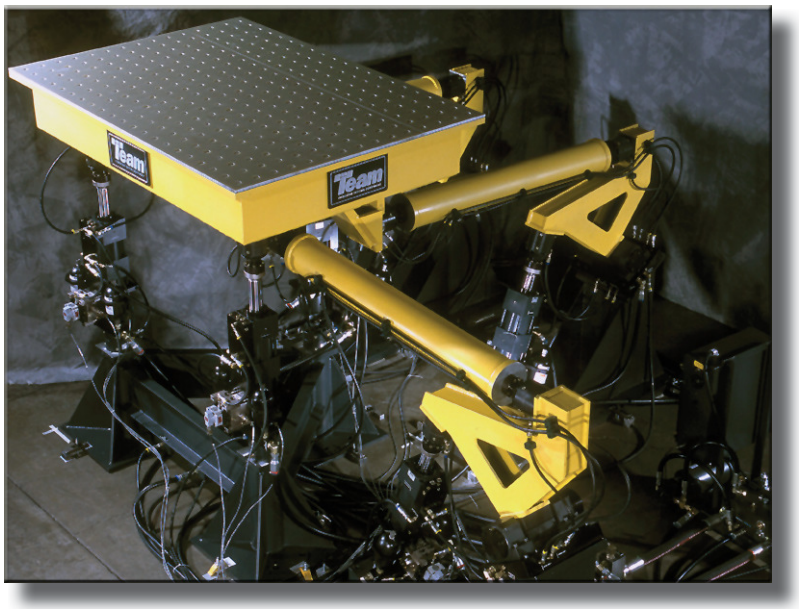
Team
Vibration Testing Equipment

Mantis™

Vibration Test System

Systems & Solutions



Engineered vibration testing solutions for improved product quality.

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Team Corporation's MANTIS™ is a Proven Performer, Providing High Frequency Full 6 DoF Excitation.

The ability to accurately reproduce field conditions is essential for efficient utilization of laboratory time. Product development and validation demand a proven test platform, where durability and reliability are key characteristics. *Team* Corporation is a recognized pioneer in the development of multi-axis test system design, incorporating lessons learned in the creation of the world's most versatile test systems.

Team Corporation is focused on providing solutions to multi-axis vibration requirements. Our heritage extends from the 1950´s and includes the design of some of the world's first multi-axis test systems. With the introduction of MANTIS™, *Team* Corporation continues to set the standard for high performance 6 Degree of Freedom (6 DoF) test systems.

Our multi-axis test systems have been delivered to leading companies in the United States, Europe and Asia, with over 30 installations in operation today. MANTIS™ is the system of choice for its high frequency capability, large displacement, extended payload capacity and demonstrated superiority in design. Through the use of hydrostatic bearing technology pioneered by *Team* Corporation in the vibration test market, MANTIS™ has the performance to simulate real-world events previously unattainable.

Custom engineering is a hallmark of *Team* Corporation. By offering both standard models and systems tailored to special requirements, MANTIS™ can meet a wide variety of testing needs. Table size, payload capacity, stroke length and a wide range of excitation levels are possible. All bearing surfaces are hydrostatic, eliminating the noise inherent with mechanical bearing designs. The high load carrying capacity and extreme stiffness of hydrostatic bearings make them ideal for reacting loads for extended time periods. An added benefit is the absence of metal-to-metal contact, eliminating friction and consequently improving long-term performance.

