

TMT primary mirror segment actuators – from prototyping to production

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Introduction

The Thirty Meter Telescope project began the development of the primary mirror (M1) segment actuators at an early stage. A down-select process led to a soft actuator design that was selected for further development, and this has progressed to an advanced pre-production 'P3' prototype. As of May 2024, P3 actuators produced in India are being evaluated by TMT in Pasadena.

Design decisions

Hard vs. soft actuator

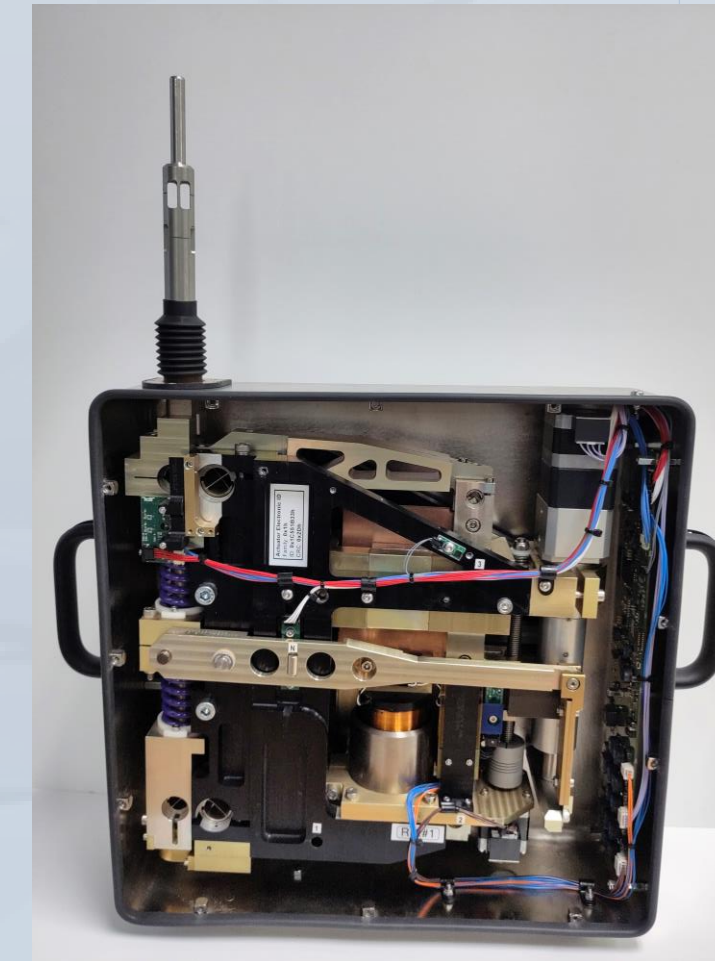
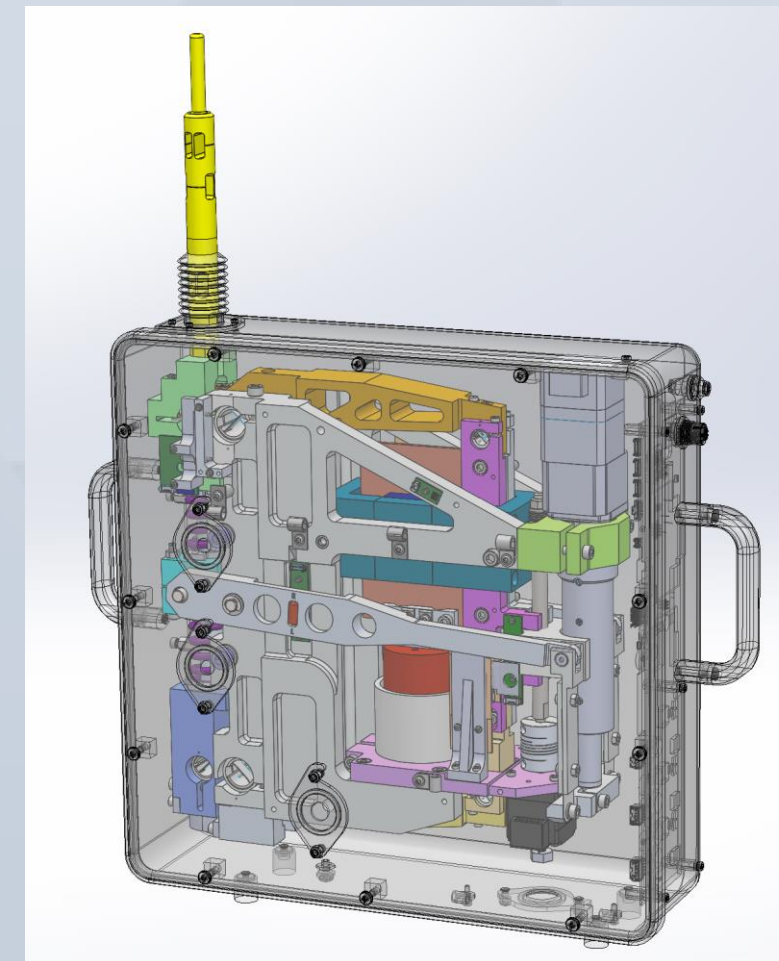
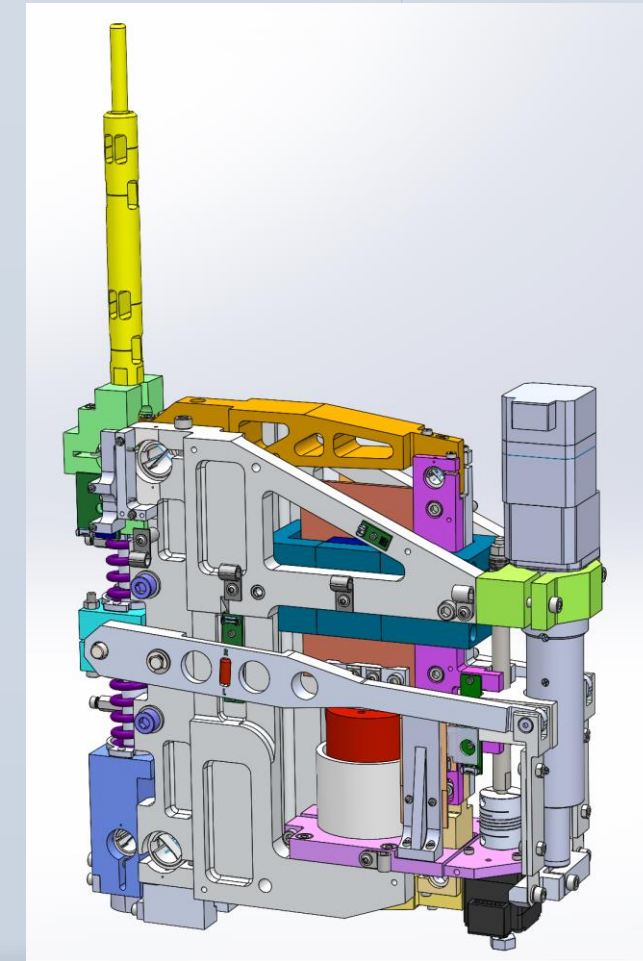
Hard (rigid) actuators have high intrinsic stiffness and therefore deliver good wind rejection performance and inherent static load-bearing capacity with simple control, but may require external damping.

