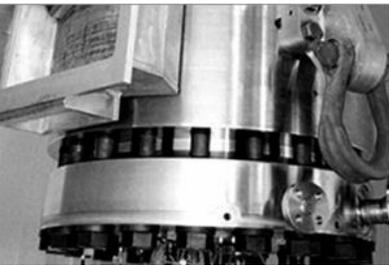




# Alternatives to High Force Linear Actuation on Military Platforms



# ***CURTISS - WRIGHT***

**Actuation Group**

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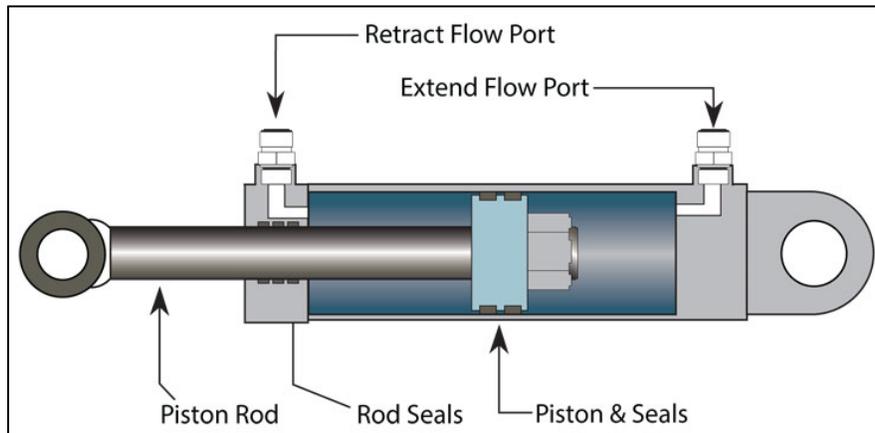
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## INTRODUCTION

Automated motion control systems are used to minimize human intervention when repeatable, mechanical movement is needed. An actuator is the end effector of any high force mechanical motion control system. Traditionally, applications for military platforms used linear hydraulic actuator systems for many of their actuation needs. Linear electromechanical actuators (EMA) have proven to be a direct replacement to linear hydraulic actuators. EMAs can effectively reduce lifecycle costs by eliminating the need for hydraulic fluids, filters and the associated maintenance of these technologies. More recently, with the growing need for multi-mission capabilities in both new designs and retrofitting existing platforms scaling linear actuators, to support larger loads and adapting to different missions, becomes an issue. One solution to the scaling and adapting issues is to use high-torque rotary electromechanical actuators (REMA). REMAs offer SWaP improvements by being more compact, efficient, and more easily maintained than linear actuators.

