TMT P2 Prototype Actuator Description and Draft Assembly Procedure

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1. Introduction

This document briefly describes the TMT P2 segment actuator, and outlines the assembly process. The objective is to identify the important steps and the overall assembly sequence in order to scope the task, and is intended for use by an experienced mechanical engineer or mechanical technician. It is not intended to be a formal or complete procedure for production, although it could serve as the basis for such a document, which would nominally be written by the production vendor.

This document should be read in full prior to beginning assembly. There is some minor fixturing identified in the procedure that will be required.

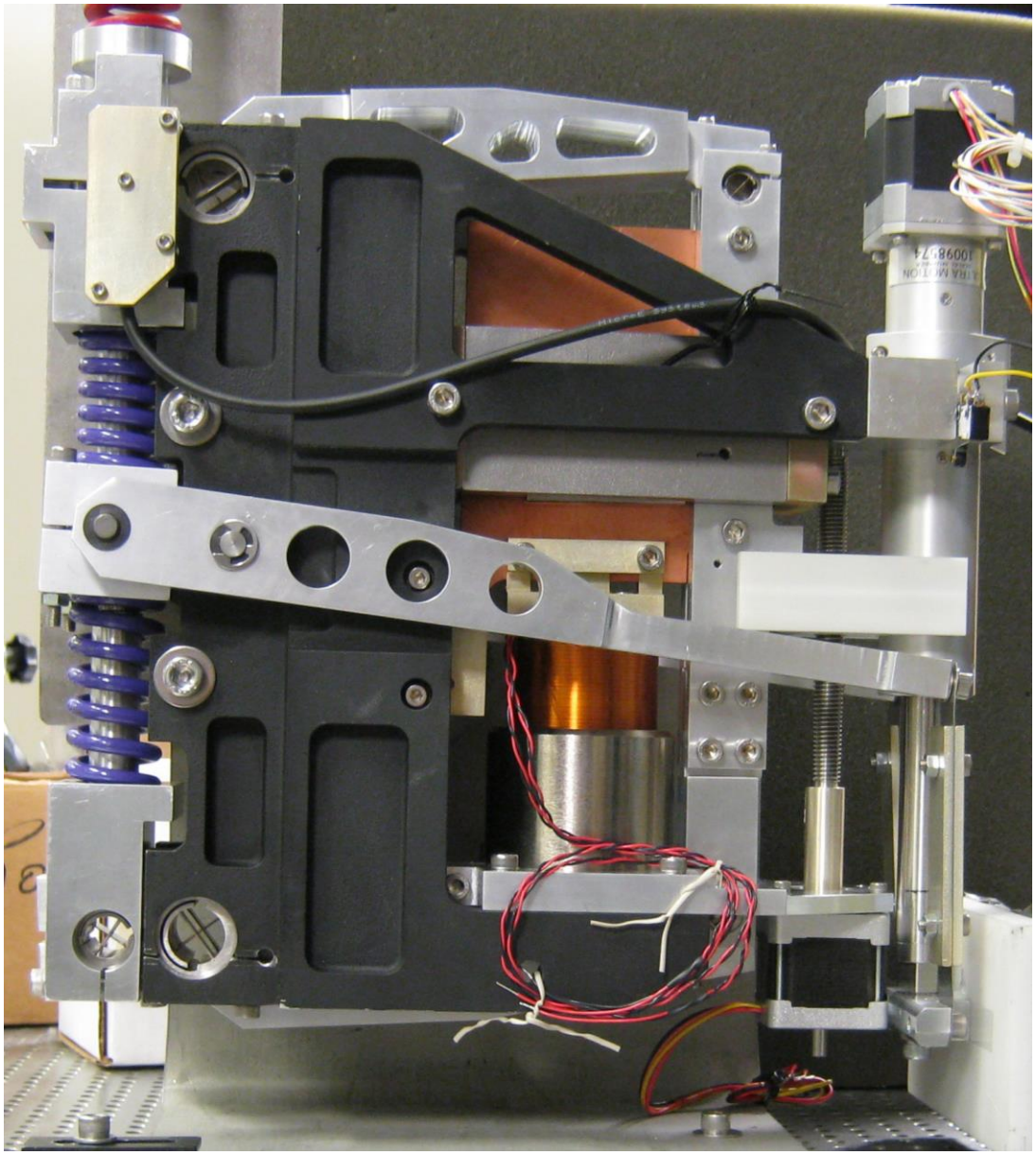
In production volumes with appropriate setup, we anticipate it will take less than 2 hours to assemble each actuator.

There were two versions of the P2 actuator built; the current version is described here. In a few places, pictures from the earlier version are used where there are not important differences.

All fasteners are metric, except for the ¼-28 screw that attaches the actuator end block to the Digit actuator.

This is a "right-handed" actuator. For production, there are equal numbers of right- and left-handed actuators. They are nearly identical, except for the housing and output limit switch bracket. Additional prototype actuators are also to be "right-handed" **[TBC].**

Assembled Actuator



(The limit switch in the upper right, the Delrin plate in the lower right, and the spring and disk at the top left are part of a test stand, and not part of the actuator)

Actuator Mechanical Parts

-100 SAT HOUSING CASTING - RH
-101 SAT HOUSING MACHINING - RH
-103 LOWER ARM
-104 UPPER ARM
-105 CONNECTING LINK
-106 OFFLOAD ARM
-108 UPPER CONNECT BLOCK
-109 LOWER CONNECT BLOCK
-110 VERT LINK CONNECT BLOCK
-111 VC MOUNTING PLATE
-112 COPPER PLATE
-113 SPRING BLOCK
-114 CLAMP BASE
-115 ACTUATOR CLAMP
-116 TRACKING SCREW
-117 DELRIN GUIDE
-118 CONNECTING LINK INNER
-120 ACTUATOR END BLOCK
-121 STEEL END BAR (quantity 2)
-122 STEEL SIDE BAR (quantity 2)
-123 FLEXURE (quantity 2)
-124 FLEXURE STIFFENER (quantity 4)
-125 CONNECTING ROD
-126 OFFLOAD ARM- INNER
-127 VC CONNECT CLEVIS
-128 ENCODER MTG BRKT
-130 TRACKING SCREW SLEEVE
-131 SAT TO SSA ADAPTER
-132 ENCODER OUTPUT BRKT
-133 LS BRACKET
-134 OFFLOAD PIVOT PIN
-140 OUTPUT FLEXURE ROD
-141 ROD RESTRAINT TUBE

Major Procured Parts

Procured mechanical parts

TMT201	4	5/16" Rulon bushing (see below)
TMT202	2	0.75" flex pivot C-Flex ID-20
TMT203	2	1" flex pivot C-Flex JD-20
TMT204	2	0.5" flex pivot C-Flex GD-20
TMT210	2	Lee Spring HEFTY Die Spring LHL 1250B 04.
TMT220	1	Assorted fasteners, pins, clips, etc. (see below)
TMT230	2	2" x 2" x 1/2" N52 NdFeB magnet

Procured active parts

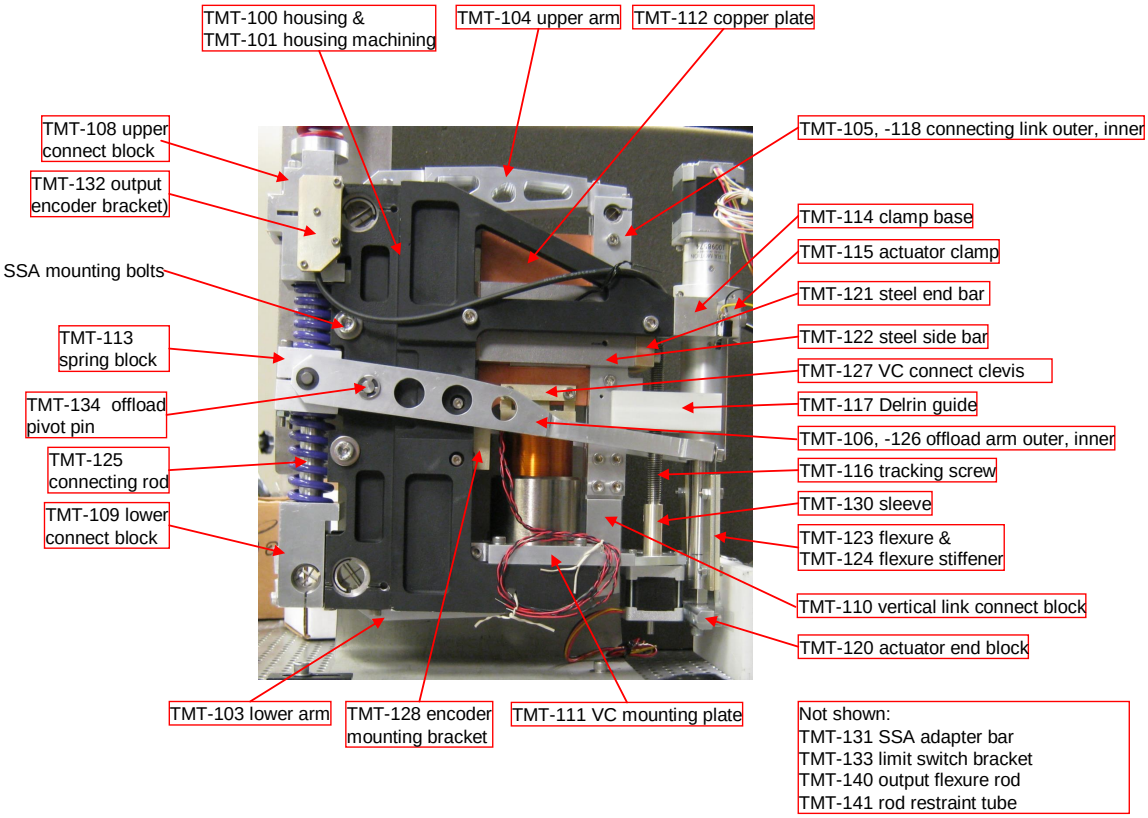
TMT301	1	UltraMotion Digit linear actuator D-A.083-HT17-3.5-/4 (specific model may change slightly)
TMT310	1	Micro-E Systems MII linear encoder, MII5850-AB-16384-1-1-0 (specific model may change slightly)
TMT311	1	Micro-E Systems MII scale MIIL18 (specific model may change to 303-R3683-01)
TMT320	1	Voice-coil actuator, H2W NCC15-24-050-1R
TMT330	1	Stepper motor NEMA17, Anaheim Automation 15Y202D-LW4 or similar
TMT340	1	Limit switches, Hall sensor IC, indicator magnet (not required for prototype)