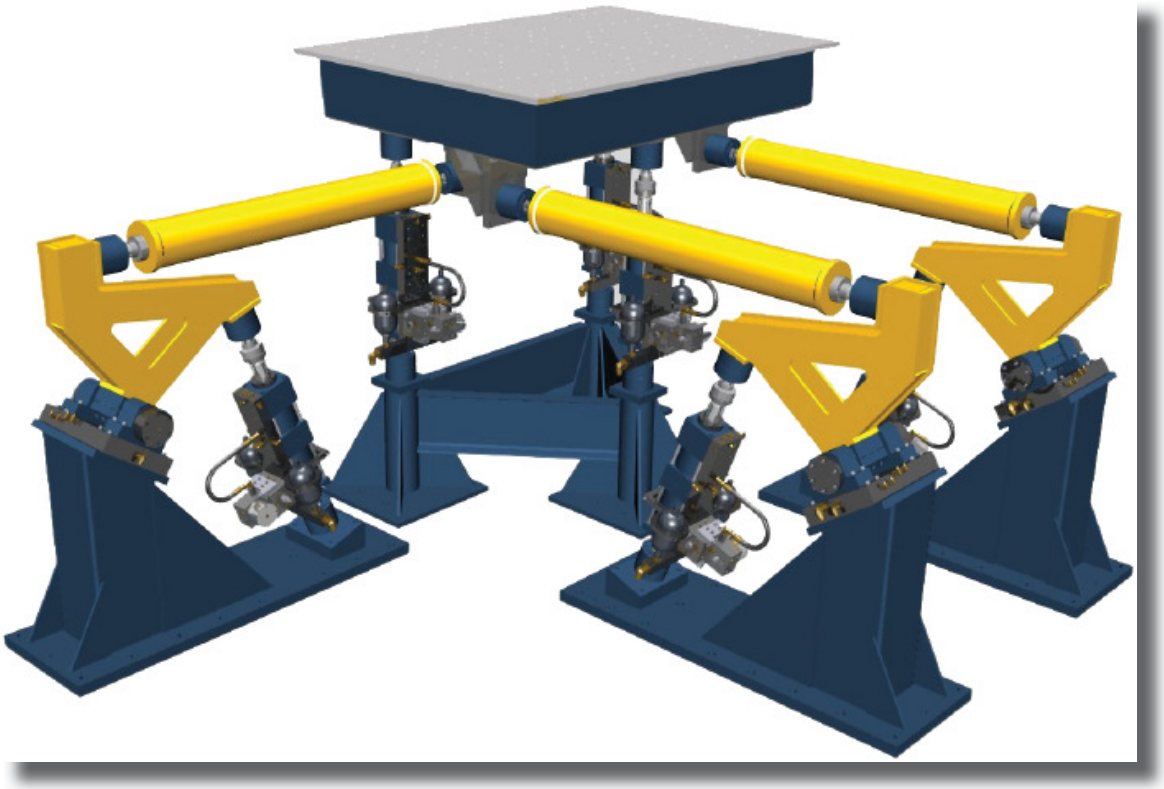
MANTIS™ permits users their choice of test controller options as well. The design of MANTIS™ does not limit the customer to a proprietary test controller. A demonstrated ability to operate with every multi-axis test controller on the market, including offerings by MTS, Data Physics, LMS, IMV, IST and FCS-COM ensures the best combination of application software and price. This versatility permits the customer to maintain commonality within the lab, reducing the time needed to bring operators on-line with new equipment.

System availability is essential to maintaining cost effective lab operation. High frequency vibration testing places severe stress on typical swivel connections used to attach actuators to the moving table. *Team* Corporation pioneered the use of hydrostatic bearings to combat this design weakness. Our hydrostatic bearing connections never need adjustment, resulting in more efficient use of laboratory testing time by eliminating the need to "tune" table response to each different drive file.

Installation in a thermal chamber is complicated for conventional table designs and adds an increased level of stress to test system components. With all actuators located below the table surface and a proven thermal protection package, installation in a chamber poses no extraordinary problem for MANTIS™.

By eliminating the sources of the most common maintenance problems, our customers are assured a high level of system availability. When service is required, *Team* Corporation has a dedicated group of service engineers to address the problem quickly and effectively.

From concept to reality - *Team* Corporation employs state-of-the art computer drafting, engineering and analysis software to produce engineered test solutions our customers use to improve their product quality.



Design software 3-D rendering of the MANTIS™.

Actuator and valve assembly.

