MOOG HERITAGE

Founded in 1951 by Bill Moog in East Aurora, New York, Moog has developed a reputation throughout the world as a company with employees and motion control solutions that are at the forefront of the markets we serve. Our high-performance motion control solutions, systems and components control a variety of industrial machines manufactured and installed all over the world - installations where precision, velocity, force and acceleration are critical. With total company sales of close to US $2.5 Billion, Moog is recognised as a global market leader for technology and innovation in our target markets, continuously improving machine design and performance.

MOOG INDUSTRIAL GROUP IN THE UK

Moog has had a relationship with the UK since 1958, when Bill Moog licenced George Dowty to manufacture Moog Servo Valves in Gloucestershire. Moog was established officially in the UK in 1968, moving from Cheltenham to Tewkesbury in 1979. Since 2015 we provide both UK and global support from our new production facility, playing a key role in the design, manufacture, development, and service of Moog industrial products and their applications. This includes the centre court’s all-electric retractable roof at Wimbledon, and as a leader in sub-miniature actuation, providing race winning motion control products for every Formula 1 racing car.

The Tewkesbury site is easily accessible by road (Junction 9, M5) and by rail (Ashchurch).

We employ people with roles embracing machining, assembly and test, design and applications engineering, purchasing, logistics, sales and marketing. We view our customers as part of our business and we, a part of theirs. We take a collaborative approach to solving their most difficult motion control problems with electric, hydraulic and hybrid solutions. Our team is dedicated, agile, flexible and customer focused.

MOOG IN THE UK

Further sites are based in Reading (slip rings and components), Aberdeen, Ulverston and Edinburgh (sensors and tools for ROVs and AUVs), Southampton (pitch control systems for wind turbines), Wolverhampton and Tewkesbury (Aircraft Controls), Bicester (Space and Defence).

ABOUT MOOG

Moog designs and manufactures high-performance motion control solutions for a variety of industrial applications including plastics, metal forming, power generation, steel production, test and simulation, wind energy, motorsport.

UK BASED ENGINEERING PROJECTS INCLUDE:

- **SCX Special Projects** - the all-electric retractable roof on the Centre Court, Wimbledon - over 150 axis of control, supplying control system, linear actuators, servo motors.
- **Formula 1** - dual gain micro servo valves to provide higher precision and high speed control, such as gearshift and throttle.
- **James Fisher Nuclear** - Control System for Moduman 100 Manipulator Arm for Nuclear Decommissioning
- **Instituto Italiano di Tecnologia (IIT)** - Sub miniature hydraulic servo actuator with integrated electronics and controller to control leg motion on the HyQ "Hydraulically actuated Quadruped".
- **Lockheed Martin** - Tank Turret Testing System for stabilisation and performance on the upgraded Warrior Tank.
When Researchers at the Istituto Italiano Di Technologia (IIT) wanted to bring to life their HyQ “Hydraulically actuated Quadroped” to assist humans in their response to emergencies such as search and rescue operations in dangerous places, they approached Moog for a solution.

**The Challenge**

To provide the Istituto with a sub miniature and extremely high response hydraulic solution to control the leg motion of the HyQ which would have to react rapidly when the legs hit the ground, enabling precise reactive control of the rigidity/elasticity of the limbs, absorbing the shock of impact, and preventing stress and damage to the centre body.

As our customers challenge us with difficult motion control problems we’ll continue to respond with designs, services and products that are reliable and efficient.

Where products are already in service, then we have a comprehensive, popular and cost effective range of plant maintenance services, including repairs, services and skills training.

**The Solution**

The concept of “actively compliant” legs was made possible by the extremely high response of the Moog E024-LA miniature hydraulic Servo Valve integrated with a Moog servo actuator and additive manufactured manifold to control leg motion.

**The Result**

A transference of F1 micro hydraulics technology to human emergencies providing:

- Precise reactive control of the rigidity/elasticity of the limbs of the Quadruped.
- Shock absorption of impact and prevention of stress and damage to the central body.
- A robust, reliable, ultra-compact light-weight hydraulic solution capable of precise control in milliseconds.
- One of few robots capable of doing the “flying trot” where all four legs leave the ground simultaneously.
- Transference of Moog technology developed originally for Aerospace to F1 to human emergencies.

**NEW QUADRUPED ROBOT TAKES BIG STRIDES TOWARDS SAVING LIVES**

When Researchers at the Istituto Italiano Di Technologia (IIT) wanted to bring to life their HyQ “Hydraulically actuated Quadruped”, to assist humans in their response to emergencies in dangerous places, they approached Moog for a solution.

**WHY MOOG?**

By choosing Moog, you benefit from a number of key advantages:-

- Proven systems and applications expertise, creating high performance, customised motion control solutions.
- Significant domain expertise in customer’s machine design and performance as well as end-user industries.
- High performance solutions and products in both hydraulic and electric technologies.
- Global engineering and services network to support customers around the world.
- World-class manufacturing facilities staffed with skilled, experienced and dedicated workforce.
- Flexible organisation focused on collaborating with customers to meet their unique needs.