McMaster Co. part numbers for selected items

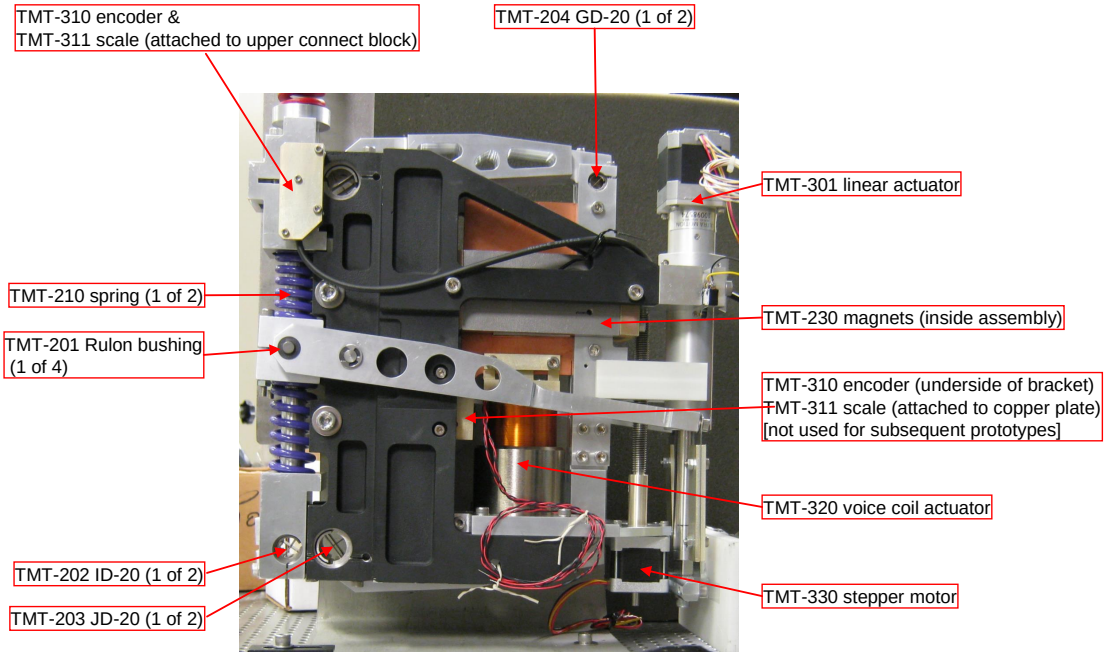
6377K106	4	Rulon-J bushing, TMT201 5/16" ID
98408A132	2	Retaining clip [for offload pivot pin]
97395A510	2	Dowel pin 5/16" dia x 1.5", 316 SS [attach to spring block]
90295A160	6	Plastic washers, Nylon [for offload assembly]
6627K14	2	PEEK bushing for snubber 1/4" ID [attaches to actuator clamp base]
98408A122	1	Retaining clip [for top of tracking screw]
98355A080	1	Cotter pin [for tracking sleeve]

(For production quantities, it will likely be less expensive to fabricate the bushings and dowel pins from stock)

The actuator annotated with the machined parts



The actuator annotated with the procured parts



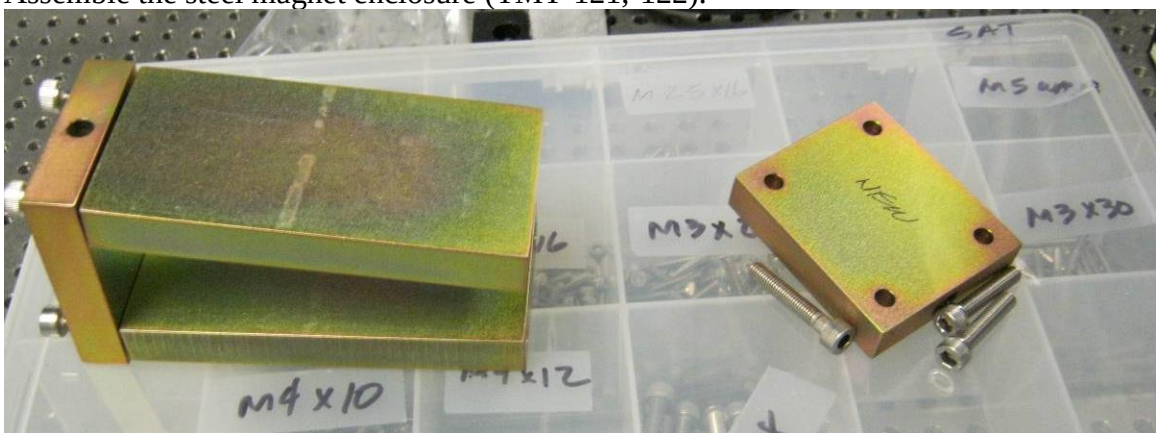
2. Assembly process

Please refer to the annotated pictures above for identification of parts. For several of the steps, it may be convenient to mount the actuator vertically on a bracket using two bolts through the SSA mounting holes in the housing shown in the pictures above.

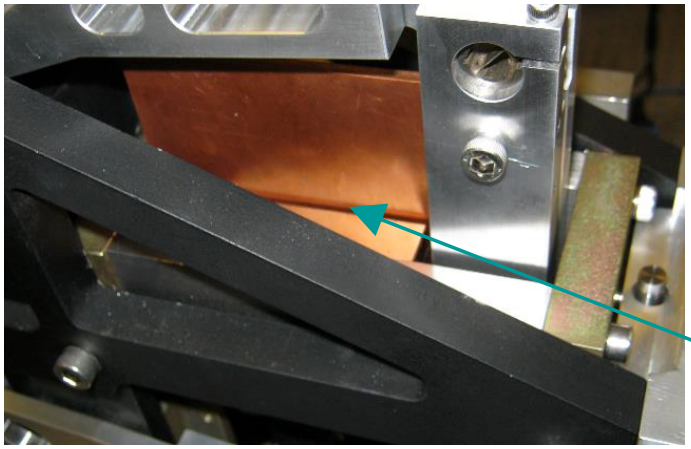
2.1. Assemble the magnetic damper

<u>WARNING.</u> The magnets to be installed are very powerful. They are attracted to each other and to steel parts with >100# force at short distances. Wear leather gloves when handling and installing the magnets. Use extreme care not to get magnets near steel parts or work surfaces, other magnets, or each other, until they are installed in the enclosure (which closes the magnetic circuit).

Assemble the steel magnet enclosure (TMT-121,-122).

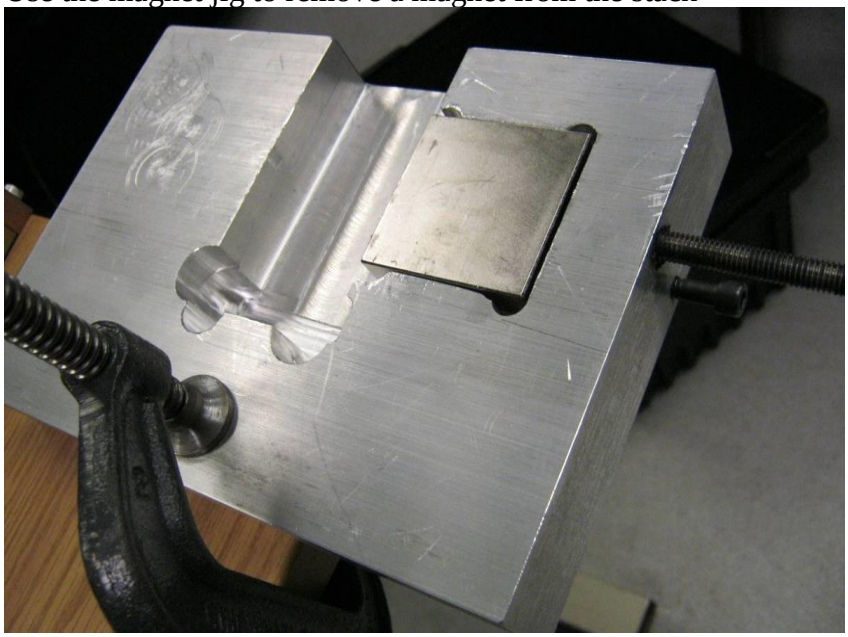


Insert the magnets (TMT-230). The magnets are mounted one to the bottom plate, one to the top plate, with their poles aligned (e.g. the N pole of the bottom magnet and the S pole of the top magnet face the gap, so that if the steel flux return were not present, the magnets would pull themselves together). They are centered approximately 5 mm left of the centerline to allow at least 2 mm clearance for the connecting link, as shown here in the assembled actuator:

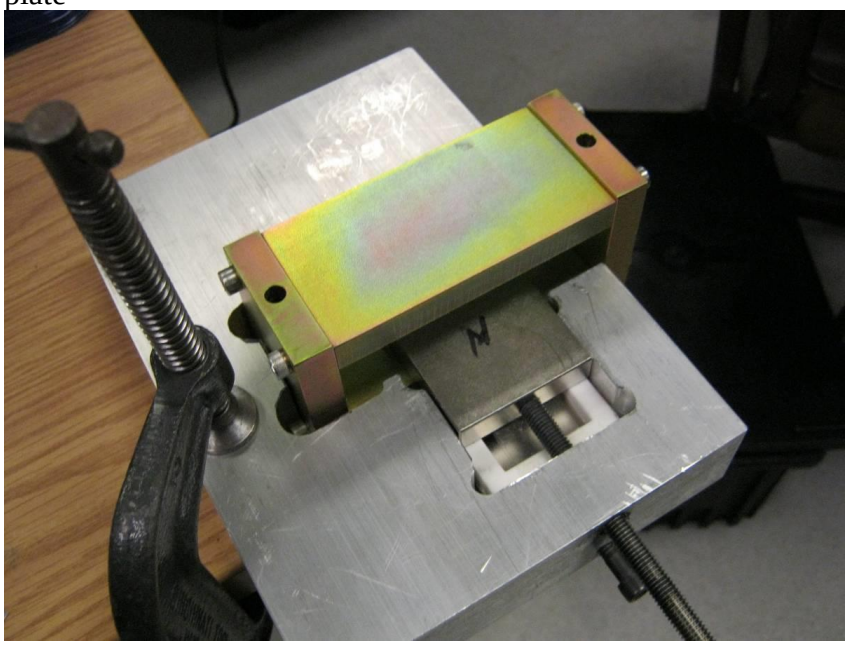


The magnets are usually shipped from the manufacturer in a stack with plastic spacers between magnets. We built a simple aluminum tool for separating and inserting the magnets, described below. Other assembly processes are possible.