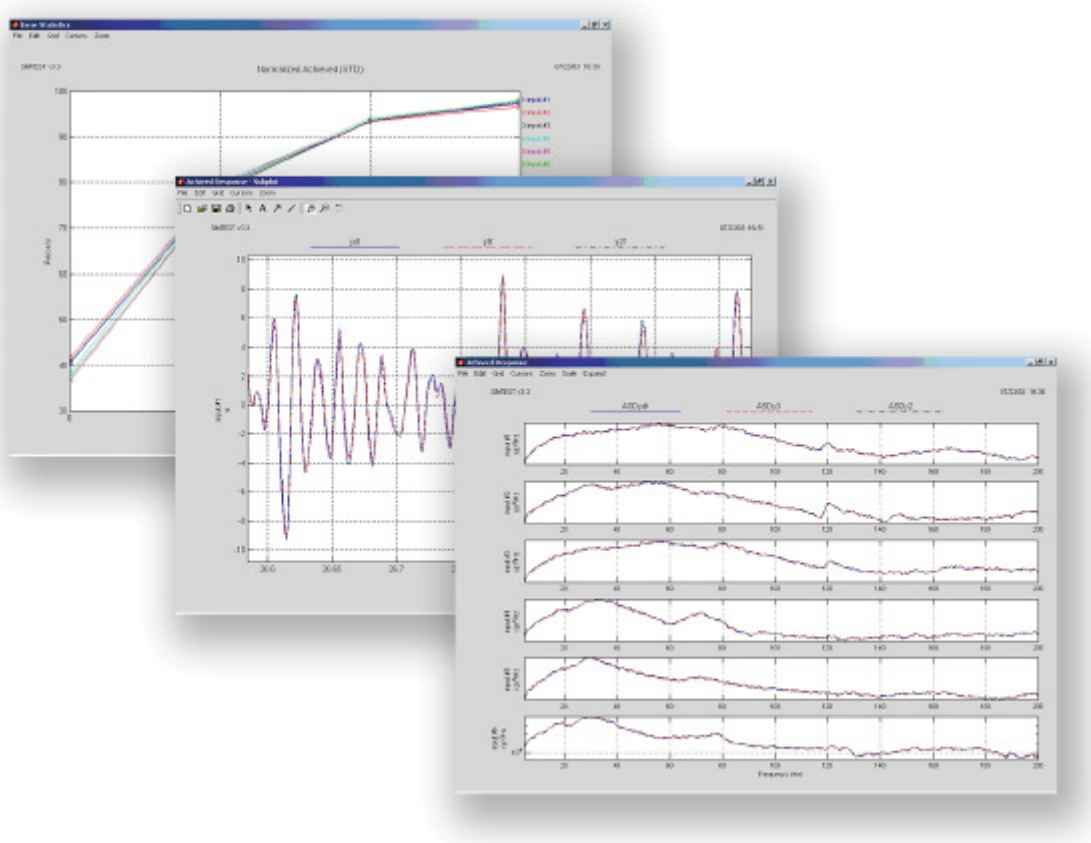
MANTIS™ can been used successfully to simulate the service environment of a wide array of automotive sub-assemblies, including instrument panels, seating systems, fuel tanks, radiators, and others. The ability to accurately reproduce the measured service conditions to a higher frequency level than other, more conventional systems is a critical advantage of MANTIS™. The test excitation methods that can be used include:

Simulation

Test data preparation involves the elimination of low-level portions from the recorded field data. The result is a compressed drive file exhibiting only the high-energy transients produced on the test track. To be effective, the laboratory test system must be able to reproduce this compressed drive file, accurately tracking the rapid changes in displacement, velocity and acceleration over a broad frequency band. MANTIS™ is ideal for this application; in fact, the primary design criteria during the development of MANTIS™ were accurate reproduction of extreme field conditions.

Simulating Real-World Conditions is Key to Compressing Test Schedules

Applying operational vibration loads to vehicle components and sub-assemblies requires the reproduction of road surface irregularities in all 6 Degrees of Freedom (6 DoF). *Team* Corporation´s MANTIS™ has the proven capability of accurately replicating typical road loads both in full 6 DoF through an extended frequency band of more than 100 Hz. Analysis of recorded road data shows considerable energy is present at these higher frequencies, necessitating a system capable of controlled excitation through a broad bandwidth. MANTIS™ has demonstrated the ability to provide this functionality.



Example of Road Data Replication showing Desired and Actual Response to 200 Hz.

Random

Some test programs define a test profile using an auto-spectral density or PSD. Here, the laboratory test system must produce a Gaussian distribution of amplitudes, which results in the proper combination of acceleration levels through a defined frequency band. The result is a statistically stable program that has proven effective and is used extensively in vibration testing. With a higher frequency capability, MANTIS™ can be used to generate a PSD encompassing a broader range of operational conditions.