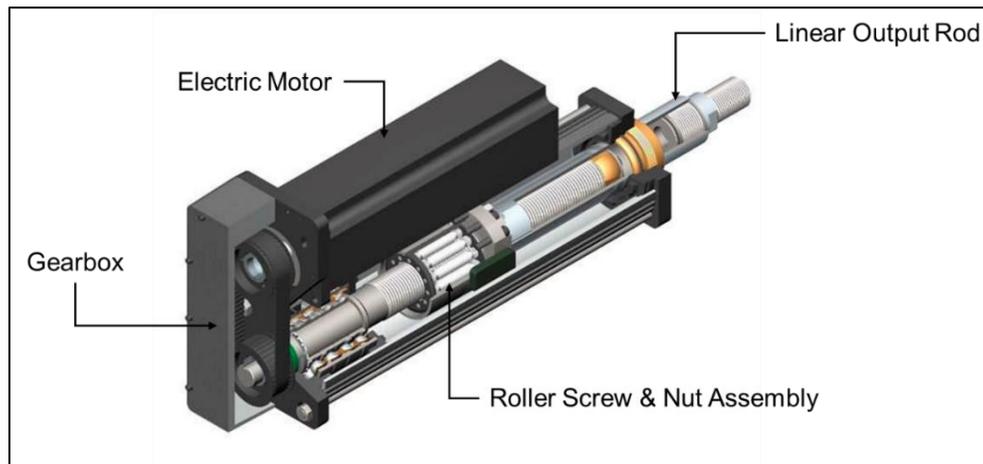
## BACKGROUND

Hydraulic actuators, commonly known as “cylinders,” have been used on ground and naval defense platforms for decades. Hydraulic cylinders have very high force to size ratios, which made them very popular on military vehicles. Generally, the construction of the cylinder is relatively simple, consisting of an output rod inside a pressurized chamber. Pressurized fluid is directed to one side of the piston to either extend or retract the piston rod, see Figure 1. However, while hydraulic cylinders are relatively simple and powerful, the rest of the hydraulic system is rather complicated. Hydraulic systems typically include a pump, fluid reservoir, control valves, filters, and pressurized fluid lines in addition to the cylinders. Each additional component introduces inefficiencies, requires maintenance, and are possible failure points. The extra components also take up vital space on vehicles and can be complicated to install and maintain, especially in the field. What’s more, with increasing use and need for automated systems to manage the complexity of modern military systems, integrating distributed control and intelligence, although not impossible, can be more cumbersome with hydraulic-based technologies.



**Figure 1- Basic Hydraulic Cylinder**

Many vehicle designers and users are recognizing the benefits of electromechanical actuation over hydraulic actuation. The primary benefits include lower maintenance effort, simplified control of speed/force/position/advanced motion profiles, and, importantly, higher energy efficiency, which results in a lower total life-cycle cost to the end user. Most linear EMAs convert rotary motion of electric motors to linear motion. This can be done through a variety of screw mechanisms (Acme screw, ball screw, planetary roller screw, etc.). Curtiss-Wright EMA planetary roller screw mechanisms (see Figure 2) produce high accuracy and force and maximize mechanical efficiency. Because linear EMA configurations can have a similar size and envelope to cylinders, they are direct replacements to hydraulics in many systems.



**Figure 2 – Basic Curtiss-Wright Electric Linear Actuator**

Linear EMAs are a good replacement for linear hydraulic cylinders, but both approaches still have limitations. The biggest limitation of linear actuators is their scalability. High-force linear actuators are much larger than lower force actuators. This causes many issues in handling, maintenance, and meeting space requirements. In some cases, high-force EMAs are simply too large to be lifted or moved by hand or without special fixtures to install, remove, and perform maintenance on the actuators.

## ALTERNATIVE SOLUTION

High-torque rotary actuators can be alternative to linear actuators (both electric and hydraulic) for many applications. High-torque rotary actuators use a motor with a gearbox and output arm to reduce the speed of the motor and increase its torque. This setup vastly reduces the size and weight compared to a linear EMA of a similar output force. By eliminating the EMA integrated mechanism to convert rotary movement to linear, a rotary actuator also increases the system efficiency compared to a similar linear actuator. An example of a high-torque rotary actuator is a Curtiss-Wright PH™ Series rotary actuator.

The Curtiss-Wright PH Series rotary actuator is an innovative, high-torque rotary solution which combines proven compound planetary geared actuator technology with Curtiss-Wright Exlar® robust and low maintenance brushless DC motors. This combination results in high-torque rotary motion in a compact package (Figure 3). This rotary actuator approach can be an excellent alternative to a linear actuator in applications where size, weight, and energy efficiency is important.