Use the magnet jig to remove a magnet from the stack

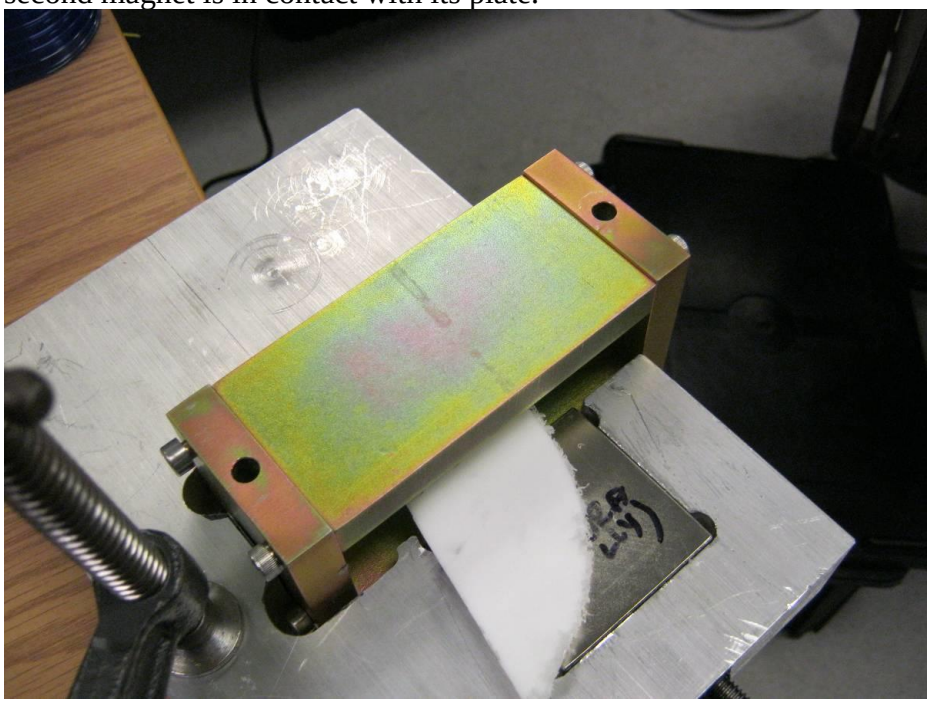


and push it into the magnet enclosure, where it will be strongly attracted to the bottom plate



(You can see in the photo the annular square plastic spacer which separates the magnets in the stack.)

Flip the magnet enclosure over, and also the magnet stack, and install the other magnet so that the poles are aligned as described above. Use a plastic spacer (the white semicircle in the picture below), slightly thinner than the gap, to keep the magnets apart until the second magnet is in contact with its plate.



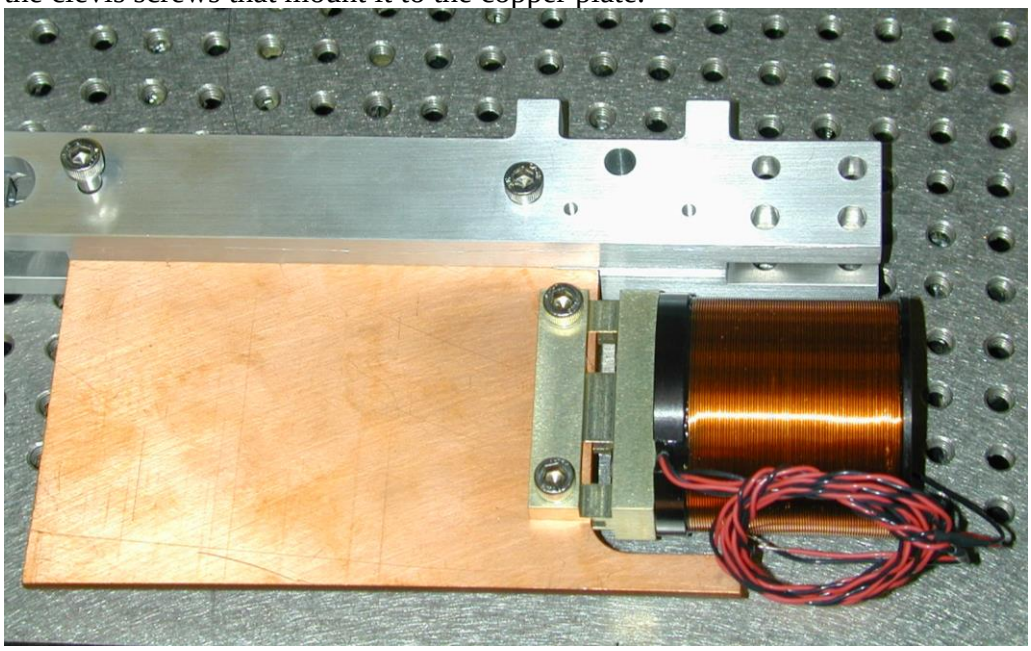
After installation, the attraction of the magnets to the steel plates will keep them in place in the assembly. For production, we would probably use some wicking adhesive, but that's not needed for the prototypes.

2.2. Install the voice coil and damper

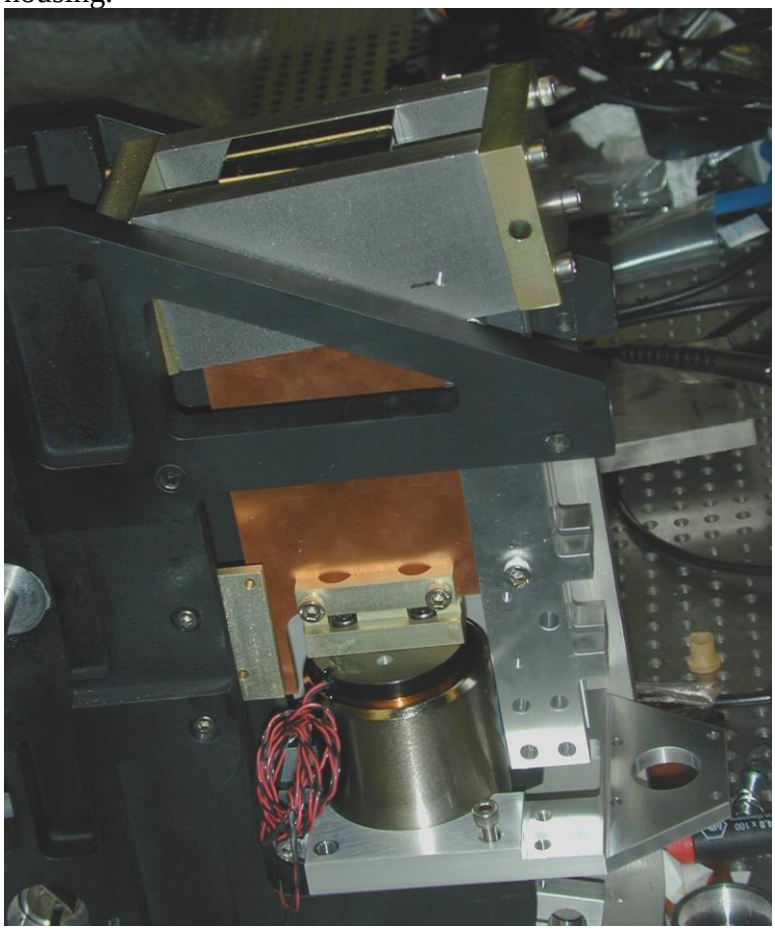
Install voice-coil magnet assembly (TMT-320) and its mounting plate (TMT-111) into the housing.

(You do not have to attach the encoder bracket, shown in the upper left hand corner, yet).

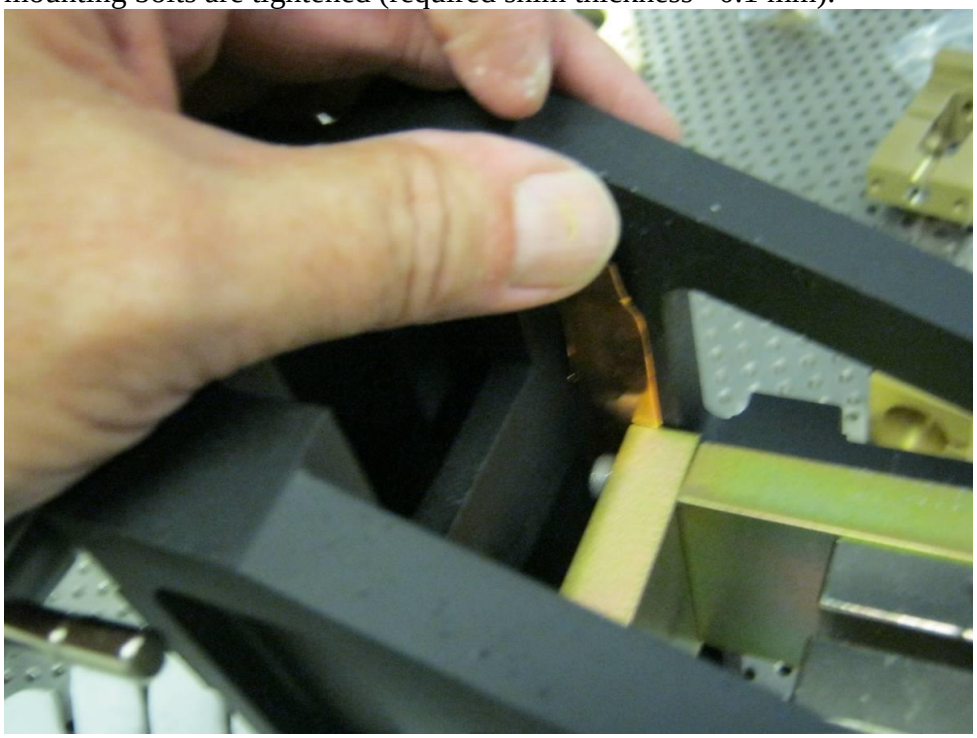
Assemble connecting links (TMT-105, -118), copper plate (TMT-112), voice-coil clevis (TMT-127), and voice-coil coil assembly (TMT-320). Tighten only one screw to clamp the copper plate. After aligning the copper plate, remove the screw shown loose on the left side of the picture. Tightly connect the voice coil to the clevis, but only hand tighten the clevis screws that mount it to the copper plate.