Soft actuators have low intrinsic stiffness, which is therefore typically delivered by control action (i.e. a closed loop servo system). However, their dynamic response, which can include damping, is highly optimizable via control design and tuning of the closed loop servo system.

Quasi-passive offloading

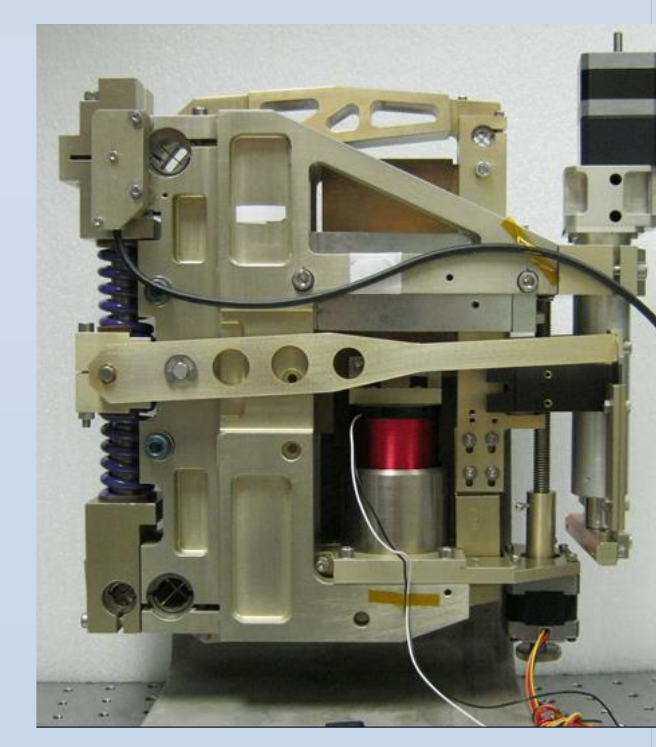
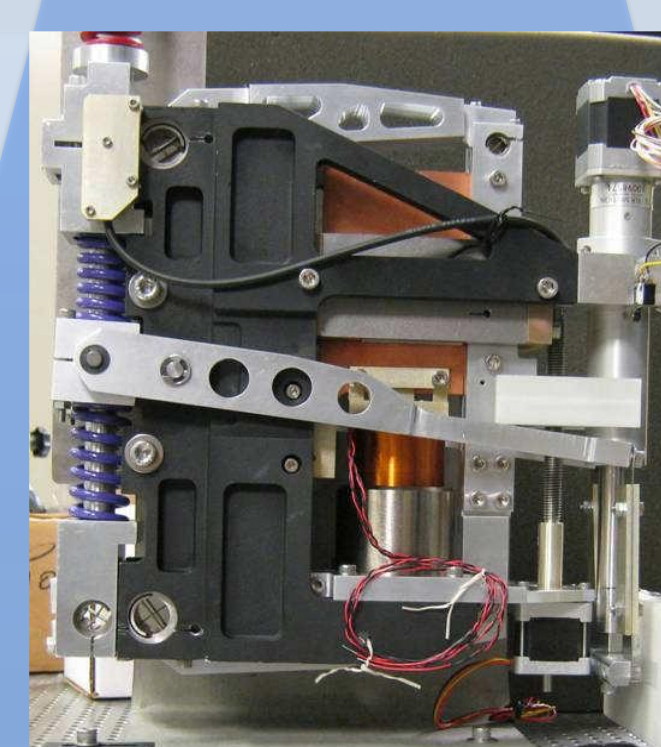
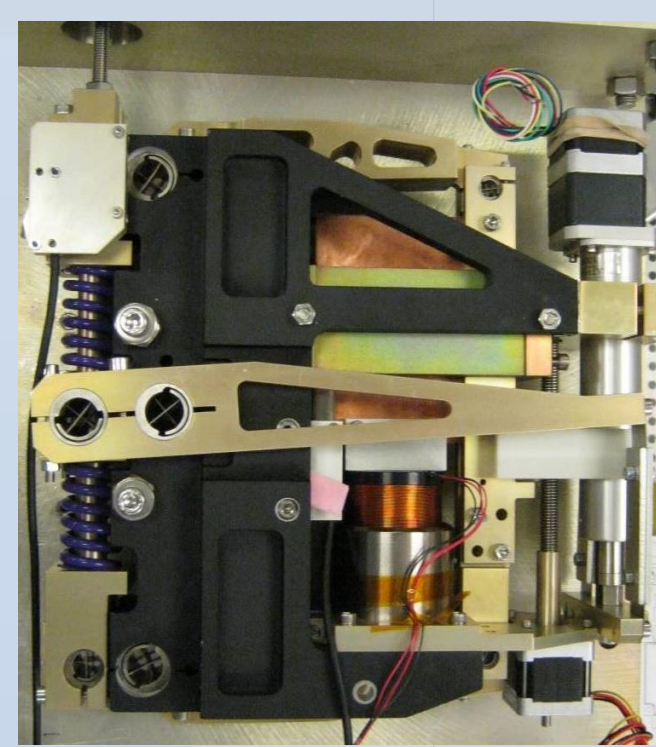
A disadvantage of a soft actuator is that it provides no inherent rigidity (stiffness) to support the quasi-static load of a primary mirror segment. This limitation was circumvented in the successful P1 designs by incorporating a self-adjusting spring-based lever mechanism to carry this static load. It requires another servo loop to control, but delivers considerable benefit in terms of overall power saving at the soft (voice coil) actuator while retaining the dynamic advantages of the 'soft actuator' approach.