Sine

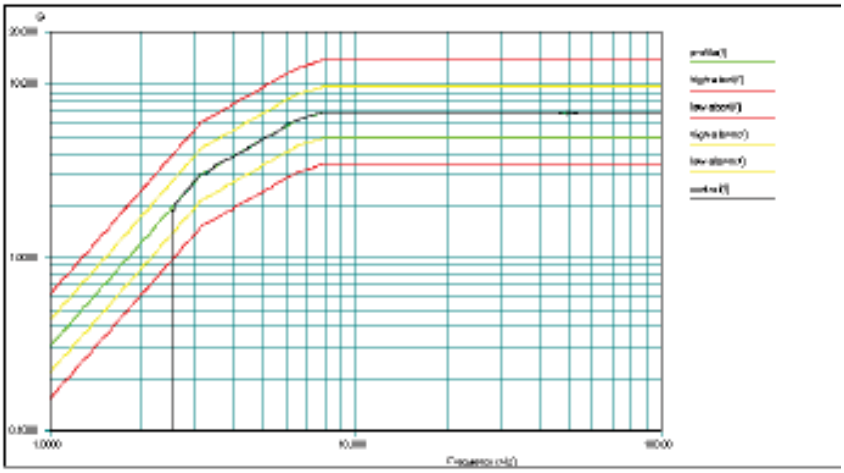
Sinusoidal excitation is used to isolate resonances, accumulate damage at specific frequencies, or excite squeaks and rattles that are frequency dependent. The frequency and/or amplitude of the sine wave may be swept or dwelled to allow the user a flexible means of resonance identification. MANTIS™ has an extremely stiff table structure and actuator connection scheme. This minimizes the dynamic response of the test system, permitting more accurate sinusoidal test results.

Durability

MANTIS™ is ideally used to assess the durability of a wide variety of components and subassemblies ranging from fuel systems to seats, instrument panels and interior components. Test methods are usually based on simulation of multi-axis service conditions where maintenance of phase between the axes is important. Cycle or block cycle loading can be used where accelerated tests of simple components, like brackets need to be accomplished. The high transmissibility of our hydrostatic bearing connections in MANTIS™ provides a more stable table response during long duration durability testing.

Noise and Vibration

Squeaks and rattles are a predominant indicator of subjective vehicle quality. MANTIS™ is particularly well suited to investigate such noises. Caused by components either rubbing together or resonating, these noises are generally nonlinear in nature, occurring at discrete frequencies or amplitudes. The ability of MANTIS™ to reproduce the excitation causing these noises makes it invaluable in their isolation. And, the use of hydrostatic bearings throughout the design of MANTIS™ reduces the overall level of noise generated by the test system, improving the ability of the test lab to characterize noise qualities of the test object.



Plot of EX Series actuator performing a sine profile at 7 g´s out to 100 Hz.

EX Series fatigue-rated actuator assembly with HydraBalls.

Engineered for the Accuracy, Durability and Dependability Demanded by Test Professionals

System dynamics influence the performance of any vibration test system. Engineering a system that has not only the required specifications of force, velocity, displacement and frequency response, but also exhibits well-damped and controllable dynamic behavior is a formidable task. *Team* Corporation designed the MANTIS™ incorporating an array of proven components to achieve the exceptional level of performance demonstrated in operation.

Team Corporation, with over 50 years of design experience in vibration test systems, focused the development of MANTIS™ on dynamic behavior. The goal was to eliminate structural resonance within the operating band of the system. This ensures test results will not be influenced by system dynamics.

Team Corporation accomplished this task by designing a system to address customer requirements, not by revamping an existing design. The result is MANTIS™, a system that optimizes actuator design and table stiffness for high frequency response.