Install the copper plate/voice-coil sub assembly, and the magnet assembly into the housing.



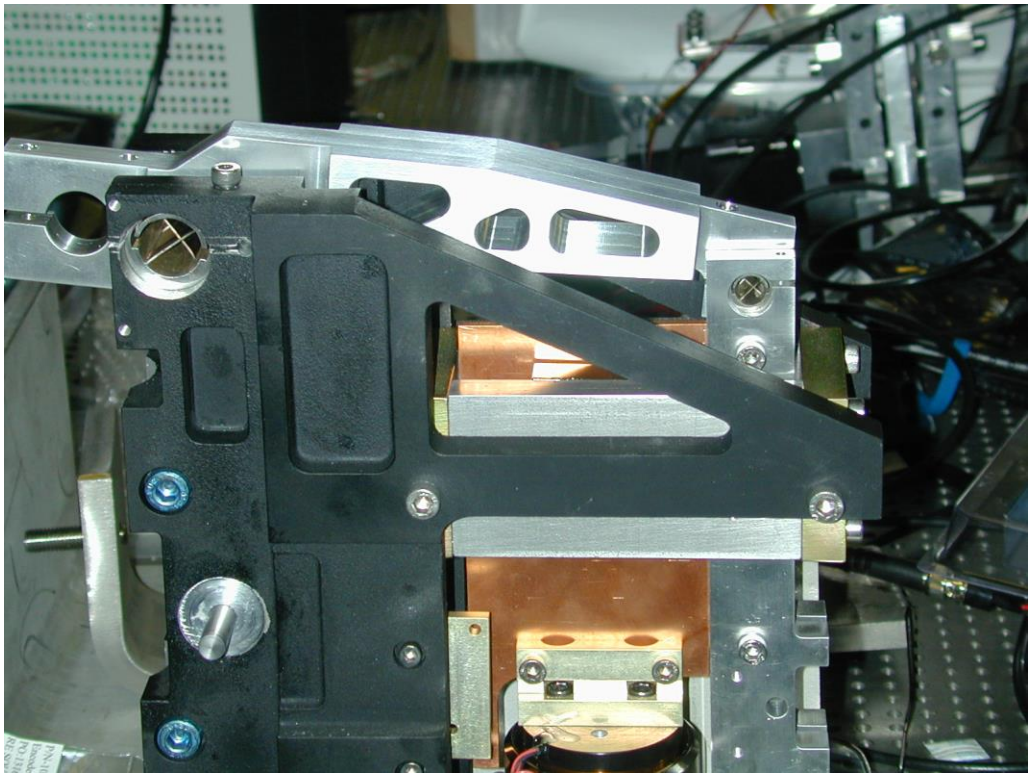
When attaching the magnet assembly, shim it symmetrically (left and right sides) at the inner end to take up any casting clearance. Otherwise the casting could crack when the mounting bolts are tightened (required shim thickness ~0.1 mm).



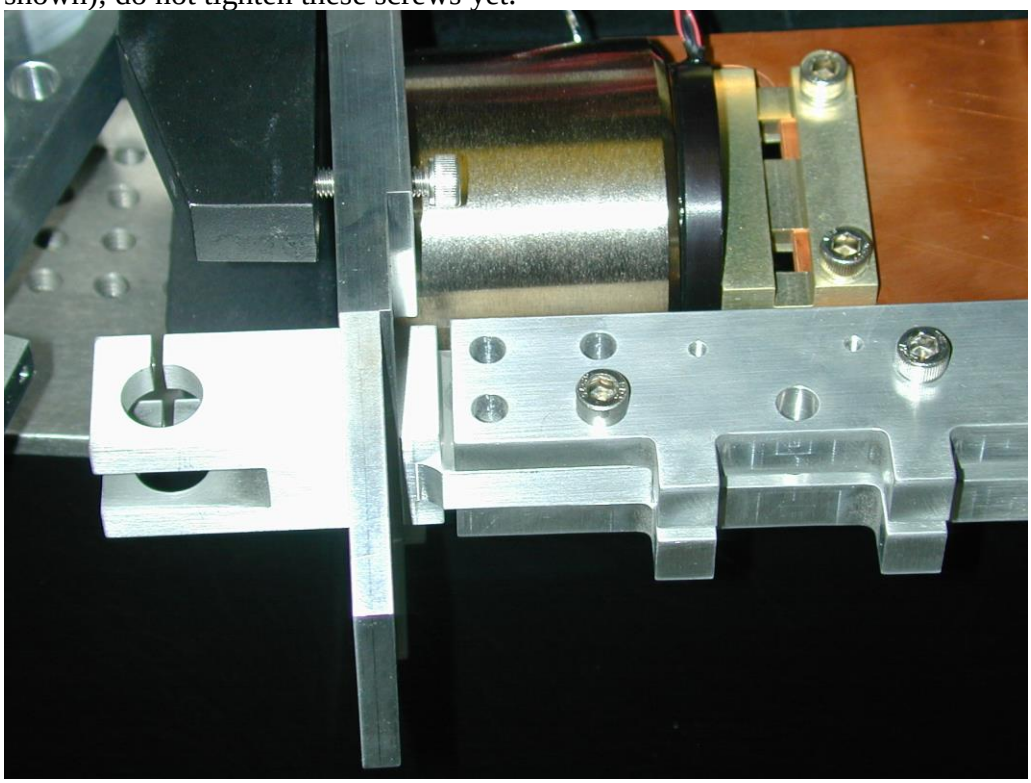
Center the copper plate, attach the second screw holding it in place. Use a ½" dowel pin in the upper flex pivot hole, and a ¼" dowel pin in the lower through-hole, to center the two halves of the vertical linkage. Tighten the two copper plate screws, and remove the pins. Only hand tighten the clevis screws at this stage.

2.3. Install the four-bar linkage

Install the upper arm (TMT-104) and the two flex pivots shown (1” upper flex pivot [TMT-203], ½” upper flex pivot [TMT-204]), but do not tighten any flex pivot clamp screws.

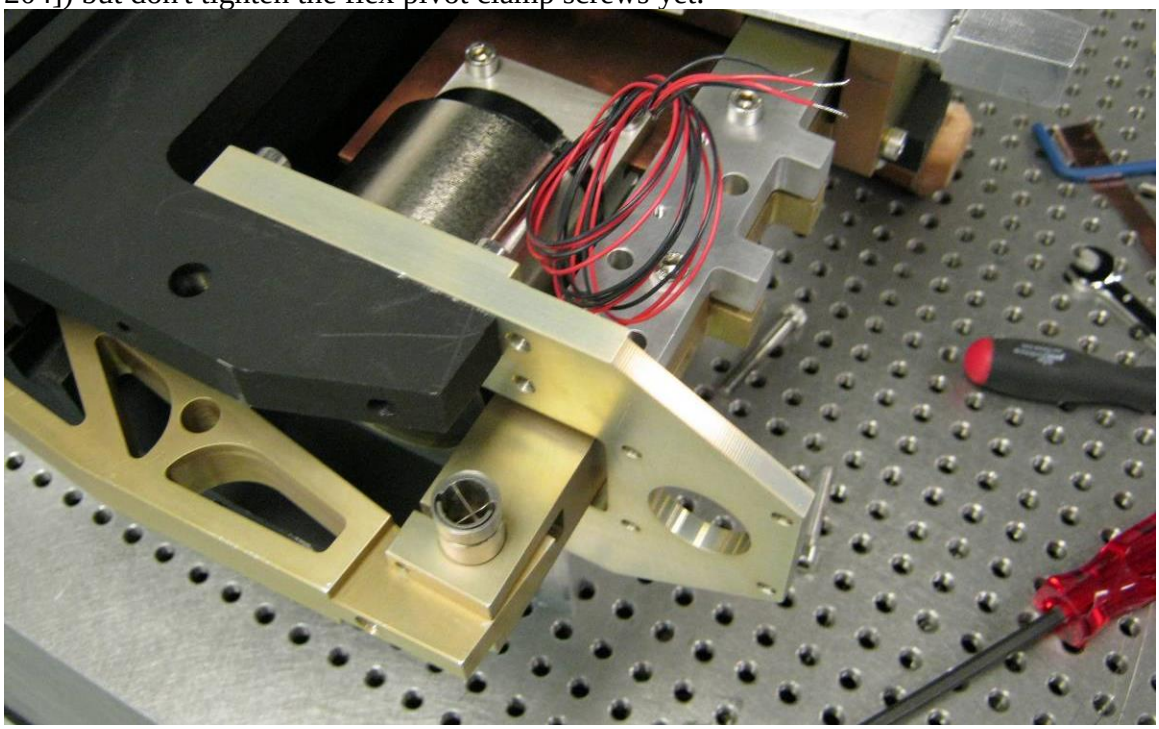


Install the vertical link connecting block (TMT-110) with 4× M5 screws and nuts (one shown); do not tighten these screws yet.

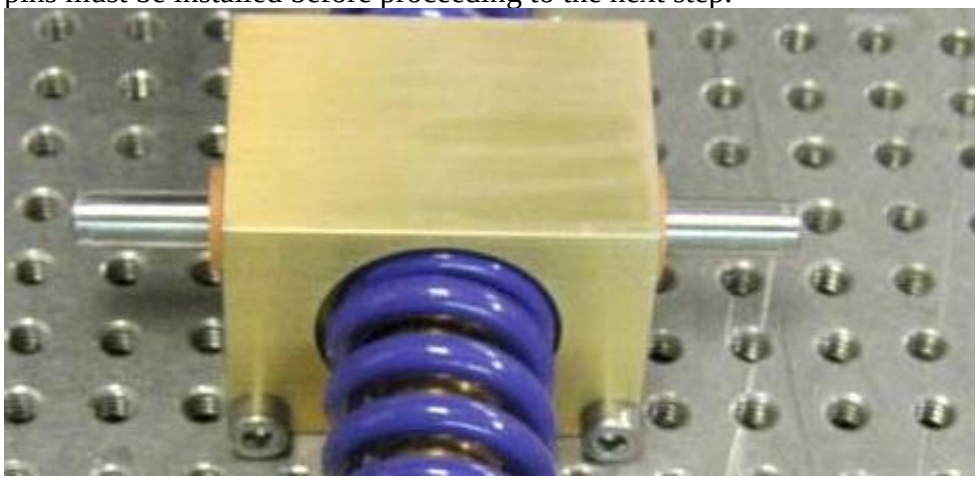


Lay the actuator horizontally, and install the lower arm (TMT-103) and the two corresponding flex pivots (1” lower flex pivot [TMT-203], ½” lower flex pivot [TMT-

204]) but don't tighten the flex pivot clamp screws yet.