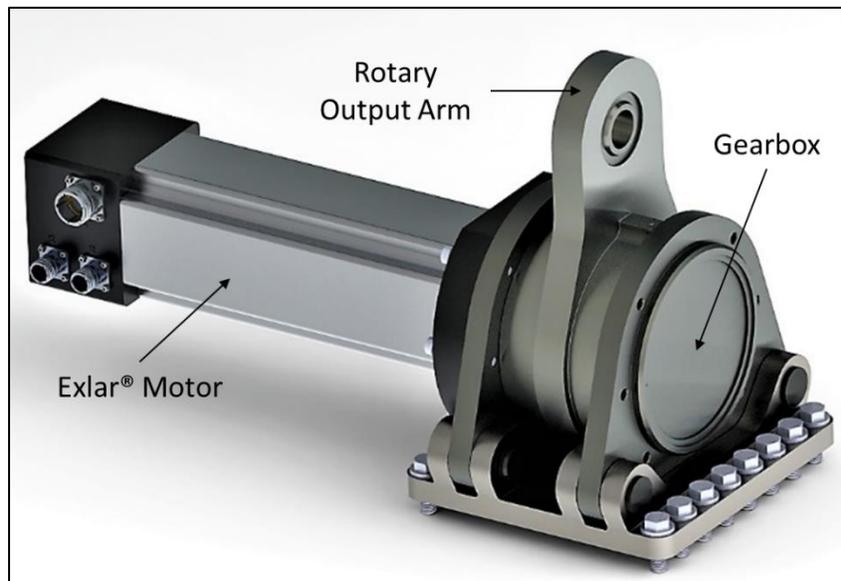


Figure 3 - Curtiss-Wright PH7X Actuator

To meet the need for varying loads while also maintaining commerciality, Curtiss-Wright has developed three different sizes of the PH actuator. Table 1 summarizes the basic specifications of the three PH Series rotary actuators. They are sized by the radius of travel from the integrated output arm (i.e., the lug of the output arm is 7 inches away from the axis of rotation of the Exlar motor on the PH7X actuator).

Similar to other Curtiss-Wright actuators, the PH Series products can provide various options such as a manual input feature to support actuation on power loss, incremental or absolute position feedback, outer finishing and coating options, and support a wide range of input power to support different applications (e.g., NATO standard 28VDC for ground vehicles or 440VAC for naval platforms.)

**Table 1 Design Specifications of PH Series Rotary Actuator**

<b>PH Series Design Specifications</b>	<b>PH2X (2" OD)</b>	<b>PH4X (4.5" OD)</b>	<b>PH7X (7" OD)</b>
L10 torque load for 10,000 cycles [in-lb <sub>f</sub> ]	9,200	24,000	175,000
Maximum Gear Reduction	3433:01		
Maximum L10 Output Force [lb <sub>f</sub> ]	4,600	9,500	25,000
Typical Exlar motor pairing	SLG060	SLG090	SLG115
Typical actuator weight [lbs]	~25	~50	~150

## EXAMPLE APPLICATIONS

For years, hydraulics and linear actuation have been used in high load applications. Once ground and naval defense platform designers began to recognize the benefits of using all electronics on some vehicles and programs, linear EMAs were quickly seen as a direct (or close to direct) replacement to the hydraulics. Some of these actuation systems can be further optimized by using Curtiss-Wright's PH Series rotary actuators. High torque rotary actuators are an excellent replacement in the actuation of many hinged-components such as ramps, doors, hatches, radar deployment, gun elevation, missile launch elevation, etc.

### ***Naval Example - Jet Blast Deflector Onboard Aircraft Carriers***

One of the possible linear to rotary optimizations that can occur is onboard aircraft carriers. A jet blast deflector (JBD) is raised behind the engines of a plane before it takes off. These JBDs are used to protect other aircraft and crew from the hot exhaust gases of the airplane that is about to take off (Figure 4). The JBDs are currently raised and lowered using either a hydraulic or EMA linear actuator. The linear actuator pushes a lever arm attached to a rotating shaft. The shaft then rotates two sets of two linkages to raise the JBD. This whole actuator and linkage system can be replaced by a set of electromechanical rotary actuators and single linkages.

Weight, space, and complexity can be saved by switching to a rotary actuator. As the linkage mechanism would be different from the traditional approach used on JBDs, a PH series actuator would not be a direct drop-in replacement to existing ship designs, but the time and cost required to retrofit the JBD system would be worth the benefits of using a PH series actuator. The smaller size allows for easier installation and maintenance in the cramped spaces aboard naval ships. On smaller vessels, the weight savings can be significant enough to allow for more payload to be carried in place of the older actuation units.



