Collars with Set Screws
2	Completed Bulkhead Assemblies

Procedure

1. Slide two 3/8" shaft collars onto the 3/8" x 10-1/2" axle as shown in the illustrations below.
2. Slide one of the bulkhead assemblies onto the axle.
3. Slide a 3/8" shaft collar onto the axle and secure it flush with the end of the axle. It is not necessary to over tighten the set screws on the shaft collars. Over tightening will raise the metal on the axle and make it difficult to remove the shaft collar.
4. Slide the bulkhead assembly firmly against the secured shaft collar on the end of the axle. Slide the interior shaft collar firmly against the opposite side of the bulkhead assembly and secure by tightening the set screw.



Assembly 9

Wheels and Tires

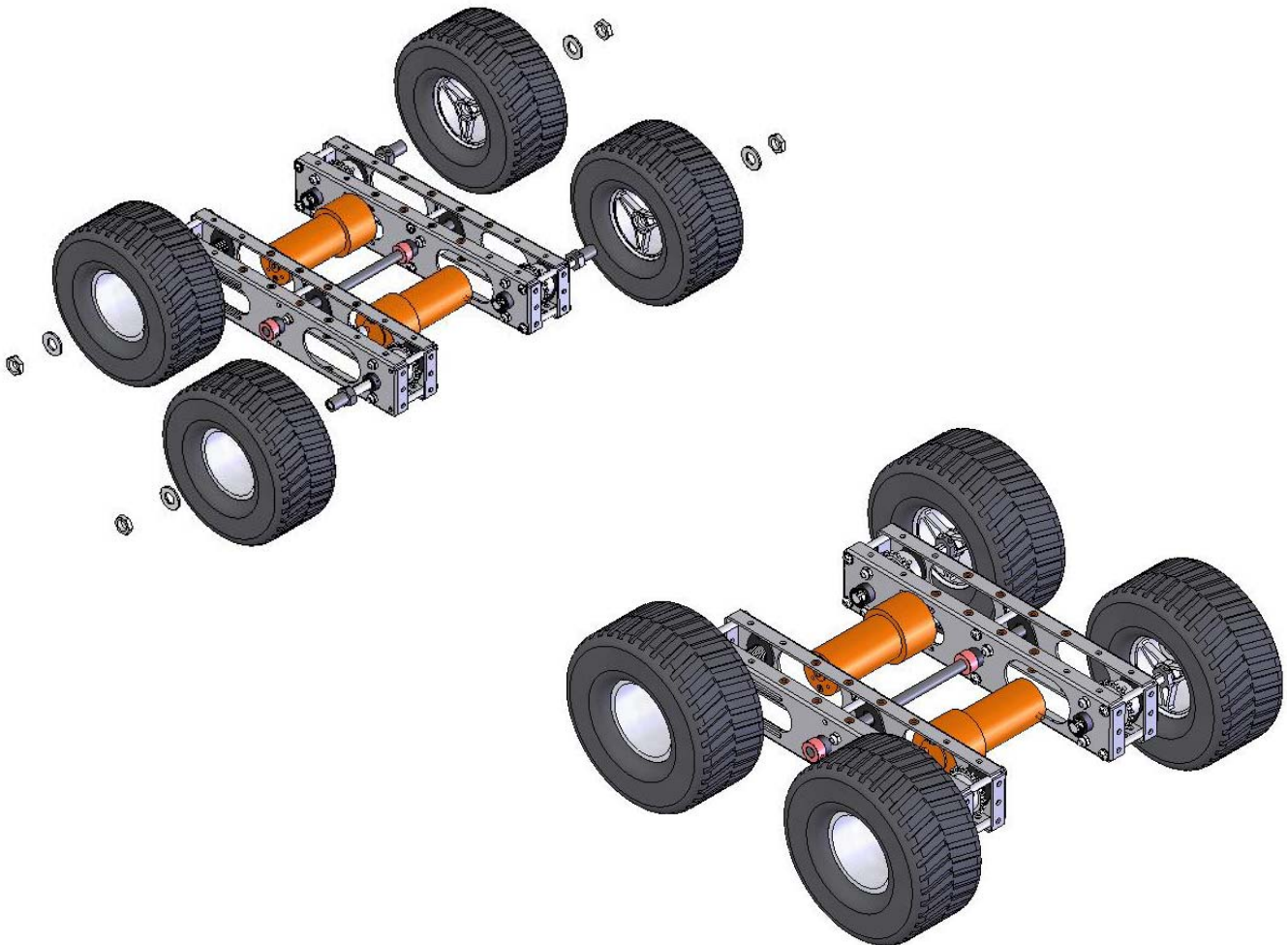
(1 Assembly required) (Multiply listed quantities x 1)
(Average assembly time: 2 students about 15 - 20 minutes)

Components and Tools for 1 Assembly

Qty.	Description
4	7" Diameter High Lug Tires
4	Wheel Rims
4	M 12 Washers (<i>From steps 5 and 6</i>)
4	M 12 Jamb Nuts (<i>From steps 5 and 6</i>)