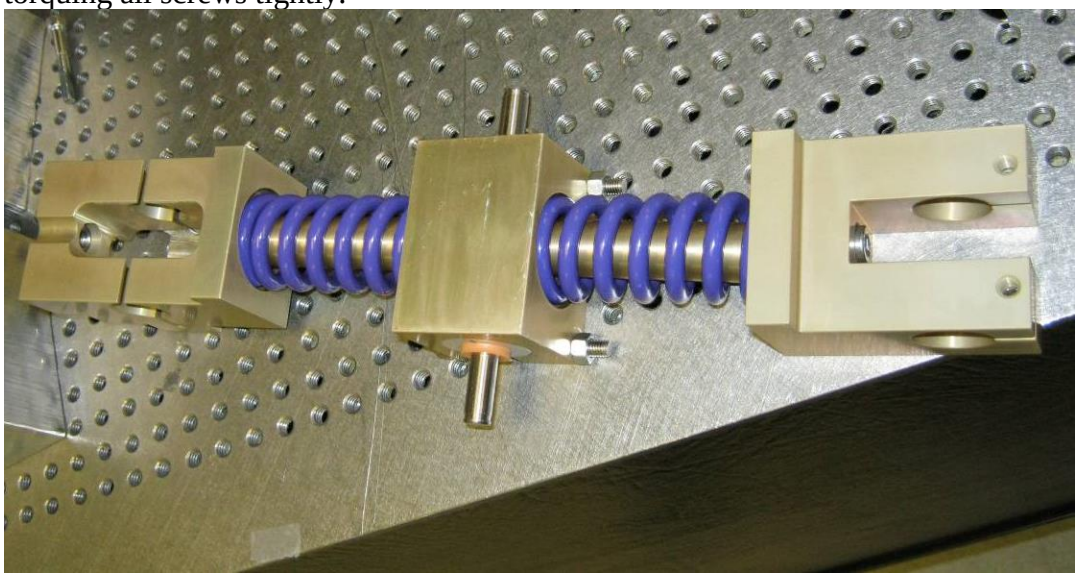
Insert the dowel pin axles into the spring block (TMT-113), and install them such that they protrude 20 mm from the outside of the block. Tighten the clamp screws. These pins must be installed before proceeding to the next step.

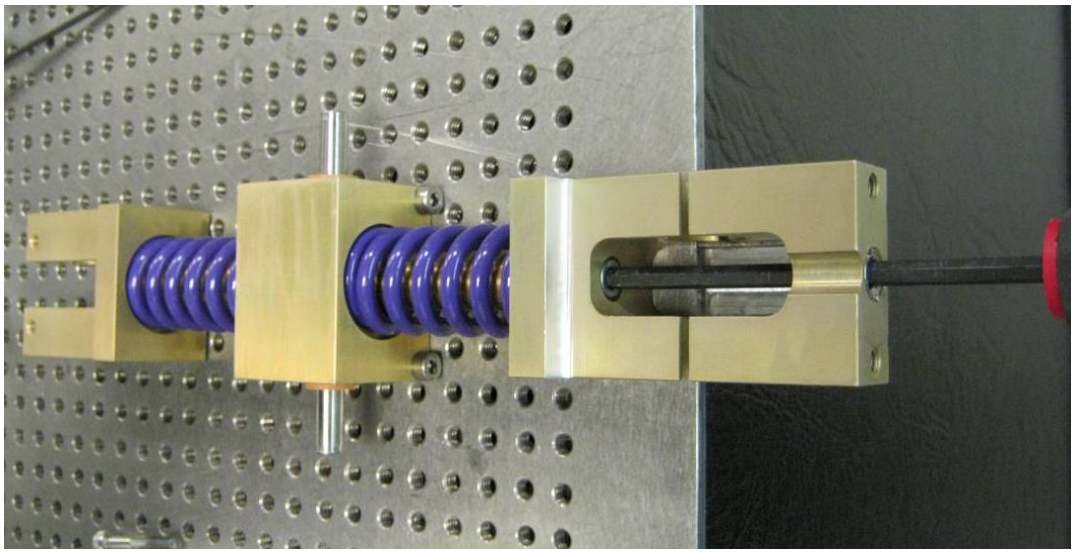


(While shown in the photo, the springs and washers are not attached at this stage).

Assemble the spring block with its dowel pins, springs (TMT-210), upper and lower connect blocks (TMT-108, -109), and connecting rod (TMT-125) as shown on a flat surface. The blocks must all align (e.g., lower surfaces parallel to the flat surface) after

torquing all screws tightly.



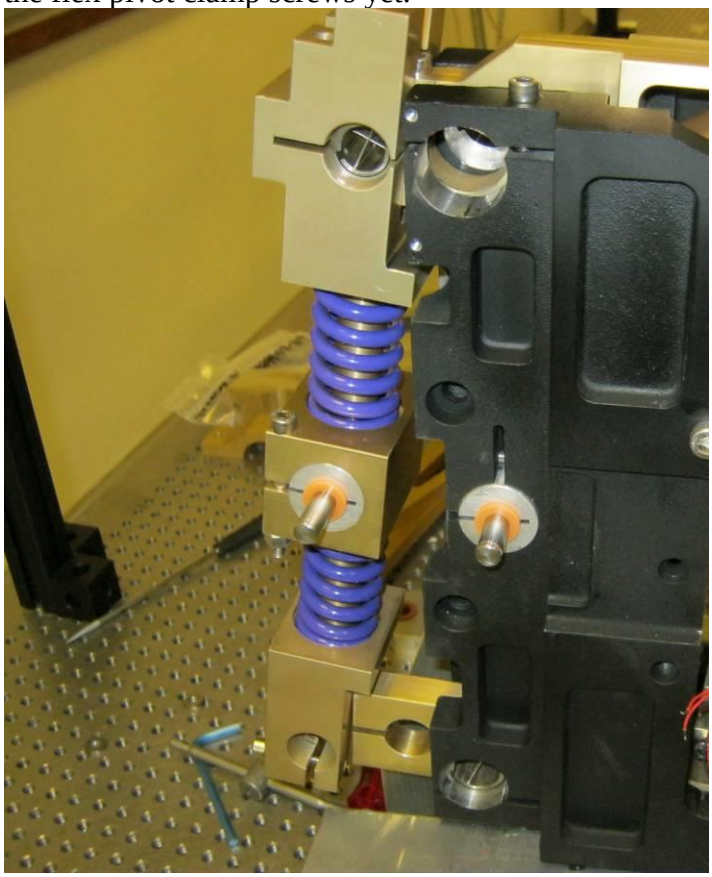


(Use an angle driver for final tightening.)

Install the offload pivot pin (TMT-134) in the actuator housing, center, and tighten the two clamp screws in the housing.

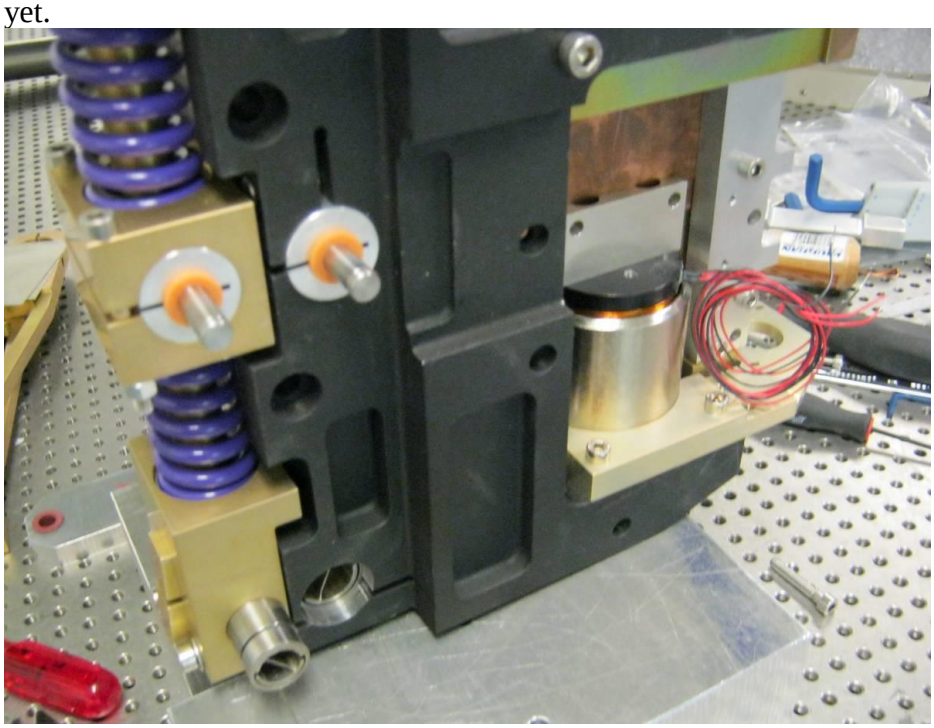
(The pivot pin adapter shown in the picture is not required for the current housing design. You can see one of the two clamp screws extending across the slot above pivot pin; they are accessed from the left hand side of picture. Different spacer washers are used in the current design, installed later).

Install the spring block assembly and upper ¾”flex pivot (TMT-202), but don't tighten the flex pivot clamp screws yet.



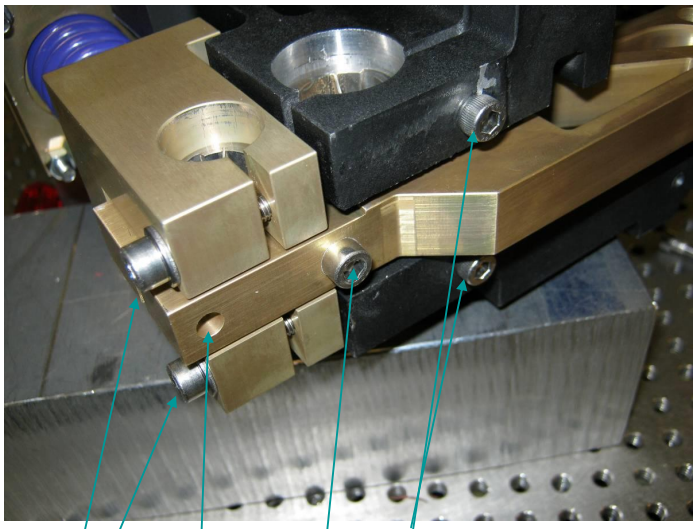
(The dowel-pin adapters shown in the picture are not required for the current housing and spring block designs. Different spacer washers are used in the current design, installed later).