**CUSTOMER FOCUSED ENGINEERED SOLUTIONS**

Our engineers collaborate with OEM customers to design Moog motion control solutions for machines and systems where precise control of position, velocity, force and acceleration are critical. Our electric and hydraulic technologies enable machine builders to create unique and flexible designs that perform with greater efficiency, increased uptime and lower maintenance costs.

As our customers challenge us with difficult motion control problems we’ll continue to respond with designs, services and products that are reliable and efficient.

Where products are already in service, then we have a comprehensive, popular and cost effective range of plant maintenance services, including repairs, services and skills training.
STANDARD AND CUSTOMISED SOLUTIONS

From advanced customised miniature high performance control systems for Formula 1 racing cars and autonomous robots, to heavy duty environments such as the steel industry, to special engineered solutions for Wimbledon’s retractable roof, Moog supplies precision motion control solutions to meet a range of demanding applications.

POWER GENERATION, GAS AND STEAM TURBINES

With the cost of any outage critical to the profitability of a power station, we are equipped to offer both steam and gas turbine actuator service and repair in a timely manner in addition to our complete line of ATEX approved and explosion-proof Servo Valves, Liquid Fuel Metering systems and Fuel Pumps for low viscosity fluids. We also offer other engineered solutions such as Skids and Start Packs and continued service support for the Whitton product range such as Fuel and Lube Oil Pumps.

INDUSTRIAL MACHINERY

Performance-driven companies developing their next-generation machines turn to Moog for either electric or hydraulic high performance automation solutions for Pharmaceutical, Material Handling, Metal Forming, Food Processing & Product Sorting, Packaging, Plastics, Robotics, Steel & Iron Production.

MOTORSPORT

Motorsport presents unique challenges for motion control suppliers. Whereas Formula 1 looks for low weight, small size and fast and completely reliable operation performance. Rallying looks for ruggedness and the ability to perform in fairly brutal conditions such as extreme temperatures, adverse weather and demanding time constraints. Moog works with all the leading teams providing them with highly responsive, light-weight race-winning motion control.

TEST

Manufacturers and test labs around the globe can expand and set up test rigs easily, increase throughput and productivity, improve test accuracy and get results quicker, while keeping the tested specimen totally safe. Typical applications supported by Moog include: aero-structures and landing gear, ground vehicle components, off-shore structures and renewable energy.

SIMULATION

Training centres around the world, providing flight and automotive simulation systems with unsurpassed levels of performance, fidelity and reliability turn to Moog as the leading designer and manufacturer of 6 Degrees of Freedom (6DOF) motion base systems for Level D full flight and driver training simulators, control loading actuators and helicopter and fighter G-seats.

OIL AND GAS

The performance of your downhole, topside, and subsea/marine equipment including ROV’s can be improved with Moog’s high performance motion control, surveillance and data communication solutions for oil and gas applications such as Slip Rings, Actuators, Brushless Servo Motors, Multiplexers, Servo Valves, Camera Systems.

AUTONOMOUS ROBOTICS

Some of the world’s most advanced mechanical robots where mobility, agility, dexterity and speed are required, now use Moog’s range of sub miniature products, including Moog additive manufactured complex manifolds for high pressure hydraulics.
When the All England Lawn Tennis and Croquet Club made the decision to install a retractable roof over the Centre Court at Wimbledon they had envisaged a hydraulic solution. However, following a design review with Moog, an electric solution was developed.

**The Challenge**
To provide an electric solution capable of moving over 1000 Tonnes of steel above 15,000 fans, within a tolerance of +/- 12.5mm over a span of 75 metres, and when not in use to occupy the minimum space.

**The Solution**
To move the two sections of roof, comprising 10 “trusses” each weighing 100 tonnes, Moog provided Brushless Servomotors, Electric Actuators, Servodrives, Servocontrollers, Control Panels, Main Control Desk, SCADA and Data Logging, Also Design, Specification Development, Engineering, including dynamic modelling, commissioning and future service and support.

**The Result**
Motion control of a unique retractable roof on an iconic building:
- Over 150 Axis of control.
- Controlled movement of 10 “trusses” each weighing 100 tonnes.
- Can be fully deployed in 8 minutes.
- Demonstrates Moog’s ability to provide Electro-Mechanical Actuation (EMA) technology, and software.
- Completed on time for June 2009 championships and continues to be highly reliable in rain and sun.
- Designed for long life and low maintenance.
- Serviced and Supported by Moog.
MOOG PRODUCTS FOR WORLD-CLASS ELECTRO-MECHANICAL AUTOMATION APPLICATIONS

Moog offers world class electro-mechanical products and systems, with products such as Servo Motors, Ball, Inverter and Planetary Roller Screws, Actuators, Servo Drives and Motion and Machine Controllers.

SERVO MOTORS

Moog deliver an extensive product range of Servo Motors specifically designed for highly dynamic servo industrial applications.