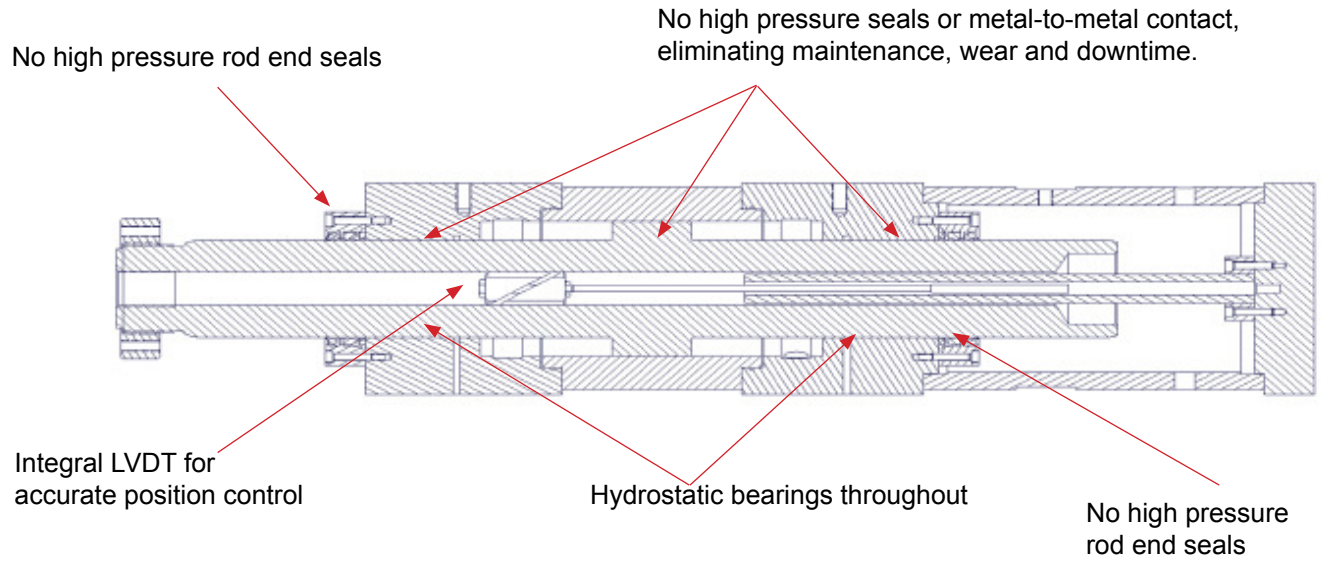
Evaluation of a multi-axis test system begins with an exploration of bare-table capabilities. But proof of system performance is only demonstrated by system response with a mounted test object. The influence of a test object on system response is considerable, changing the center of gravity effects performance levels and test object resonances will alter the dynamic behavior of the entire assembly. The robust design of MANTIS™ minimizes the effect of payload resonance, permitting the innovative actuator and coupling design to achieve high levels of performance. These integral features ensure the best possible reproduction of desired test profiles. They also contribute to the broad frequency response exhibited in actual test results.

Hydrostatic Actuator

The key innovation to MANTIS™ was the development of a new actuator, one that is powerful yet compact, has frequency response well above anything on the market and incorporates all the features that have made *Team* systems synonymous with quality. Produced in-house, *Team* is able to apply strict quality assurance procedures to manufacturing and maintain control of all production scheduling to ensure technical excellence and on-time deliveries.

Our actuator design uses no dynamic seals; every bearing surface within the assembly is hydrostatic. Hydrostatic bearings are well recognized as the best solution for supporting and transmitting loads in a vibration test system. They are remarkably stiff ensuring very high transmissibility of force. Eliminating any metal-to-metal contact generates no friction and no wear on adjacent surfaces. For all intents, they can be considered to have infinite life. Requiring no periodic adjustment, maintenance is virtually non-existent.

A fundamental limitation to servo hydraulic actuator performance is a phenomenon called “oil column resonance”. Dependent upon the trapped volume of oil between the actuator piston and servovalve, it constrains the upper limit of possible frequency response. The only way to raise oil column resonance, or raise frequency response, for a given actuator size is to minimize the trapped oil volume. The actuator used in MANTIS™ reduces this trapped volume to an absolute minimum by locating the servovalve in an optimum position. This eliminates the long oil passages required by conventionally mounted valves. It also reduces the inertia of the oil column to flow, improving actuator response to changing velocity requirements. Gas charged accumulators are needed for servo hydraulic test systems to attain short duration, high velocity transients. To provide the best response, the accumulators must be mounted as closely as possible to the servovalves on each actuator. MANTIS™ has both pressure and return accumulators located directly on each valve manifold with extremely short fluid paths. This ensures lag-free velocity response to command signals. Pressure and charging ports for each accumulator are conveniently located for simple maintenance.