Install the lower ¾” flex pivot (TMT-202), but don’t tighten the flex pivot clamp screws yet.



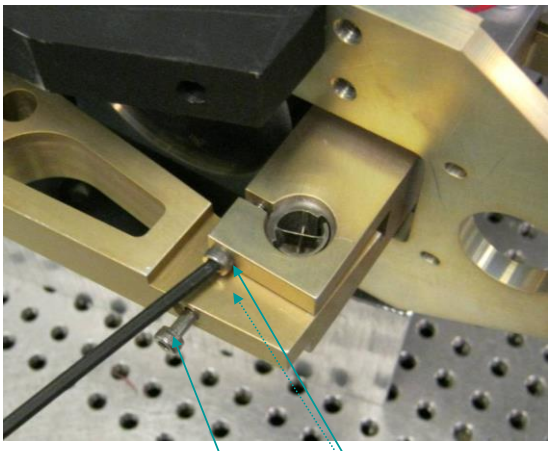
If this last flex pivot won't install, makes sure the screws holding vertical link connecting block (TMT-110) are still loose.

Center the two ¾” flex pivots in the upper and lower connecting blocks, and tighten the four screws on the blocks only. Center the two 1” flex pivots in the actuator body, and tighten the four screws on the housing only.



(Bottom flex pivot clamp screws on output side shown; upper is similar)

Center the two small flex pivots in the connecting links, and tighten the four clamp screws on the links only.

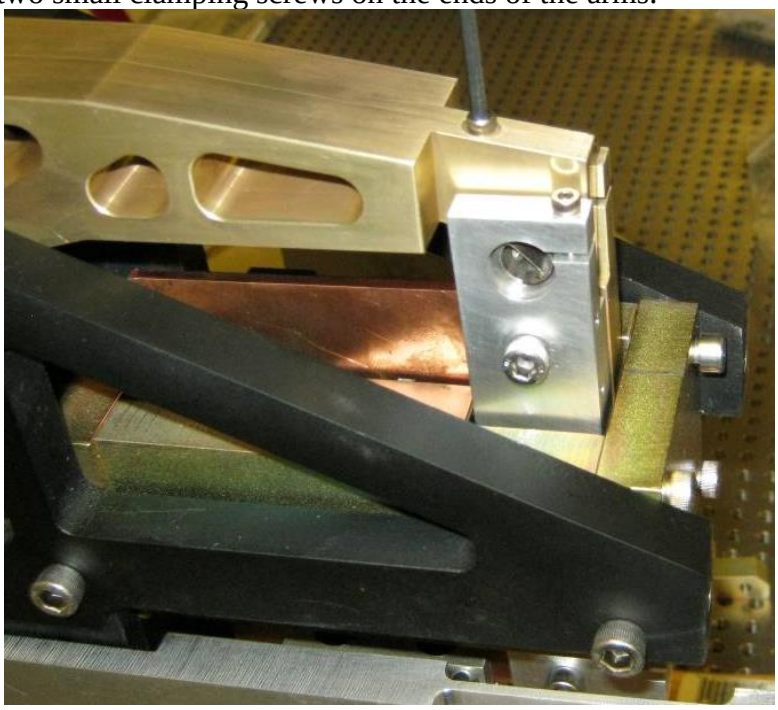


(Bottom flex pivot clamps screw on input side shown; upper is similar)

Move the four bar linkage to the middle of its range (corresponds to extending the voice coil approx 18 mm from its minimum position).

The four flex pivot clamp screws at the ends of the upper and lower arms should still be loose at this point, and the flex pivots should all be undeflected, at their neutral position. Confirm this visually.

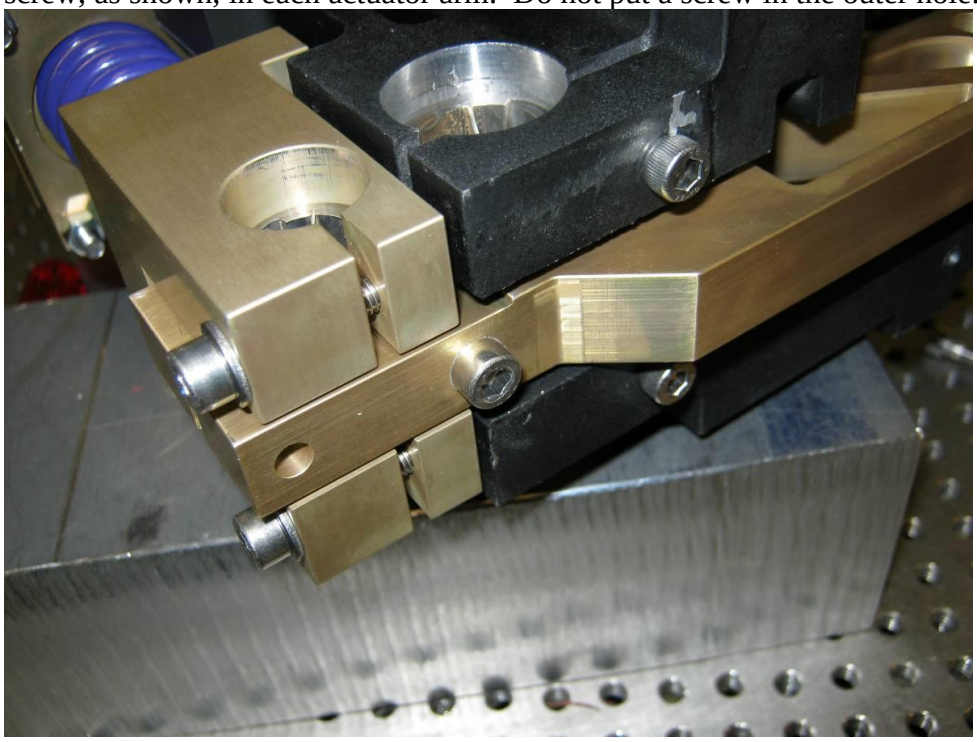
Center the upper and lower arms in the connecting link and link block, and tighten the two small clamping screws on the ends of the arms.



Center the upper and lower arms on the ¾” flex pivots in the upper and lower connect blocks.

Align the linkage by sliding the arms on the 1” flex pivots to center the copper plate between the magnets and the voice coil within its magnet assembly, and tighten the single

screw, as shown, in each actuator arm. Do not put a screw in the outer hole.



Finally, tighten the four screws on the connecting link.

Adjust the alignment of the voice coil clevis to maximize clearance over the range of motion, and tighten those two screws. (Some adjustment is also possible by adjusting the connecting link, if required).

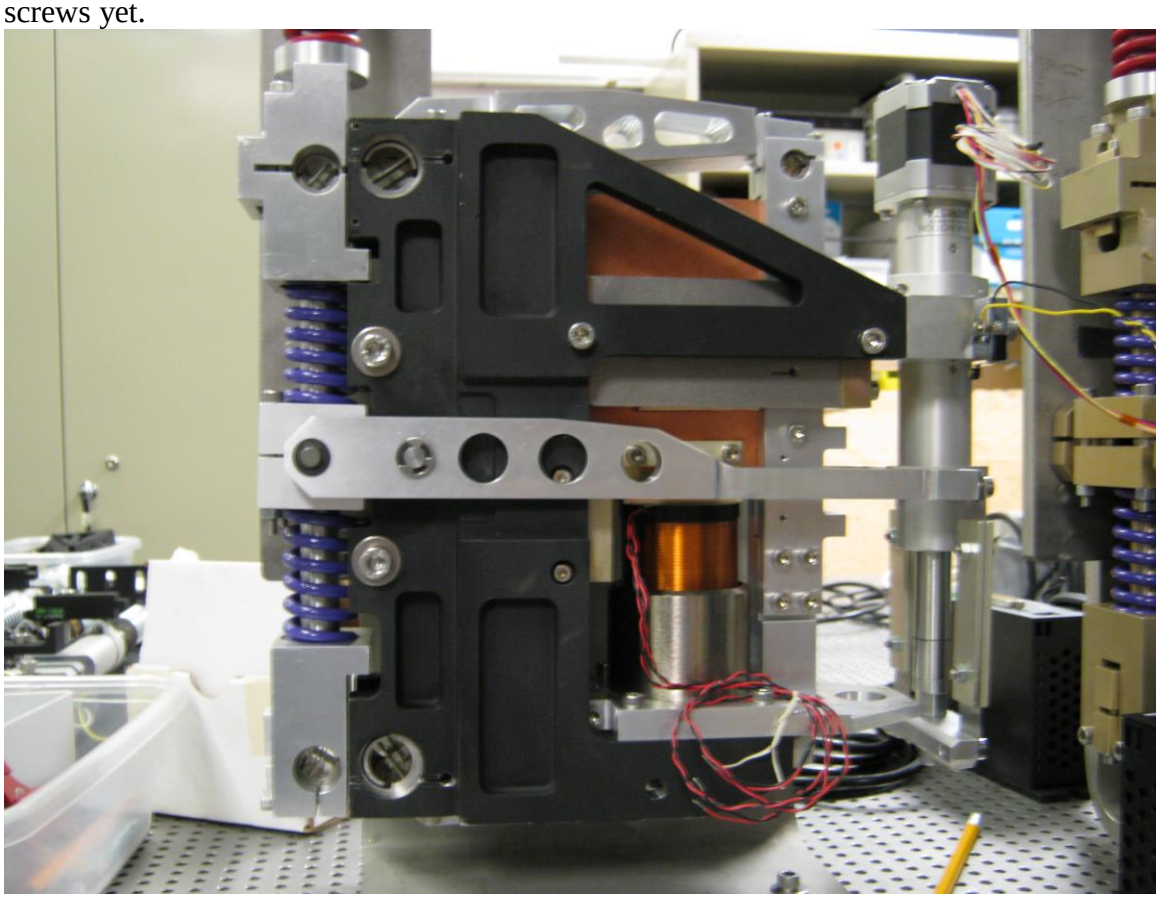
At this point, all fasteners should have been tightened – this would be a good time to check.