<table>
<thead>
<tr>
<th>RANGES</th>
<th>COMPACT DYNAMIC</th>
<th>MAXIMUM DYNAMIC</th>
<th>EXPLOSION PROOF (ATEX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Torque (NM)</td>
<td>from 0.15 to 74.2</td>
<td>from 2.2 to 1.034</td>
<td>from 0.52 to 66.68</td>
</tr>
<tr>
<td>Peak Torque (NM)</td>
<td>from 0.50 to 240</td>
<td>from 10 to 2,012</td>
<td>from 1.0 to 239.3</td>
</tr>
<tr>
<td>Speed (RPM)</td>
<td>Up to 11,700</td>
<td>Up to 11,700</td>
<td>Up to 7,800</td>
</tr>
<tr>
<td>Size (mm)</td>
<td>6 Frames: from 40 to 190</td>
<td>7 Frames: from 40 to 190</td>
<td>3 Frames: from 70, 140, 190</td>
</tr>
</tbody>
</table>

Moog Servo Motors at a glance

- Superior motor dynamics improving cycle time
- Modular and compact lightweight construction
- Proprietary, low cog design for smooth, low speed operation
- Flexible options for easy integration
- Available as frameless package
- Custom windings and designs
- Explosion Proof Dynamic Brushless Servo Motor
- High Power Density

Advantages

- Easy to configure with SERVOSoft™ sizing tool.
- High dynamic and low inertia driving improved machine throughput.
- Industrial standard interfaces provide compatibility with mechanical and electrical systems.
- Compact Dynamic – 4 Sizes available in two weeks.

HIGH SPEED LINEAR MOTORS

Moog’s High Speed Linear Motors offer dynamic and precise linear motion positioning for robotics, factory automation, processing, packaging, material testing machines and other industrial applications. As a high force, direct drive solution, Moog’s linear motors extend maintenance intervals and reduce the cost of ownership of any linear motion system.

Moog Linear Motors at a glance

- High Speed Performance: up to 4.5M/sec
- Fast acceleration: up to 40G
- Encoders with 0.1 μm resolution, optical and Hall types available
- High force motors up to 2,000 lbf [9 kN] force
- Fan cooled and liquid cooled options for maximum performance
- Custom designs for any application
- Available as a component in a complete system solution that includes brushless linear motors, drives, motion controllers, cabling, filters and accessories

Advantages

- Various screw diameter-pitch combinations available to allow easy integration into the machine.
- Wide selection of screw end shafts to meet the exact needs of the application.
- Robust design suited for heavy duty applications, vibrations and harsh environments.

BALL SCREWS AND PLANETARY ROLLER SCREWS

Moog Ball and Planetary Roller Screws are designed to provide a unique and competitive edge.

<table>
<thead>
<tr>
<th>RANGES</th>
<th>BALL SCREW</th>
<th>ROLLER SCREW</th>
<th>INVERTER ROLLER SCREW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Load Rating (kN)</td>
<td>Up to 400</td>
<td>Up to 670</td>
<td>Up to 300</td>
</tr>
<tr>
<td>Static Load Rating (kN)</td>
<td>Up to 900</td>
<td>Up to 1,400</td>
<td>Up to 750</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>from 13 to 100</td>
<td>from 16 to 90</td>
<td>from 18 to 48</td>
</tr>
<tr>
<td>Stroke Length (mm)</td>
<td>Up to 3,600</td>
<td>Up to 1,800</td>
<td>Up to 200</td>
</tr>
<tr>
<td>Leads (mm)</td>
<td>from 4 to 50</td>
<td>from 2 to 36</td>
<td>from 3 to 20</td>
</tr>
</tbody>
</table>

Moog Ball and Planetary Roller Screws at a glance:

- Extensive range allows you to find the best solution to your specific performance requirements that meet the demands of ISO accuracy for classes 1-3-5
- The range covers a wide selection of static and dynamic loads with an extended range of accelerations for extremely fast cycle times
- Alternative designs and re-circulating systems that meet noise and vibration requirements for very quiet applications

Advantages

- Various screw diameter-pitch combinations available to allow easy integration into the machine.
- Wide selection of screw end shafts to meet the exact needs of the application.
- Robust design suited for heavy duty applications, vibrations and harsh environments.
FLEXIBLE ELECTRO-MECHANICAL LINEAR SERVO ACTUATORS
Moog Electro-Mechanical Linear Servo Actuators are a pre-engineered and highly customisable solution for high performance industrial applications that need maximum speed and force.