Team's fatigue rated EX Series actuators provide superior durability test system performance.

Hydrostatic Bearings

Coupling the actuator to the moving table is perhaps the most problematic issue in multi-axis system design. The coupling must be free of backlash to prevent corruption of test data by rapid load reversals. Typical solutions on other multi-axis test systems use pre loaded mechanical bearings. In order to function, these bearings have internal clearances that are minimized through a manually adjusted preload clamp mechanism. If the preload is set too low, the result will be poor transmissibility of force and noisy operation. If the preload is set too high, large bending moments are transmitted to the actuator piston, resulting in accelerated wear. Correct preload is vital to system performance and must be checked prior to test initiation. Finally, mechanical bearings wear very rapidly in high frequency testing. This wear phenomenon of the bearing surface is called "fretting." As a result of fretting, the swivel connection requires regular preload adjustment and an accelerated replacement schedule.

Team solved the inherent problems of actuator coupling by using a spherical bearing completely supported through a hydrostatic oil film. Called the HydraBall, this device has all the beneficial features of a linear hydrostatic bearing, namely very high transmissibility of force with no friction and no wear. A HydraBall is located on each end of the MANTIS™ actuator. Pressurized oil is continuously supplied to each HydraBall, without any operator or software intervention. By using proprietary restrictor design, the hydrostatic film is always maintained, even under the highest inertial acceleration and deceleration events. This eliminates backlash, and therefore improves test results. HydraBalls require no adjustment and no maintenance, increasing system availability and reducing operational costs.

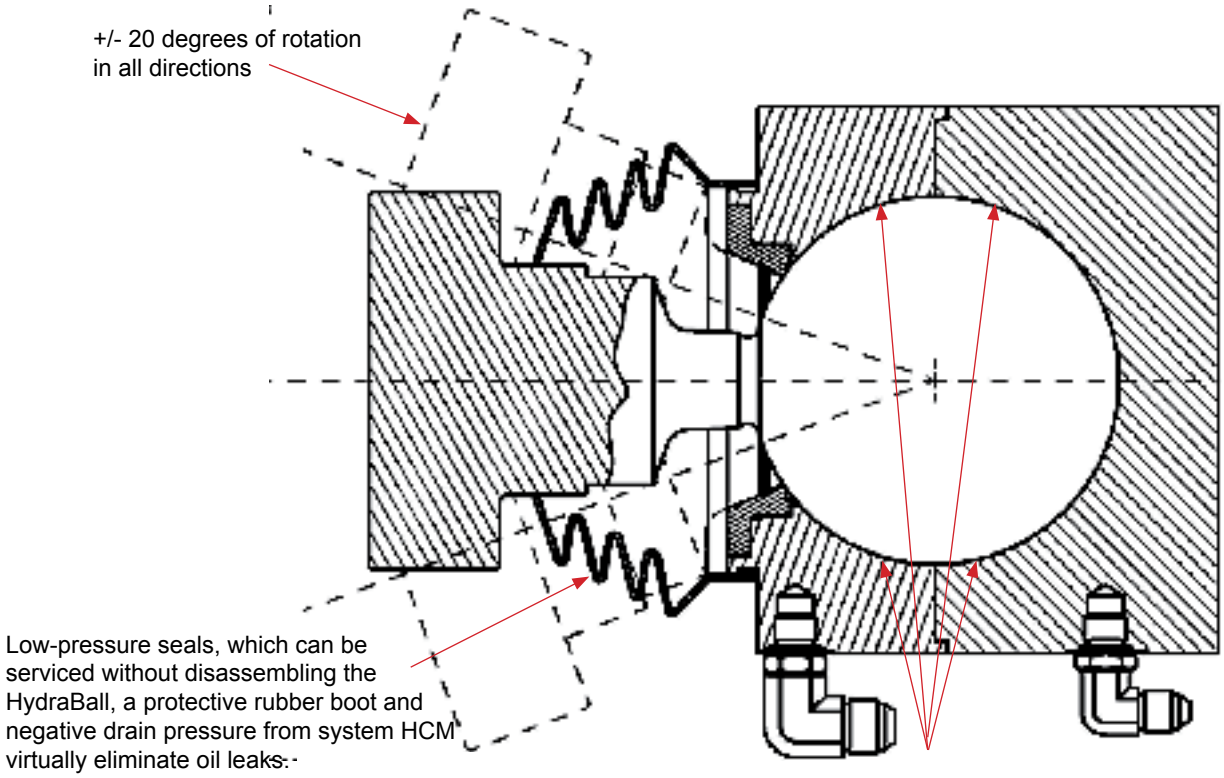
The actuators providing horizontal excitation are mounted vertically to reduce the amount of floor space needed to install MANTIS™. A bell crank is used to create horizontal displacement of the table from these three vertically mounted actuators. The journal bearing supporting each bell crank experiences high loads. In other designs these high loads result in accelerated wear. Bearing wear is characterized by increased backlash and any backlash contributes to noisy table operation. *Team* developed a hydrostatic bell crank bearing to eliminate the problems associated with mechanical bearings used in competing designs. As with our HydraBalls, the hydrostatic oil film is extremely stiff and introduces no friction to the mechanism. With no friction, there´s no wear and periodic adjustment is never required.