M1CS actuator development



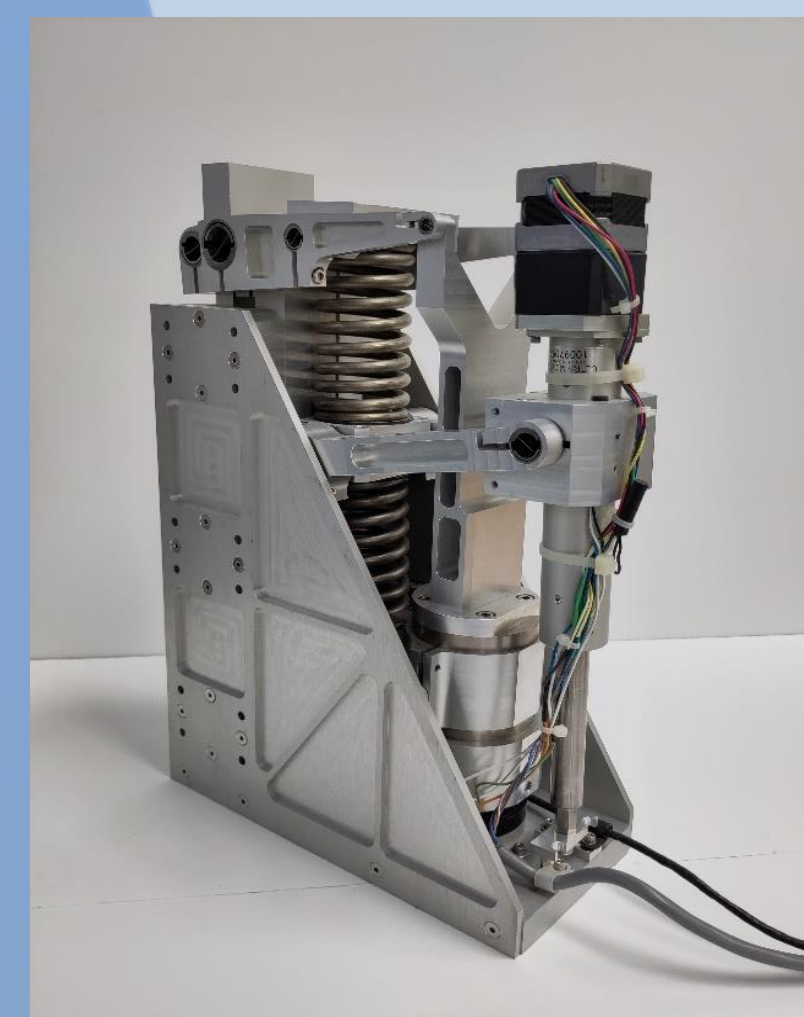
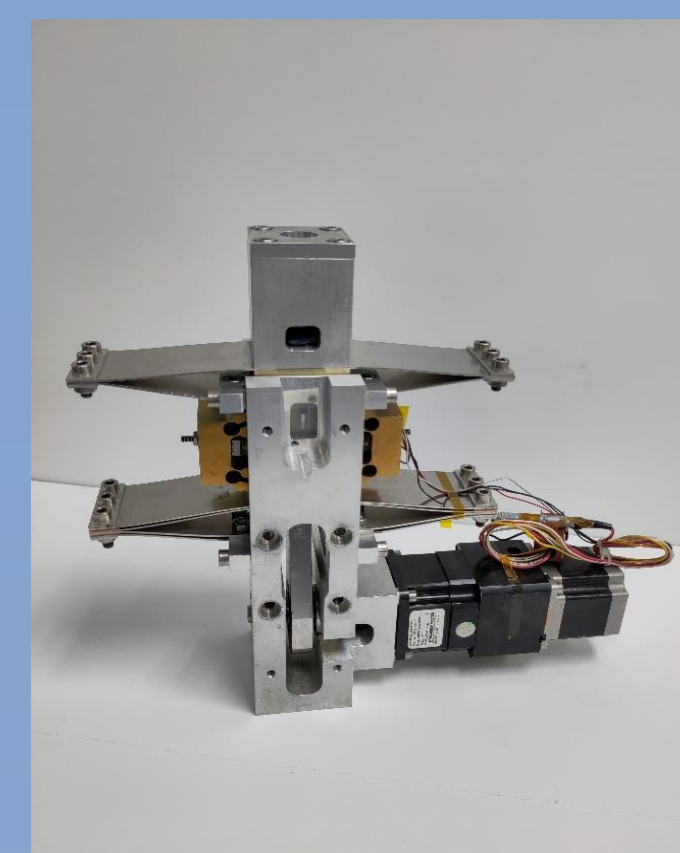