Finally, confirm that the mechanism can move freely with good clearance and without any binding or friction whatsoever over its full range of motion.

2.4. Install the offload mechanism and motor

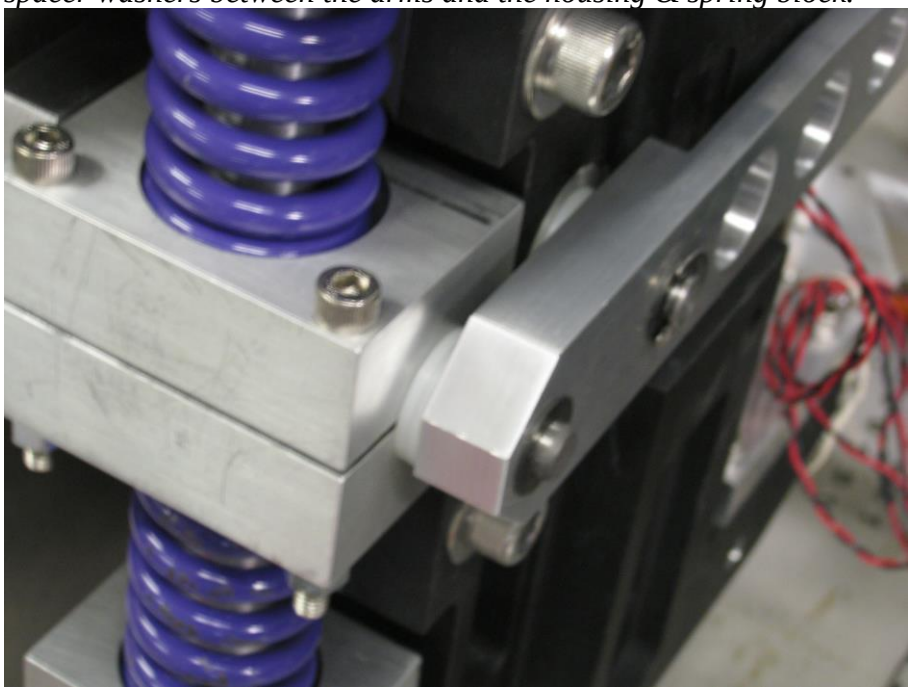
Install the offload arms (TMT-106, -126) and the four Rulon bushings (TMT-201); make sure there are plastic spacer washers behind the arms to prevent the arms from touching the casting or the spring blocks. Install the two clips on the ends of the offload pivot pin in the actuator housing.

Install the stiffeners (TMT-124) to the blade flexures (TMT-123), and then install the blade flexures as shown on the right side of picture. Do not fully tighten the flexure end screws yet.

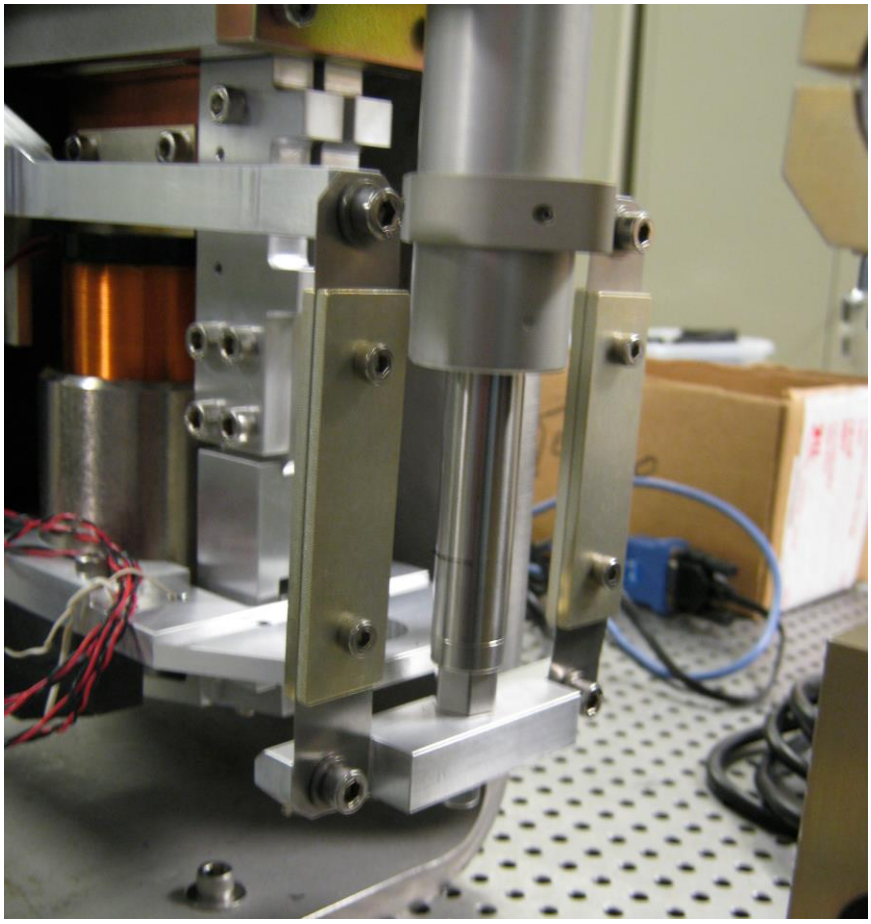


(while shown in the picture, the offload motor is not yet installed at this stage).

Detail showing spring clips at end of the offload pivot pin through actuator housing, and spacer washers between the arms and the housing & spring block.

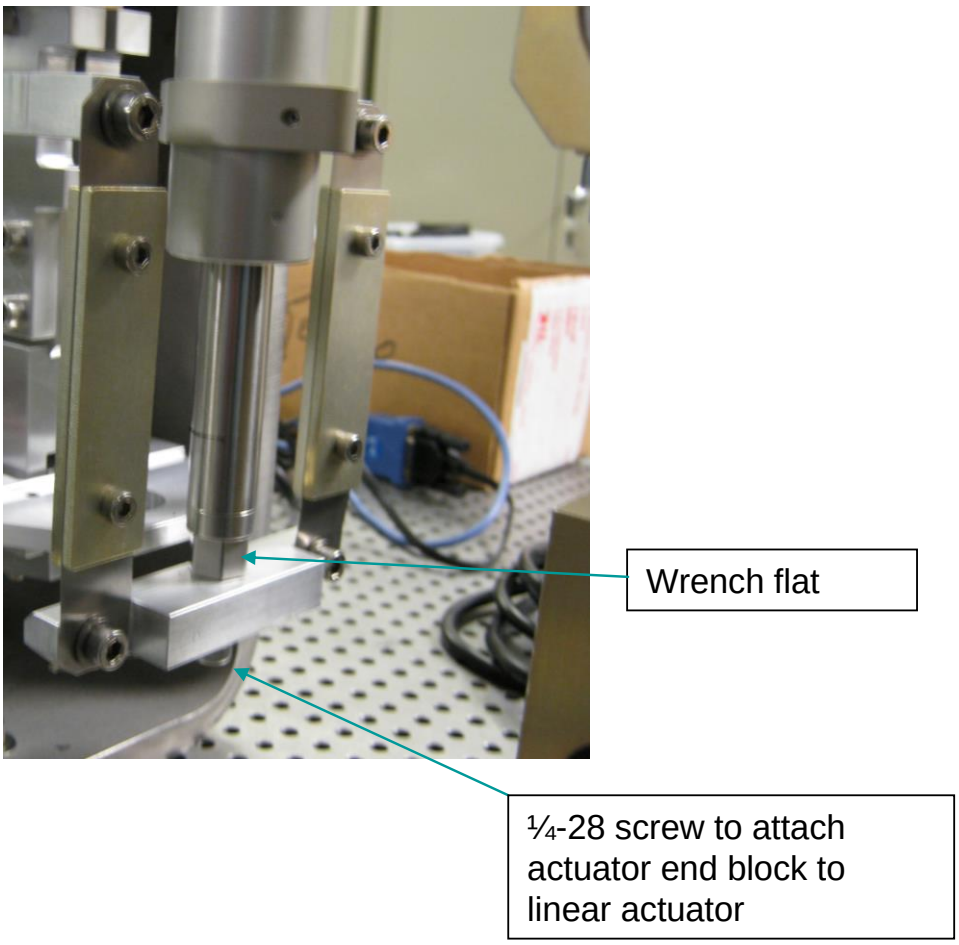


Detail showing the blade flexures and stiffeners, washers, and the orientation of the end block.



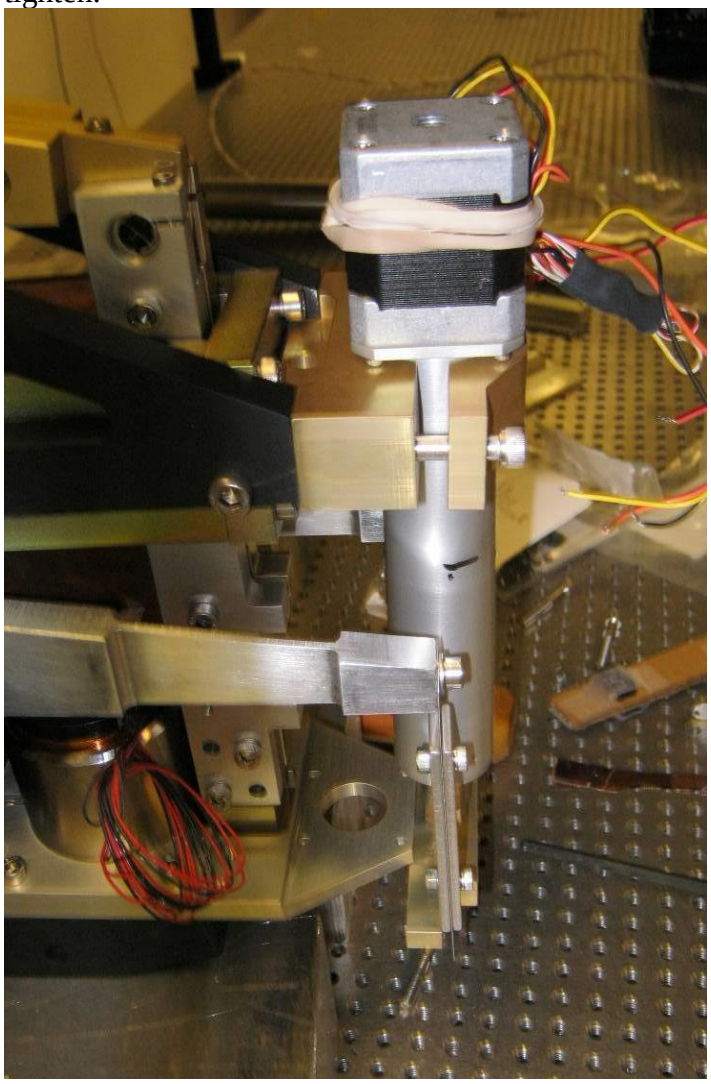
Verify that the actuator arms can move freely over their range of travel.