<table>
<thead>
<tr>
<th>RANGES</th>
<th>ELECTRO-MECHANICAL LINEAR SERVO ACTUATORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Force (kN)</td>
<td>from 1.0 to 96</td>
</tr>
<tr>
<td>Peak Force (kN)</td>
<td>from 3.6 to 450</td>
</tr>
<tr>
<td>Rod Speed (mm/sec)</td>
<td>Up to 1,600</td>
</tr>
<tr>
<td>Stroke Length (mm)</td>
<td>Up to 2,500</td>
</tr>
</tbody>
</table>

Moog Electro-Mechanical Linear Servo Actuators at a glance
- Inline and foldback design when space is at premium
- Variety of motor windings for optimum performance
- Several screw leads for speed/force variations
- Ball screw and roller screws available
- Fully customisable to provide ultra high force to 450 kN for applications such as retractable roofs and presses

Advantages
- Convenient configuration allows the actuator to be tailored to the exact needs of the application.
- High force density to minimise space requirements.
- High dynamic load capacity to provide operation long life.
- Electronic nameplate provide Plug and Play capability with Moog drives.
- Industrial standard interface provide compatibility with third party drives.

SINGLE AND MULTI-AXIS SERVO DRIVES
Moog Servo Drives provide fully digital control over position, velocity or torque for synchronous, asynchronous, linear or torque servo motors.

<table>
<thead>
<tr>
<th>RANGES</th>
<th>SERVO DRIVES MSD SERIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Current (amps)</td>
<td>from 4.0 to 450</td>
</tr>
<tr>
<td>Peak Current (amps)</td>
<td>from 8.0 to 765</td>
</tr>
<tr>
<td>Operating Voltage (VAC)</td>
<td>from 115 to 460</td>
</tr>
</tbody>
</table>

Moog Servo Drives at a glance
- Available in a wide variety of power sizes and fieldbus communication options that work with virtually all machine designs
- Deliver high dynamics, reliability, smooth low-speed performance, thermal management for operation in demanding environments
- Offer motion control functionality for every application

Advantages
- Modular design enables flexible configuration for multi axis systems.
- Compact form factor minimising machine cabinet space.
- Shared power supply and DC bus.
- Active & Bus control – for machines used internationally under different voltages.
- Single-Axis Compact - 3 Sizes available in two weeks.

CUSTOMISABLE SINGLE AXIS SERVO DRIVES
Consistent high dynamic performance, control accuracy and easy-to-adapt motion control templates.

<table>
<thead>
<tr>
<th>RANGES</th>
<th>SERVO DRIVES CSA SERIES (FORMERLY DS2110)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Current (amps)</td>
<td>from 3.0 to 140</td>
</tr>
<tr>
<td>Peak Current (amps)</td>
<td>from 11 to 300</td>
</tr>
<tr>
<td>Operating Voltage (VAC)</td>
<td>from 65 to 510</td>
</tr>
</tbody>
</table>

Moog Servo Drives at a glance
- Available in 7 power sizes up to 300 amps peak current
- Replacement or retrofit product for DS2110, DS2100 and DS2000XP
- Explosion-proof versions available with CS, UL and ATEX certifications

Advantages
- Ideal for applications requiring integrated axis motion control.
- Flexible performance supports several feedback devices, encoders and resolvers.
- Maximum motor efficiency is maintained with Field-Oriented Control (FOC).
- Works seamlessly with Moog Servo Motors and Actuators.
MOOG PRODUCTS FOR WORLD-CLASS ELECTRO-HYDRAULIC AUTOMATION APPLICATIONS

Moog electro-hydraulic products such as Servo and Proportional Valves, Industrial Cartridge Valves, Radial Piston Pumps, Motion and Machine Controllers, provide precise control of position, velocity and force - so important to the proper operation of a wide variety of industrial machinery.

Your benefits at a glance:
- Long lasting performance and reliability that increase your machine lifetime and your return on investment
- Easier installation, creating less downtime so you are operating sooner
- Higher efficiency helping you lower your energy consumption and reduce your maintenance efforts

SERVO VALVES

Moog offers an extensive product range of Servo Valves specifically designed for precise control of position, velocity and force.

Moog Servo Valves at a glance
- Pilot operated with low friction double nozzle pilot stage with high resolution and low hysteresis
- Mechanical position feedback without onboard electronics
- Direct Drive Valves with Linear Force Motor
- Analog or digital onboard electronics
- Optional fieldbus interface, pressure or axis control functionality
- 2- and 3-stage pilot operated valves with ServoJet or nozzle flapper pilot
- Analog or digital onboard electronics
- Optional fieldbus interface, pressure or axis control functionality

Advantages
- High wear-resistance and durability
- Robust and proven track record in broad range of industries
- Convenient selection and configuration of valves to suit the application
- Easy integration into the hydraulic system using standard interfaces
- High accuracy and repeatability for demanding applications
- Fail-safe and Explosion proof versions available

RANGES

- D634, D637, D639
- D661 to D665, D681 to D685
- D671 to D675, D941 to D945

Rated Flow @ \( \Delta p \) 70 bar (1,000 psi)
- From 0.95 to 757 l/min
- From 5 to 100 l/min
- From 4 to 1,000 l/min

Maximum operating pressure (bar)
- From 210 to 350
- 350
- From 315 to 350

100% Step Response @ \( \Delta p \) 210 bar (3,000 psi)
- From 3 to 40 ms
- From 8 to 20 ms
- From 3 to 19 ms

PROPORTIONAL VALVES

Moog offers an extensive product range of Proportional Valves specifically designed for precise control of position, velocity and force.