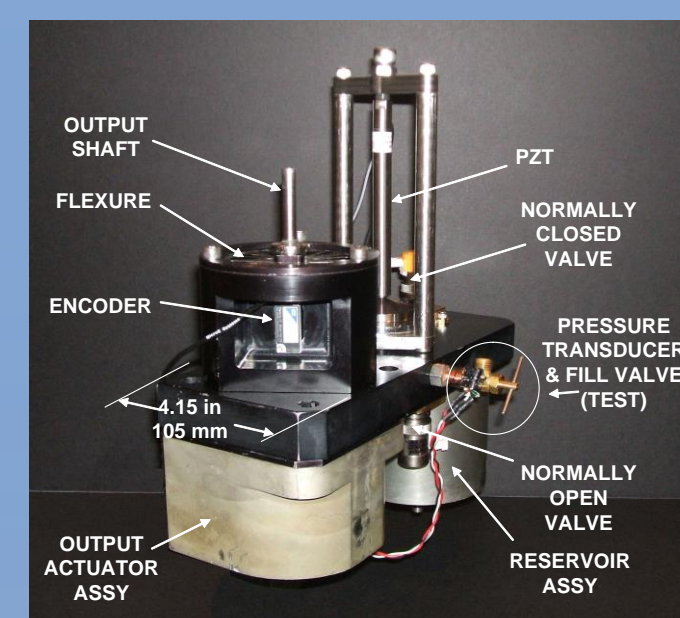
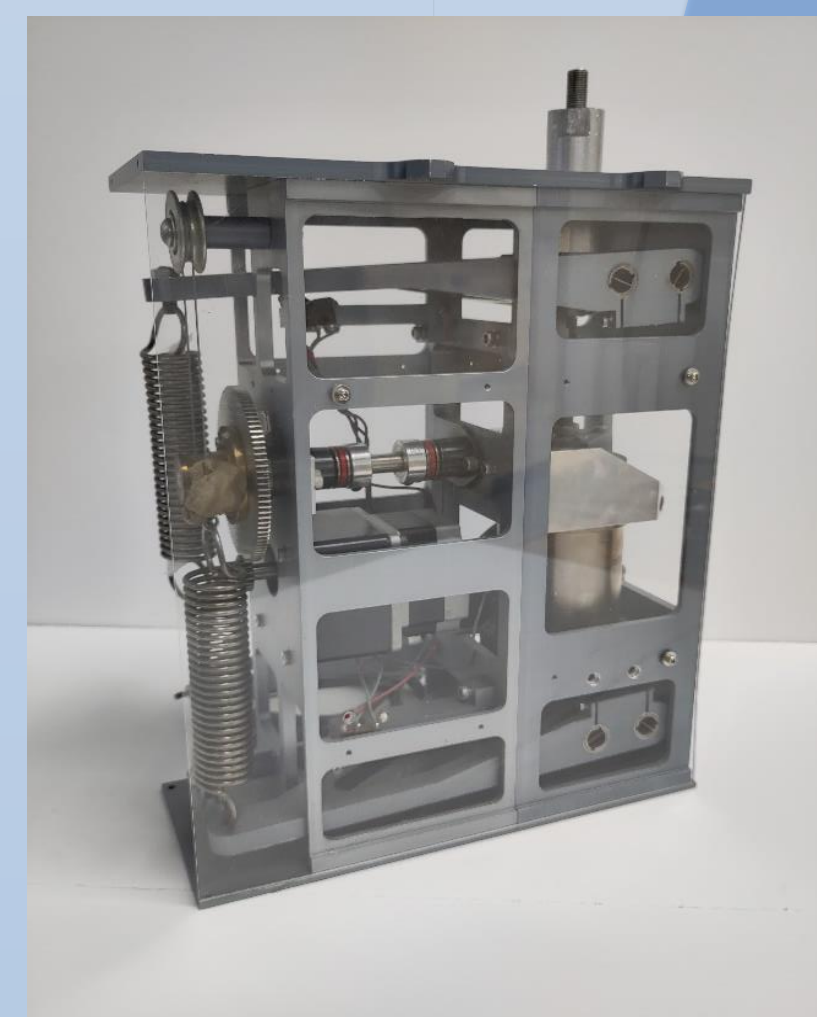
P3