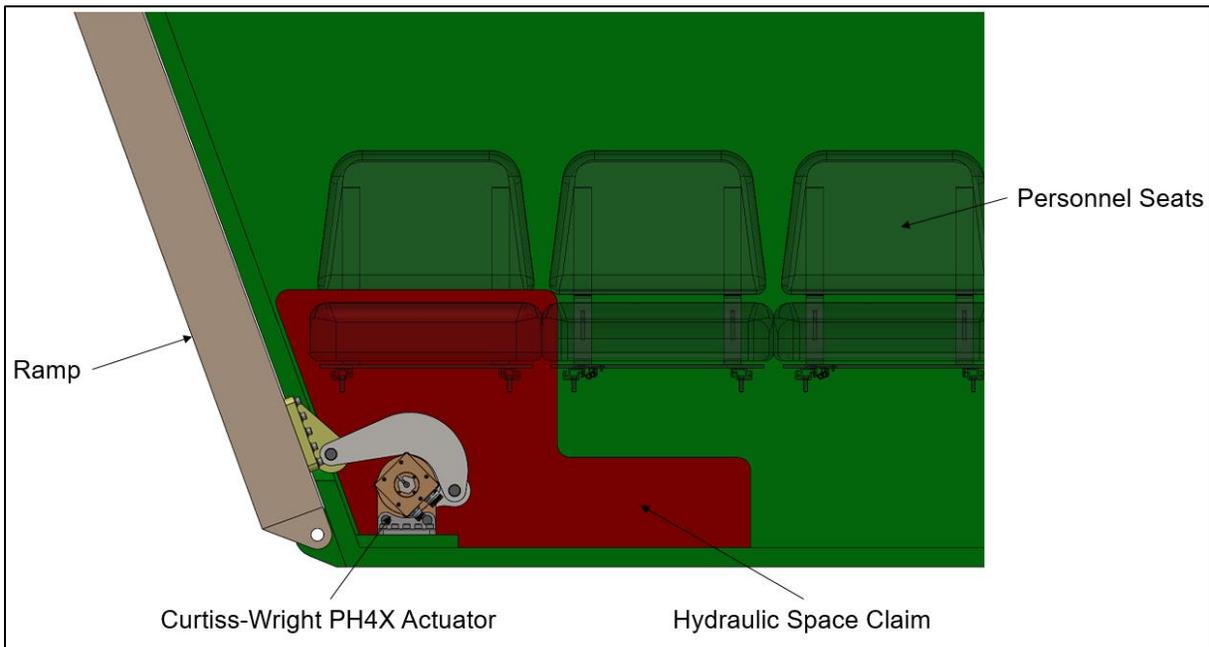
Figure 4 - A jet blast deflector is raised to protect one F/A-18 Hornet from the jet exhaust of another.

### ***Ground Vehicles Example - Doors/Ramps on Armored Vehicles***

Another example for linear actuators to be replaced with a high torque rotary actuator is on armored ground vehicles. Many of these vehicles use hydraulic linear actuators to open/close hatches and doors, raise/lower ramps, and control the position of guns or turrets. In the case of opening a rear door/ramp, the door is pushed open by the actuator at the back of the vehicle to act as a ramp/opening for personnel and gear.

Accommodating the supporting equipment such as hydraulic pumps, reservoirs and fluid conveyance takes up valuable space in the vehicle. In addition, traditional hydraulic systems can support lowering the door/ramp under loss of power by incorporating pressure “bleed” valves in the system and relying on vehicle orientation to use gravity assist, but raising or opening when the vehicle is not optimally oriented is more problematic, potentially jeopardizing personnel.

An example of the benefits of the change would be to free space for an additional seat in an armored troop carrier. Converting the traditional linear hydraulic actuator to the PH REMA provides the option in add an additional seat or to increase payload. Additionally, the change reduces the vehicle's weight and reduces field maintenance effort (MTTR) thus increasing overall efficiency.



**Figure 5 - Illustration showing space savings of a Curtiss-Wright PH4X REMA in place of hydraulics onboard an Armored Personnel Carrier.**

## DESIGN CONSIDERATIONS

For applications benefitting from reduced footprint and weight, a Curtiss-Wright PH series rotary actuator is the superior actuation solution. Replacing a linear EMA with a rotary EMA on existing platforms may require a redesign or modification of the sub-system, but the benefits gained from retrofitting to a rotary actuator can vastly outweigh the cost of a redesign to fit the new actuator into an existing platform. There are many benefits to using a rotary actuator over a linear actuator, such as size, weight, better manual input location, and “follow-on” systems.