Moog Proportional Valves at a glance
- Direct Drive Valves with Linear Force Motor
- Analog or digital onboard electronics
- Optional fieldbus interface, pressure or axis control functionality
- 2- and 3-stage pilot operated valves with ServoJet or Direct Drive Valve pilot
- Analog onboard electronics
- Optional fieldbus interface, pressure or axis control functionality

Advantages
- Numerous models with a range of sizes, performance characteristics and mounting options available
- Flow-optimized design for high rated flows
- Fast commissioning of digital products using Moog Valve and Pump Configuration Software (MoVaPuCo)
- Fail-safe and Explosion proof versions available

RANGES

- D634, D637, D639
- D661 to D665, D681 to D685
- D671 to D675, D941 to D945

Rated Flow @ \( \Delta p \) 10 bar (145 psi)
- From 24 to 60 l/min
- From 30 to 1,500 l/min
- From 30 to 1,500 l/min

Maximum operating pressure (bar)
- 350
- 350
- 350

100% Step Response @ \( \Delta p \) 210 bar (3,000 psi)
- From 20 to 25 ms
- From 9 to 48 ms
- From 10 to 44 ms
MOOG HYDRAULIC SERVO ACTUATORS

Moog designs and manufactures industrial actuators for industrial applications including: Metal forming, Blow Moulding, Wood and Paper Manufacturing, Autonomous Robots and Power Generation – with capability to meet your force requirements.

RANGES

1. **Moog Hydraulic Servo Actuators at a Glance**
   - Combines high performance cylinders, linear feedback devices and servo valves in one assembly.
   - Developed to offer the advantages of custom engineered units.
   - Choice of servo valves, feedback transducers, working areas and strokes.
   - Maximum compatibility with other Moog components.

Advantages
- High performance servo control with Moog G761 servo valves.
- Wide array of sizes and flexibility.
- Ultimate safety and protection for machine.
- Economical solution for customers.
- High performance seals for longer life and low friction.
- Easy to replace rod bearings and seals for simple maintenance.

INDUSTRIAL CARTRIDGE VALVES

Moog offers a broad product range of servo cartridges and cartridge valves for directional, pressure, check and throttle functions.

RANGES

1. **Moog Cartridge Valves at a glance**
   - Modular set of building blocks to cover a wide variety of functions and applications.
   - Actively operated for fast and accurate switching.
   - Optional position monitoring for safety applications.
   - 2- and 3-way throttle control.
   - Different performance and fail-safe options available.

Advantages
- Compact manifold design for high flows by using cartridges.
- High robustness and reliability.
- High flexibility through modular design.

RADIAL PISTON PUMPS

Moog Radial Piston Pump (RKP) is a variable displacement piston pump, available in various sizes (from 19 to 250 cm³ per revolution) and offers a highly dynamic control of pressure, flow and horse power in industrial applications.

RANGES

1. **Moog Radial Piston Pump at a glance**
   - Robust and compact design.
   - Low noise emission.
   - Broad range of compensator types and various control options available.
   - Low pressure pulsation with less resonances.
   - High efficiency.

Advantages
- Flexible configuration according to application demands.
- Reduced effort for noise damping measures.
- Improved control in hydraulic cycle.
- Less installed power, less effort to cool fluid.
- Increased machine productivity, process stability and repeatability and condition monitoring capability.
- Well suited for a broad variety of special fluids and for use in explosive environments (ATEX Certification).
MOTION AND MACHINE CONTROLLERS
Moog offers a wide range of Machine and Motion Controllers and Software to meet your specific needs.

SERIES

MSC-R

MSC II

MC 600

Moog Motion and Machine Controllers at a glance

- Motion Controllers and Software for electric and hydraulic servo actuation applications offering rapid set-up and flexible architecture
- Ruggedised Option with high vibration resistance and extended resistance against fluid contamination and corrosion for use in harsh environments
- Machine Controllers available in modular design for high flexibility and effortless implementation into new systems

Advantages
- Modular design enables the solution to be scaled to the needs of the machine
- Industry standard fieldbus enable convenient integration with other machine elements such as sensors and drives
- Designed to perform in harsh environments
- Resistant against various aggressive fluids

RKP LIQUID FUEL METERING SYSTEM
Energy Efficiency for Gas Turbine Operators

RANGE OUTLINE

- Fuel metering for gas turbines.
- Wider applications where very precise fuel metering of liquid flow is required.
- Uses Tandem Variable Displacement RKP Pumps with up-rated compensator and revised spring configuration to improve frequency response.
- Liquid Fuel Moog DDV independently controls flow to the main burner and pilot burner supplying fuel only on demand.
- ATEX certified for use in Group2, Category 3 hazardous areas.
- Suitable for turbines of power levels of up to 15MW, corresponding to fuel flow rates of up to 100 lpm at 100 bar.