Install the actuator end block (TMT-120) to the end of the linear actuator (TMT-301). When tightening the ¼-28 attachment screw, use a wrench on the flats of the actuator output shaft to avoid putting a torque on the actuator (which could damage the internal anti-rotation device).



If the snubber is to be installed, do it at this stage. Instructions for installing the snubber are given at the end. For the prototype actuator, install the snubber to do a fit check, but then remove it before proceeding.

Install the offload actuator clamp halves (TMT-114, -115) and the actuator and hand tighten.



(see the text for the correct motor depth in the clamp)

Position the actuator in the clamp at a distance of 41 mm from the bottom of the motor. Orient the motor so that the actuator end block is parallel to the back of the VC mounting plate, and tighten the clamping screws. (In final production model assembly, a simple gauge will be used to locate the actuator). Now tighten the screws at both ends of the blade flexures.

2.5. Remaining tasks

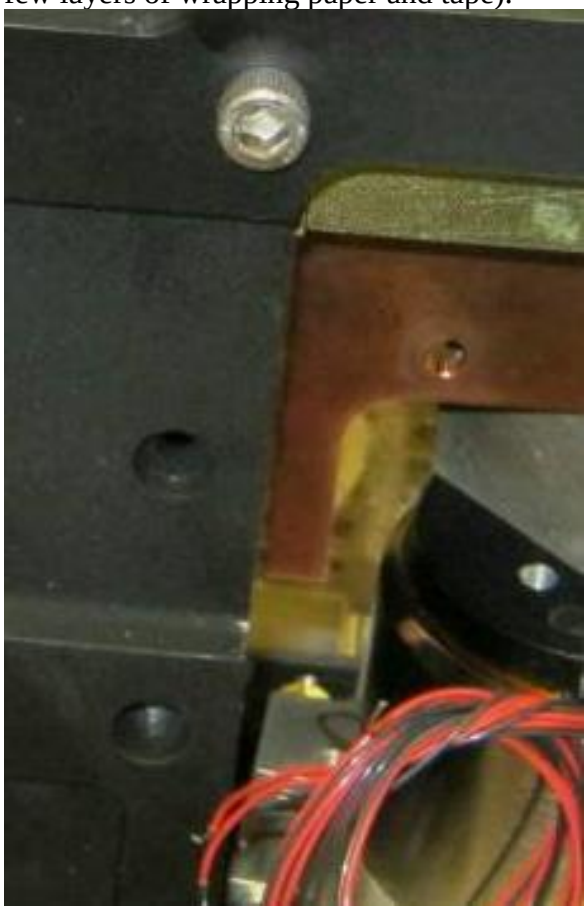
2.5.1. Encoder installation

The actuator has two possible encoder locations. We describe installation at both locations, below. The production actuator will include only one encoder. For the prototype actuators, the location is at the output [TBC].

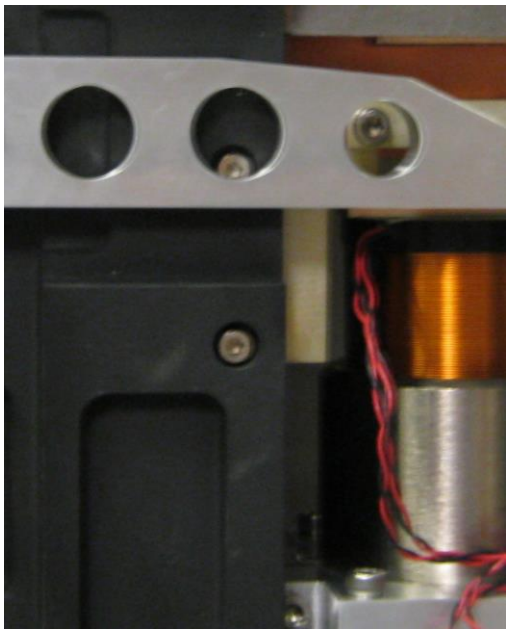
A Mercury II Alignment Tool (ATMII5000-S; an electronics box with status LEDs that connects to the encoder output) is required to verify correct encoder installation.

Voice-coil encoder: Install the encoder scale (TMT-311): it is attached to the tang at the bottom of the copper pate at a distance TBD from the bottom and TBD from the edge closest to the voice coil. For the prototype, it is positioned manually and attached using tape adhesive.

(For production, the scale would be installed on the copper plate earlier in the process using a locating template and a UV-curing epoxy, and then protected until this stage by a few layers of wrapping paper and tape).

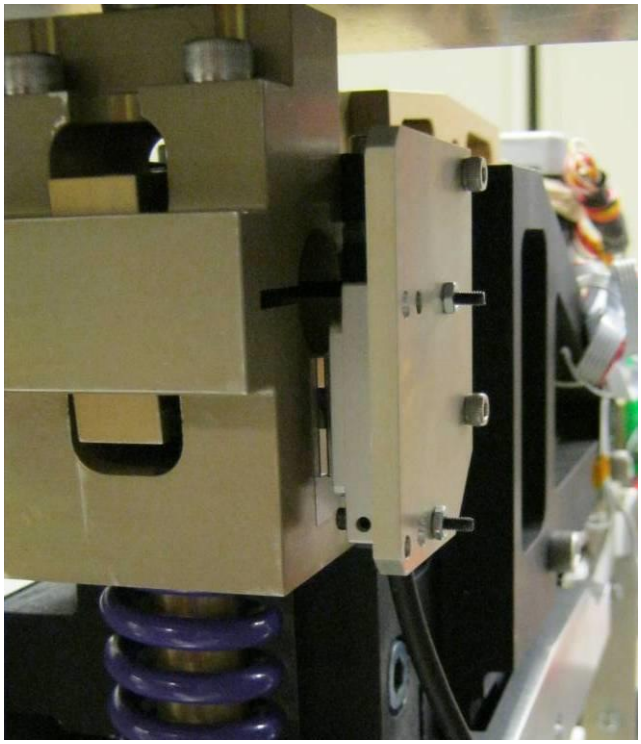


Mount the encoder head (TMT-310) to the encoder bracket (TMT-128), and mount the bracket to the housing. To avoid scratching the encoder scale, use a soft cloth to keep the encoder head from touching the scale until the screws are tightened. (For production, the encoder would also be installed earlier in the process, and protected until this stage by a few layers of wrapping paper and tape.)



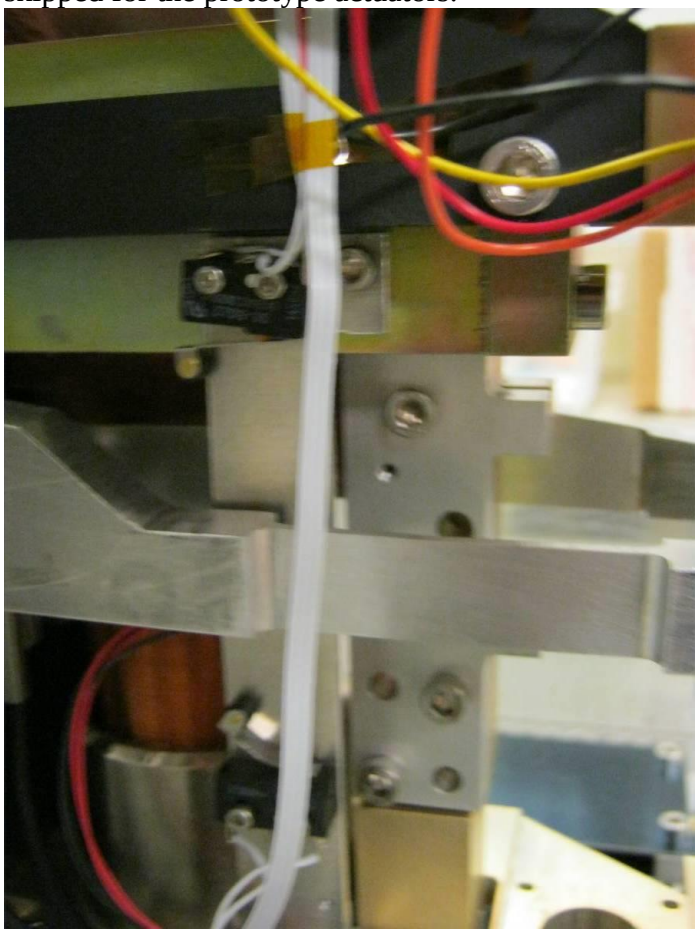
Use the Mercury II encoder alignment tool and verify proper signal over the range of travel of the actuator, and adjust the encoder mounting bracket as required.

Output encoder: The output encoder and scale is installed and verified following a similar procedure, using output encoder bracket (TMT-132).



2.5.2. Limit switch installation

Install the limit switch bracket (TMT-133), limit switches and wiring. This step can be skipped for the prototype actuators.



2.5.3. Snubber installation

Snubber installation must be done before the offload motor is installed (or the motor must be temporarily removed). Install the plastic (PEEK) bushings at both ends of the 8 mm hole in the actuator clamp base. Thread the tracking screw (TMT-116) into the Delrin guide (TMT-118); insert the screw through the hole and align the guide with the tabs on the linkage. Attach the tracking screw sleeve (TMT-130) to the NEMA 17 motor (TMT-330), and install the motor at the bottom of the VC mounting plate (TMT-111). Attach the tracking sleeve to the tracking screw, and attach a retaining clip to the top of the tracking screw where it extends through the actuator clamp base.

2.5.4. SSA adapter bar attachment

This bar (TMT-131) attaches to the back of the actuator, and is used for mounting the actuator to the SSA. Do a fit check, but do not attach it for the prototype.

2.5.5. Output flexure rod and rod restraint tube

These (TMT-140, -141) attach to the actuator output. Do a fit check, but do not attach them for the prototype.

2.5.6. Actuator marking

Mark each actuator with a unique serial number. For production, a numbering scheme will be provided.