Procedure

1. Refer to the Tire mounting guide at the end of this document to learn how to mount the tires to the wheel rims.
2. Secure the tire and wheels to the threaded hex adapters on the ends of the axles using the M-12 washers and Jamb nuts. The threaded hex adapters must be permanently secured using green Loctite™



Assembly 10

Control box

(1 Assembly required) (Multiply listed quantities x 1)

(Average assembly time: 2 students about 5-10 minutes)

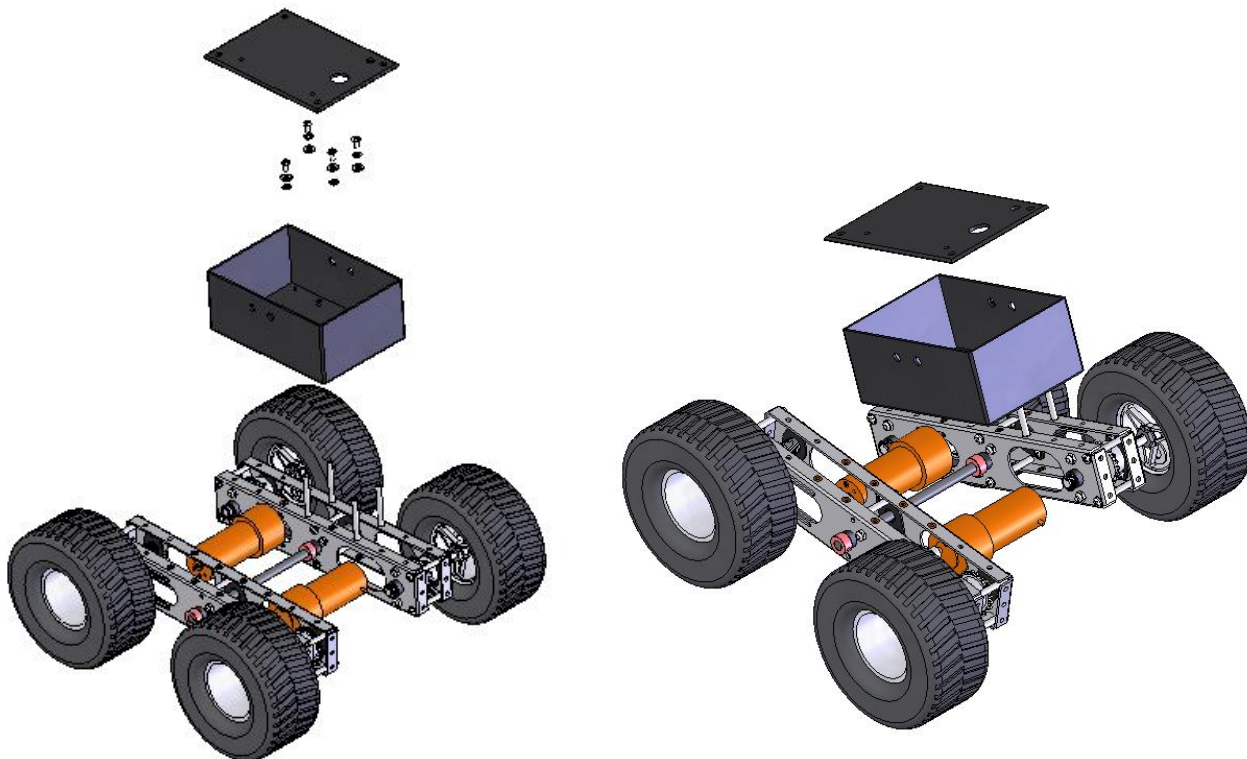
Components and Tools for Assembly

Qty.	Description
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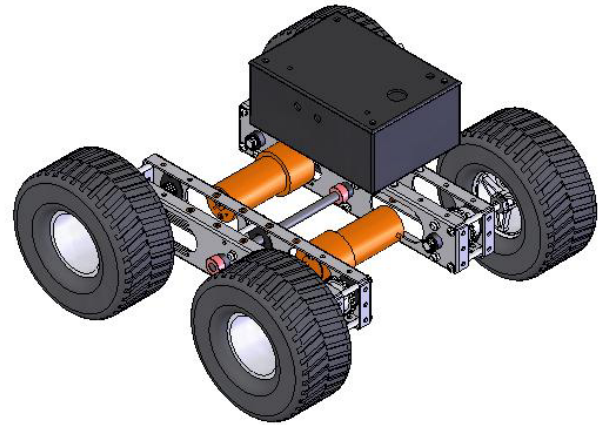
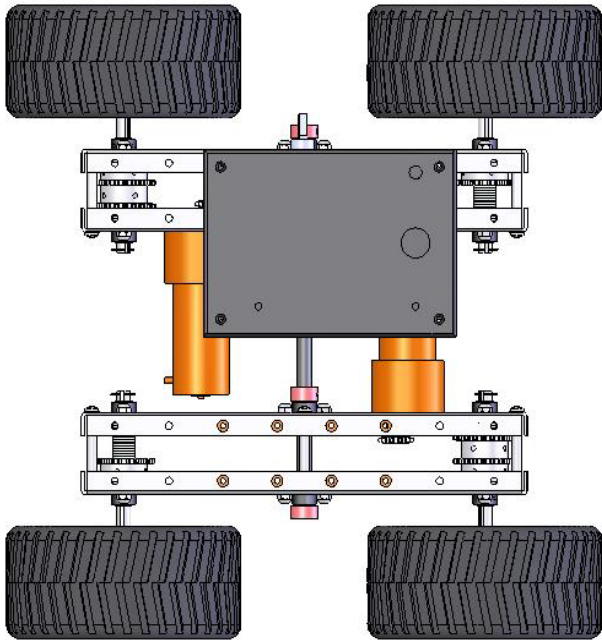
1	Pre-Drilled Project Box w/Cover
1	Single Pole Single Throw Toggle Switch
4	#10 -32 x 5/16" Dia. x 2" long aluminum standoffs
4	#10 -32 x 3/8" Phillip head machine screws
4	#10 Flat Washers
4	#10 Lock washers