The advanced pre-production P3 actuator prototype, including integrated control electronics and the enclosure.



Soft-actuator prototypes (left to right): P2a, P2c & P2e. Design changes and improvements were made throughout P2 development.

P2



P1

P1 and P2-concept hard and soft actuator prototypes developed for TMT by (clockwise from left) Marjan Research (P1), The Pilot Group (P1), Marjan Research (P2 concept), JPL (P1).



Hard actuators are successfully used to position the primary mirror segments on the W. M. Keck telescopes.

Keck

Soft-actuator prototype from 2002, developed by Marjan Research from a concept for the California Extremely Large Telescope (CELT) project, which later became the TMT.



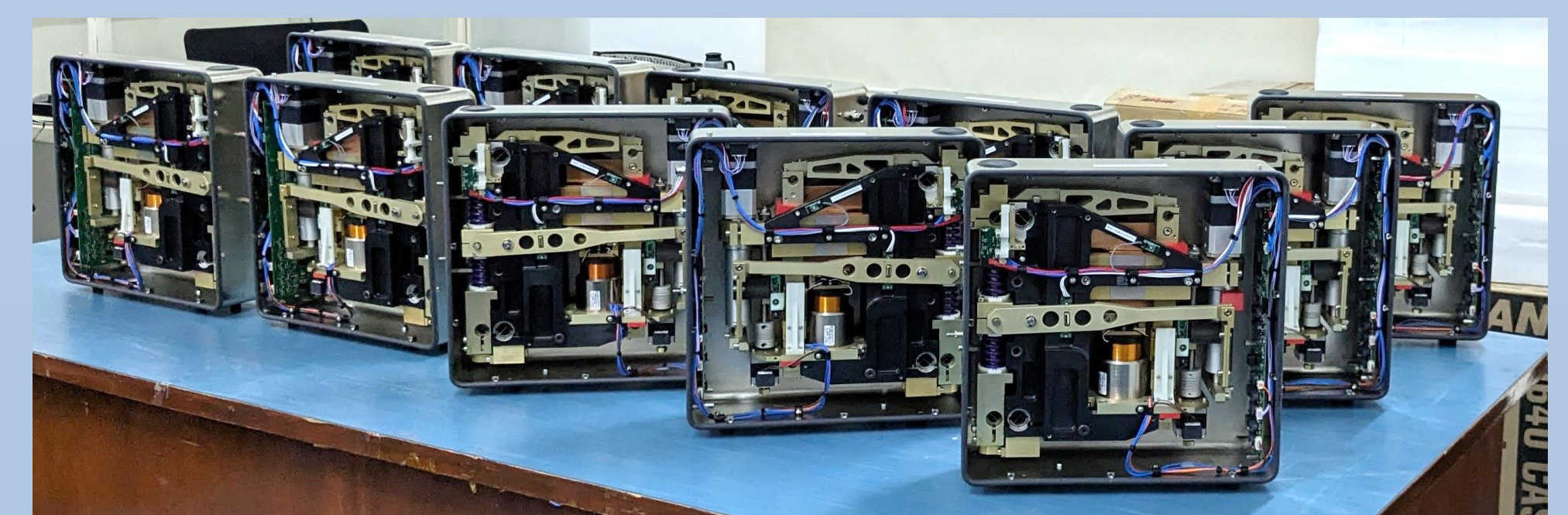
TMT P0

Design evolution

Early in the actuator development process, a down-select was carried out between hard and soft actuators. Prototypes from several vendors were tested and evaluated, and a soft actuator technology approach was selected, based on a Marjan Research design (evolved from two earlier Marjan prototypes). A series of P2 prototypes evolved from this design, incorporating improvements to performance, functionality, and interface, and informed by extensive testing. Recently, a near-final P3 design was completed and fabricated, including integrated control electronics and all interface features.

PQP & initial production

Since 2017, TMT and the India TMT Coordination Centre (ITCC) have successfully produced 49 M1CS actuators as part of P2 and P3 prototype rounds. Close collaboration and valuable feedback from the production teams has yielded consistent improvements to the design and have enhanced the manufacturability and overall quality of the actuators. A Production Qualification Phase (PQP) was critical in assessing vendor capability and performance and selecting those suitable. Vendor selection also had to meet strict Indian government requirements regarding the placement of contracts by ITCC. Four vendors were initially selected, with two active in the latest round.



P3 actuators produced by AMADO for ITCC

Current P3 testing

Eight P3 actuators produced by TMT India are currently being put through detailed performance evaluation testing in Pasadena, California having passed post-production functional testing in India. This will inform a final round of updates prior to full production approval.