HydraBalls on both the MANTIS™ actuator and drive link.

Reaction Mass

All multi-axis simulation tables are mounted on a large reaction mass to achieve their specified performance. The design of this mass is crucial to overall system response. A reaction mass must be dynamically stiff and well damped to avoid interaction between mass response and actuator function. The best way to ensure a stiff, well-damped reaction mass is to optimize its depth or thickness. Generally, such masses are constructed of steel-reinforced concrete, either mounted on air isolators or set on an isolation mat.

Team offers a reaction mass construction kit, including construction drawings and a specialized array of anchoring devices to ensure MANTIS™ is properly integrated with the mass. The reaction mass kit permits a local contractor to build the mass to *Team* specifications. Our anchoring devices are embedded in the concrete yet allow each actuator assembly attachment point to be placed into compression with the full depth of the mass. Each actuator assembly has leveling devices to ensure proper placement and is simply grouted in place once aligned. An array of anchor bolts is then torqued to design levels, securing the actuator assembly and completing installation.



If test lab availability is important to the customer, *Team* offers an air-isolated steel reaction mass with integral constrained layer damping. This approach virtually eliminates facility shutdown for installation since the reaction mass is set in place on a typical concrete lab floor. A steel mass is about 3 times as dense as concrete and has a better stiffness to mass ratio. This results in more ideal performance. An added bonus is the ability to relocate the entire system very easily as test facility requirement change.

Hydraulic Power Supply (HPS) and Hydraulic Control Manifold (HCM)

Trouble-free operation of any servo hydraulic system requires a supply of conditioned hydraulic oil. Valve and bearing clearances have critical tolerances and clean oil at a proper viscosity is vital for accurate operation. *Team* can provide the Hydraulic Power Supply (HPS) correctly sized for the application or MANTIS™ can be operated from an existing HPS. Every MANTIS™ is supplied with a Hydraulic Conditioning Manifold (HCM) which collects and distributes oil supply, return, and drain from the HPS to the MANTIS™ and back again. Monitoring devices are interlocked with the valve controllers to shutdown operation if vital bearing pressure is lost. High/Low hydraulic pressure control and scavenge pump operation is included. A fully functional remote controller is provided at the operator's station for HCM and HPS use.

MANTIS™ Hydraulic Conditioning Manifold (HCM) provides high pressure filtration, safety interlocks, sequencing control and hydrostatic bearing drain oil scavenging.

Demonstrating Flexibility in Application, MANTIS™ Operates with Any Manufacturer's Test Controller

Where as all other multi-axis test systems are constrained to a single choice for test controller option, the MANTIS™ was designed from conception to allow the customer to decide which test controller best suits their needs.

A fundamental limitation with all other multi-axis test systems is the insistence by the manufacturer of determining the test controller to best operate the equipment. *Team*'s philosophy, however, was to design a system to fully function with any manufacturer's test controller. Our broad customer base has demonstrated this capability. MANTIS™ can be easily integrated with test controllers supplied by IST, FCS-COM, LMS, Data Physics, IMV and MTS. This functionality permits the customer to leverage their existing investment in test controllers, reducing capital acquisition costs and minimizing the learning curve for producing meaningful test results.