Advantages
- Improved reliability due to integrated construction.
- Reduced fuel consumption due to improved fuel metering accuracy.
- Reduced energy costs due to improved pumping efficiency.
- Simplified installation due to integrated construction.
- Wide range of flow rates from single standardised compact package.
- Improved start-up performance due to independent fuel metering streams.
- Reduced Noise.
- Compact.

JAMES FISHER NUCLEAR WORKS WITH MOOG TO PROVIDE A CONTROL SOLUTION FOR MODUMAN HYDRAULIC MANIPULATOR ARM

When James Fisher Nuclear required a system to control the manipulator arm they had developed for nuclear decommissioning work, Moog Applications Engineers were engaged to deliver the required product performance and appropriate Moog control system.

The Challenge
ModuMan had been designed by JFN around conventional hydraulic actuators. To ensure maximum maintainability, vital control elements needed to be located outside the operating cell. The 6-axis manipulator arm needed to be able to grasp and move materials weighing up to 100 kg, with a reach of 2.3 m through a 270 mm diameter access port in a radioactive environment.

The Solution
Moog delivered a control system comprising Moog Servo Controllers, Servo Drives and Motion Control software as well as modelling and simulation of the product design.

The Result
- Moog’s engineering knowledge, control software and servo controller technology ensured the manipulator arm could deliver a 6-axis solution with accurate motion.
- The Moog system enabled shoulder joint rotation of ±130°, Shoulder Pitch ±90°, Elbow Pitch of ±130°, Wrist Rotate ±130°, Wrist Pitch ±130°, Continuous Tool Rotate and End Effector grip width of 0-150 mm (0-5.9 in).
- The desired lift, manoeuvrability and reach capability were achieved.
- The project demonstrated a close and successful collaboration with James Fisher Nuclear and Moog Applications Engineers delivering a solution for an extreme environment.
Moog’s range of subminiature actuation products was developed from proven aerospace technology and has been successfully used in professional motorsport since 1982, providing race series such as Formula 1 with low weight, small size and high performance systems. With products having the capability to perform reliably in severe conditions such as extreme shock, vibration, temperatures and adverse weather means they can also be found in rallying, autonomous robotics, special effects and subsea applications.

To help utilise these products we have a team of engineers experienced in system modeling and performance estimation.

### SUB-MINIATURE HYDRAULICS

<table>
<thead>
<tr>
<th>SERIES</th>
<th>E024 SERVO VALVE WITH LVDT</th>
<th>E243-500/501 FAILSAFE SWITCHING VALVES</th>
<th>E242 DIRECT DRIVE VALVE PROPOR-TIONAL VALVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>KEY APPLICATIONS</td>
<td>F1 - Clutch, Differential, Throttle, Inlet Trumpet, Rear Wing Actuation, Gearbox, Turbo Charger</td>
<td>Rear Brake Pressure Limiting and other High Integrity Systems requiring system monitoring</td>
<td>WRC - Differential Control and Gear Shift</td>
</tr>
<tr>
<td></td>
<td>Autonomous Robotics</td>
<td></td>
<td>Subsea - Thrusters</td>
</tr>
</tbody>
</table>

### SUB MINIATURE ACTUATION

Moog Sub-Miniature Actuation at a Glance

- A range of products and system actuation for all types of motorsport including F1, WRC, Moto GP, Touring Car, World Endurance Racing (WEC)
- Also used in Special Effects, Oil and Gas and Autonomous Robotic Applications
- In the forefront of motorsport since 1982 and developed from Moog aerospace standard products
- Supported by a dedicated global motorsport design, development, manufacture and service team in the UK.

### Advantages

- Sub-miniature.
- Light-weight.
- High performance.
- Homologated by the FIA – approved for use with the Standard F1 ECU.
- Extremely high power density.
OUR PRODUCTS

TEST AND SIMULATION

Our approach is to build interchangeability of hardware, software and accessories into our subsystems. This ensures maximum flexibility and ease of use as well as the ability to pass innovations learned across applications to our other customers. From our unique force-loop model, to failsafe measures to protect the test article, to advanced interconnect networks, we are known as the leading-edge control systems supplier in the markets we serve.

Your benefits at a glance:
• Unique force loop model for exacting control and faster testing.
• User-friendly operation for maximum flexibility in your test lab and less set-up time.
• Easily configurable failsafe safety features to protect test articles and maintain testing.
• Expandable to ensure you can upgrade when required.