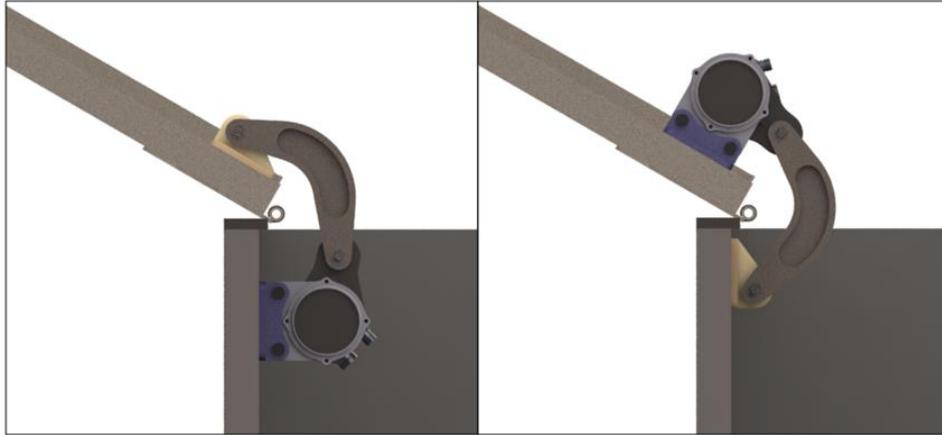
Replacing a linear actuator with a rotary actuator is not a drop-in replacement. It is not meant to be; it is meant to provide additional benefits to the vehicle design. Some design work and retrofitting likely will be required. The attachment points, on both the stationary and moving side, of the actuation system will need to be redesigned to fit the new actuator. Also, linear actuators are typically placed further from the hinge point of an actuation system, adding stiffness to the system. With that, doors, ramps, and panels are more like cantilever beams when a rotary actuator is used. The structure in motion may need to be reinforced to support themselves. Supporting structures might also need to be reinforced/stiffened to increase the harmonic frequency of the system to eliminate large vibrations during movement cycles. However, even with some extra design considerations for changing to rotary actuation, the total system benefits are significant.

highlights the size and weight savings that the PH Series product range provides over a traditional linear actuator with a similar output force. The size and weight savings is significant enough that, on smaller vehicles or watercraft, an extra person or additional supplies can be transported.

**Table 2 Comparison between PH Series and Electromechanical Linear Actuators of similar output force**

<b>PH to Linear Comparison</b>	<b>PH2X (2" OD)</b>	<b>PH4X (4.5" OD)</b>	<b>PH7X (7" OD)</b>
Max Linear force [lb <sub>f</sub> ]	5,000	10,000	20,000
Approximate PH Actuator Weight [lbs]	25	50	150
Approximate PH Actuator Volume [in <sup>3</sup> ]	95	150	570
Approximate Linear Actuator Weight [lbs]	105	215	320
Approximate Linear Actuator Volume [in <sup>3</sup> ]	900	1,875	2,850

Reducing the size and weight of the actuator system also allows the PH Series actuator to be configured in a “follow-on” configuration (see Figure 6). This means that the actuator stays attached to the door or ramp of the system, allowing for a larger opening through the door/ramp in many cases.



**Figure 6 - Left: PH4 actuator in standard configuration; Right: PH4 actuator in "Follow-On" configuration.**

The PH product's reduced size and weight allows for easier maintenance on the actuator. Due to the weight of the unit, an EMA linear actuator can require special fixtures/equipment, such as a crane to move. However, a PH Series actuator can typically be lifted and moved by hand with one or two people. Not only is maintenance easier to perform, but there is also far less maintenance required in comparison to a hydraulic system. There are also fewer wear parts than linear actuators.

A final benefit to the Curtiss-Wright PH series rotary actuator is the built in manual input feature. When power is lost or disconnected from the actuator, the manual input feature allows the actuator to be rotated using a standard socket driver or power tool. Hydraulic actuators will be limited to hand pumps or simply relieving pressure during a power loss. If the fluid conveyance lines become compromised, relieving pressure is the only option for hydraulic actuators.

## CONCLUSION

Energy efficient, high force linear EMAs can be a direct drop in to hydraulic approaches, increasing efficiency, lowering cost of ownership, and increasing actuation accuracy. While linear EMAs can be a direct drop-in to hydraulic systems, many linear systems can be converted to rotary EMAs for additional benefits. Rotary EMAs are more compact, more efficient, and more easily maintained than linear actuators. If the system allows for a rotary actuator, a Curtiss-Wright PH series rotary actuator is the best solution to an actuation system.

## **Curtiss-Wright Ground and Naval Defense Business**

The Ground and Naval Defense (GaND) business segment, part of Curtiss-Wright's Industrial Division, designs, develops and adapts commercially-derived technologies and products to deliver actuation solutions for mission critical applications for ground and naval defense platforms. The GaND business delivers value to its customers by:

- Deploying commercial-based offerings that speed time to market while reducing upfront design and engineering costs.
- Using electromechanical technologies that are more energy efficient and sustainable than many fluid power alternatives.
- Offering consultative engineering services to help our customers adopt electric technologies faster while minimizing risks in change.

## **About Curtiss-Wright**

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