Every MANTIS™ is supplied with the necessary servo hydraulic valve drivers to interface with drive signals tailored by the selected test controller. The valve drivers accept the voltage signal generated by the test controller and create the appropriate drive signal to each actuator. The position response of the actuator LVDT is fed back to the valve driver, providing real-time position response. The control accelerometers provide acceleration response directly to the test controller, enabling monitoring and correction of the desired acceleration versus the actual acceleration. *Team*'s sophisticated valve driver is a "set and forget" device, transparent to the customer and stable in operation.

Team Corporation has developed close relationships with various suppliers of test controllers. The customer can decide the best combination of hardware and software; *Team* can then act as the prime contractor, supplying both the hardware and software as an integrated package or supply MANTIS™ as a component of the entire test system. The choice is yours. *Team* can provide the solution that's best for your needs.

Regardless of which direction is selected, *Team* works closely with the test controller supplier to ensure a seamless system installation. With the option of selecting the best economy in hardware and software, the customer can receive the benefit of high performance provided by MANTIS™ coupled with a test controller that provides the software modules fulfilling their needs.

Hydrostatic rotary bearing provides pivot for lateral bell cranks.

Team Corporation's Service and Support Group Ensures Test System Availability

Testing programs can be severely affected by downtime due to system maintenance or repair. The MANTIS™, with friction-free hydrostatic bearings and no periodic mechanical adjustment, provides the customer with unmatched reliability. In the event of a breakdown, *Team*'s dedicated service engineers are able to provide effective support in a timely and cost effective manner

A test system is only effective if it can be used when needed. Periodic maintenance must be anticipated and carefully planned to minimize program interruptions. The MANTIS™, with its fully hydrostatic bearing design and lack of dynamic seals, eliminates the most common sources of periodic maintenance. No longer is it necessary to adjust swivel preload or rebuild actuators to replace leaking piston seals. What has been a biannual service requirement on typical multi-axis systems is now fully eliminated.

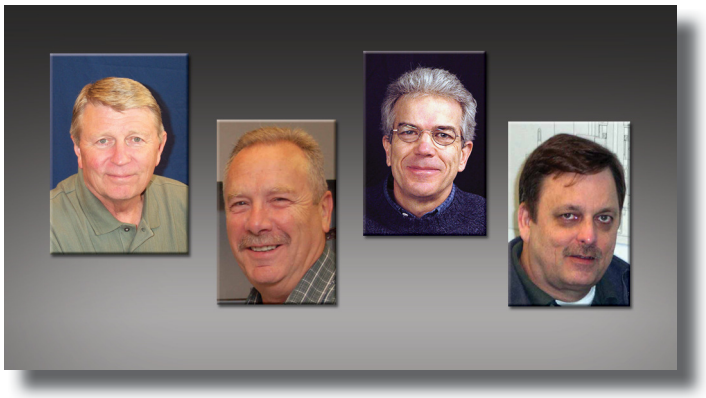
First and foremost, *Team* Corporation offers annual maintenance contracts to ensure a consistent level of system availability. In the event of unanticipated service requirements, *Team* can dispatch service engineers to provide more extensive maintenance as needed. To augment our customer support function, fully capable service is available locally at select sites.

The only regular maintenance consists of hydraulic filter element replacement. *Team* has established a policy to provide filter element model numbers as defined by the filter manufacturer, allowing the customer to procure these items locally. Of course, *Team* also maintains an inventory of these items to ensure continual availability for the customer's convenience.

Tell *Team* Corporation Your Needs

Personal and confidential service is the cornerstone of *Team* Corporation's commitment to systems excellence. Contact *Team* Corporation directly to see if one of our standard designs is right for your application. Your system needs will be reviewed by our staff of engineering experts. With over 35 years of experience dealing with horizontal test system solutions, *Team* brings a wealth of knowledge to the discussion, suggesting alternative design options to maximize your system capabilities. Let *Team* become your partner in system solutions.

Team servovalve spool and sleeve assemblies.



L to R: Bob Tauscher, CEO; Bruce Huntley, General Manager;Bill Woyski, VP of Research & Development; Doug Lund, VP of Engineering.

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