TEST CONTROLLERS

Expandable Range of Test Controllers giving you maximum flexibility in your test lab and less set-up time

<table>
<thead>
<tr>
<th>SERIES</th>
<th>MODULAR TEST CONTROLLER</th>
<th>PORTABLE TEST CONTROLLER</th>
<th>AUTOMOTIVE TEST CONTROLLER</th>
<th>AEROSPACE TEST CONTROLLER</th>
</tr>
</thead>
<tbody>
<tr>
<td>KEY APPLICATIONS</td>
<td>Aerospace</td>
<td>Aerospace</td>
<td>4-Posters Test Systems</td>
<td>4-Posters Test Systems</td>
</tr>
<tr>
<td></td>
<td>Automotive (durability and fatigue)</td>
<td>6-Degree of Freedom (DOF) Test Rig</td>
<td>Durability and fatigue testing</td>
<td>Iron bird</td>
</tr>
<tr>
<td></td>
<td>Vibration, shock</td>
<td>Shock and performance evaluation</td>
<td>Shock and performance evaluation</td>
<td>Aircraft/airframe</td>
</tr>
<tr>
<td></td>
<td>Performance Evaluation</td>
<td></td>
<td></td>
<td>Spacecraft structural integrity</td>
</tr>
</tbody>
</table>

Moog Test Controllers at a Glance
• Supported by Moog Integrated Test Suite Software enabling you to set up and run more tests faster and more efficiently.
• Replication, Sinesweep and Vibration modules also available.
• Supports both electric, hydraulic and pneumatic test systems

Advantages
• Force loop model for exacting control and faster testing.
• User-friendly operation - less set-up time.
• Easily configurable failsafe safety features to protect your valuable test articles.
• Expandable with add on features when required.

MOTION SYSTEMS

For a wide range of payload applications

<table>
<thead>
<tr>
<th>RANGE</th>
<th>MOTION BASES</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAYLOADS</td>
<td>1,000 kg to 16,000 kg</td>
</tr>
</tbody>
</table>

Moog Motion Bases at a Glance
• Electric and Hydraulic tables available
• DOF 2 – 8 depending on your requirements
• Quick installation and commissioning and smaller footprint
• Better replication range, greater customisation
• Safer, more reliable performance
• Lower energy consumption and lifecycle costs
• More user-friendly software

Advantages
• Provides high fidelity and the smallest turn around bump available.
• High reliability with digital control loops that do not drift or deteriorate.
• Easy integration with control loading, vibration tables and G-seats.
• Redundant mechanical and software safety architecture.
• Built in test features recording performance parameters.
• Easy to install, use and maintain.
• Simple support via Moog Simulation Software
• Extensive global support.
When Lockheed Martin wanted to test the turrets on the improved Warrior Tank as part of the Warrior Capability Sustaining Program, they turned to Moog to help capture real test track data and replicate it in their laboratory.

**The Challenge**
Under real test track circumstances, engineers found it difficult to consistently replicate dynamic motion inputs and their work was further limited by weather conditions and the ever-changing terrain. The product development included the fitting and integration of a 40 mm Cased Telescoped Gun in the turret, requiring optimised gun aiming and stability performance during manoeuvres to represent a typical battlefield mission.

**The Solution**
Moog delivered a Turret Test System which included a 6 Degrees-of-Freedom (DOF) motion base capable of handling payloads up to 24,000 kg, a Control Cabinet and Replication Software Module from the Moog Integrated Test Suite Software.

**The Result**
- Lockheed Martin were able to accurately simulate the vehicle movements as recorded on the test track.
- Due to the features of the Moog software, user training was reduced to 2 - 3 days.
- Accurate playback of the target file achieved (RMS error typically <10%).
- The development time of the new turret was reduced, and 100% motion repeatability achieved.

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**HYDRAULIC TEST ACTUATORS**
Moog Hydraulic Test Actuators with Hydrostatic or Polymer Bearings to deliver higher reliability, less maintenance and increased dynamic performance for test laboratories looking for a competitive edge.

<table>
<thead>
<tr>
<th>RANGES</th>
<th>TEST ACTUATOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Bearing</td>
<td>Hydrostatic or Polymer Bearing</td>
</tr>
<tr>
<td>Dynamic Force Rating (kN)</td>
<td>From 15 to 160</td>
</tr>
<tr>
<td>Stroke Length (mm)</td>
<td>From 102 to 254</td>
</tr>
<tr>
<td>Rod Diameter (mm)</td>
<td>From 45 to 70</td>
</tr>
<tr>
<td>Cylinder Bore Diameter (mm)</td>
<td>From 56 to 126</td>
</tr>
<tr>
<td>Piston Area (cm²)</td>
<td>From 8.73 to 86.21</td>
</tr>
<tr>
<td>Cushion Stroke (mm)</td>
<td>15</td>
</tr>
</tbody>
</table>

**Moog Test Actuators at a Glance**
- Innovative 8 pocket hydrostatic bearing increases side load capacity to 60% of stall output and reduces energy requirements, with manifold house
- Oil-cooled polymer bearing improves side load capacity to 15% of stall output, compared to 10% with traditional polymer bearing design

**Advantages**
- Higher level of dynamic performance, reliability, and longevity.
- Advanced coating used on the rod significantly improves seal wear for long life and less maintenance.
- Manifold houses all of piping in the actuator, removing the need for most of the exterior piping.
Our new world class service centre offers unrivalled facilities for the repair of both Moog and non Moog products.