Procedure

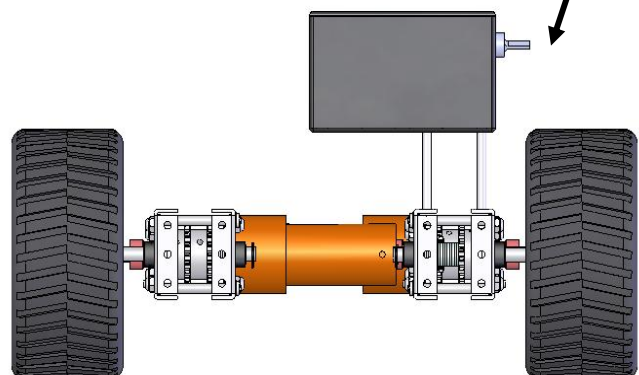
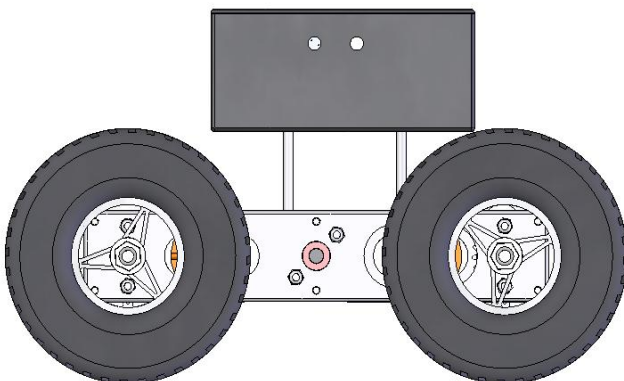
1. Attach the #10-32 X 2" aluminum stand offs to the bulkhead screws that are fastened to the threaded inserts in the bulkheads. (Assembly 7, step 13)
2. Attach the project box to the 2" standoffs using #10-32 x 3/8" Phillip head machine screws fitted with #10 lock washers and flat washers. The flat washers are necessary to provide a widely spaced clamping force on the plastic project box.
3. Attach the toggle switch to one of the pre-drilled holes on the side of the project box.



The Completed Mechanical Assembly of the H-MAC



Toggle switch mounted to pre-drilled holes on both the front and back sides of the control box. Additional 1/2" holes can be drilled for side mounting as shown.



Large Lug Tire Illustrated Assembly Tips

Mounting the Tires and Rims

The tires used on the GEARS-SMP are made from a medium soft rubber compound. These tires can support the weight of batteries, sensors and cameras. In addition, the tires can be partially filled with sand or lead shot in order to gain additional traction. Partially filling the tires with ballast will lower the SMP's overall center of gravity and provides additional stability over rough terrain.



The tires should be fitted to the rims and the foam inserts placed into the tire cavity. To accomplish this, push the rims into the tire hole. If necessary use 2 DULLED table knives or similar thin flat metal tools to fit the tire to the rim. This is where two people working together can make a difficult task easier. Be certain that the tire bead is fitted completely into the rim groove. The picture on the left shows the tire bead being fitted to the rim groove.

Make certain the tire bead is properly seated in the rim groove. Once the tires are properly mounted the tires can be permanently fixed to the rims using Cyanoacrylate glue.

To glue the tire to the rim you will need:

- An ampoule of Cyanoacrylate glue.
- Latex Gloves

Note: Do not allow your fingers to come in contact with the Cyanoacrylate glue. The glue can create a very strong bond between skin surfaces that can be painful and injurious to remove.

To adhere the tire to the rim, simply peel the tire bead away from the rim and allow a small amount of Cyanoacrylate glue to flow into the bead groove between the tire bead and the rim groove. Continue to work around the rim until the entire circumference of the tire bead and rim have been glued and properly seated. Repeat the operation for both sides of the tire. Note: The glue will set relatively quickly so it is important to practice setting the tire bead into the rim before attempting to use the Cyanoacrylate glue.



Note the direction of the V tread design. Remember to fit up two right side tires and two left side tires so the V tread point in the same direction.