SERVO AND SERVO-PROPORTIONAL VALVES

Since 1952 Moog Valves have been synonymous with industrial applications, so it makes sense to look to Moog’s own service centre and test rigs to ensure your Moog Servo Valves are repaired to OEM performance. We use Moog authentic parts and Moog trained technicians who have access to the original design and test specifications of the product as well as how the current performance relates to factors such as wear patterns, component fatigue, tolerances and revised performance capabilities. Moog customers also benefit from:

- Express Service for emergency situations.
- Technical support network from a team of global technology experts.
- Class 100,000 Clean Room for Moog’s sub miniature range.
- Facilities to assess and monitor system cleanliness including oil analysis.
- Valve testers for field use to help commission, service and troubleshoot control systems.
- FREE quarterly newsletter to keep you informed about our global projects and new initiatives.
- Training courses in partnership with the National Fluid Power Centre (NFPC) to enable engineers to install and commission their Moog Valves to maintain machine uptime.
- Installed base reviews and preferred rates to upgrade legacy and competitor servo valves to Moog Valves enabling you to rationalise your installed inventory.

SERVO ACTUATOR SERVICE FOR GAS AND STEAM TURBINES

We offer either Back-to-Base or Field Service for many types of gas and steam actuators. Our flexible fully trained and focussed team can either pack up our workshop and attend your site saving you travel time, or meet your scheduled outages or breakdown requirements at our own facility. With our cranage capacity at 5 tonne, spacious workshops, and project management skills, not only can we deal with the largest and most demanding actuator repairs and upgrades, but with fast turnaround times.

SERVO ACTUATOR SERVICE FOR ELECTRIC ACTUATORS

With our proven capability in ensuring the Wimbledon Centre Court Roof has remained operational for each Wimbledon Championship and one Olympic Games since 2009, means we also have exceptional capability to repair and service all sizes of electric actuators.

OTHER MOOG PRODUCTS

Moog does not just make and service Servo Valves, so please contact us for the best solution for all Moog products, such as RKP Radial Piston Pumps, Whitton Heritage Products, Servo Motors, Servo Drives, Servo and Machine Controllers and Screws.

OUR APPROVALS

Moog customers benefit from the following standards and approvals.

- **FIA**
  Homologation for current FIA Standard ECU.

- **British Standards Institution**
  BS EN ISO 9001:2015. Registration number is FM 13218

- **ATEX**
  BASEEFA approved for the supply of components used in “POTENTIALLY EXPLOSIVE ATMOSPHERES”. Manufactured in accordance with BS EN ISO/IEC 80079-34:2011.

- **Authorised Economic Operators (AEO)**
  Approved by H M Revenue and Customs as an Authorised Economic Operator including Security and Safety. Certificate Number GB AEOF 00092/08.

- **Environment**
  Moog Industrial Group Tewkesbury is registered as complying with the requirements of BS EN ISO 14001:2004. Registration number is EMS 576922.

 Please contact us for a full copy of our Company Profile.
### PROFESSIONAL SERVICES TAILORED TO YOUR UNIQUE NEEDS

**REPAIR**
- Moog’s factory repair services deliver less unplanned downtime
- Benefit from “like-new” or customer specific performance in your machine without unnecessary tuning
- Minimise risk of poor repair by non-authorised repair facilities with no access to authentic Moog parts, product specifications, valve test parameters or upgrades
- Gain confidence, with 12 month warranty protection, extendable to 24 months. Only available from Moog as the OEM

**TRAINING**
- Get hands-on training from Moog trainers using Moog equipment in our facilities, on-site or with our approved training partners
- Learn how to effectively manage installation and troubleshooting on your own
- Speed up repair and maintenance in order to maximize uptime

**FIELD SERVICE**
- Reduce risk and keep machines up and running faster with expert support
- Supplement your staff with expert professionals who know your applications
- Benefit from less downtime and access to original drawings and documentation
- Available in person, online, over the phone and via remote diagnostic tools

**RETROFITS/UPGRADES**
- Take advantage of exact replacements for multiple Moog motion control products to achieve “as-new” or customer specific performance
- Improve the quality and performance of machines underperforming with retrofit components that incorporate the latest technology upgrades
- Work with Moog technical experts who can recommend a course of action to add extra reliability to your operations

**OEM PARTS**
- Moog is the only provider of OEM replacement parts
- Ensure industry-leading performance in your machine
- Take advantage of global availability of spare parts
- Gain greater output and longevity of products due to Moog’s continuous design improvements

**FLEXIBLE SERVICE AGREEMENTS**
- Shift from unplanned “break and fix” approach to planned maintenance that will minimize risk of failure
- Tailor a flexible and bundled program that focuses on your operating challenges
- Reduce your total cost of ownership while taking a proactive approach to O&M services
TAKE A CLOSER LOOK.

For more information visit our web site or contact one of the locations below.

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WHAT MOVES YOUR WORLD