ServerLIFT Corporation

ServerLIFT Corporation White Paper

Best Practices - Handling IT Equipment in a Data Center

July 2012

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Executive Overview

As our technology-driven society continues to increase data processing and storage, the strain and demand on the Information Technology (IT) industry is much higher than that of most other industries. Intel CEO Paul Otellini recently stated about IT spending growth, "The most obvious result of that growth is the fact that the world's consumers and businesses in 2011 were using over 4 billion devices connected to the Internet generating over 300 exabytes of data. That has led to a $450 billion-plus data center spend for this year." Moore's Law, which states that microchips double in power every 18 to 24 months, would seem to indicate that servers will continue to require more frequent upgrades in the future.

One of the most common tasks in any data center facility is the physical handling of servers and other rack-mounted equipment. New technologies, such as blade servers, condense packed servers, and UPS systems, continue to increase both the computing power and the physical demands on data center personnel who have to install the equipment. As equipment weight reaches dangerous levels, popular server manufacturers such as Oracle and Hewlett-Packard are specifying a minimum of 2 people to install 2U servers and up to 4 people to handle heavy equipment. In fact, both companies recommend using a mechanical lift to handle equipment in their operations manuals.

Surprisingly, most data centers today lack a set of standards for handling servers and other rack-mounted equipment. The lack of standard lifting procedures for equipment handling in a data center can result in millions of dollars wasted each year on damaged equipment and workplace injuries due to mishandling accidents, repetitive stress injuries, and inefficient working practices. With expected data center hardware spending forecasted to exceed $126.2 billion in 2015the importance of having standard lifting procedures becomes more critical than ever before.

To ensure the safety of assets and the people who move them, it is recommended to implement standard methods and practices for handling IT equipment in a data center environment. While procedures requiring special techniques or fine coordination may reduce risk somewhat, they still leave employees prone to injury. Standards that replace the physical strain of employees with specialized server handling equipment are far more effective in reducing risk and increasing efficiency.

This document summarizes the challenges faced by data center employees when handling servers and other rack-mounted equipment. It offers a comprehensive list of considerations for server handling best practices.

Risk Associated with Industry Challenges

Injury and Damage Statistics in the Data Center

To date, there is very little data available and no published studies about equipment handling injuries and/or damaged equipment in the data center industry. The limited availability of information, case studies, and research specific to the data center leaves data center management unaware of or unequipped to deal with the likelihood of an incident occurring without the use of proper lifting techniques and solutions. Because of this, ServerLIFT Corporation recently conducted a blind study that would help data center professionals better understand the dangers within their facilities.

The Study Included Parameters to Ensure Unbiased Results:

1. A blind survey to ensure that all participants could answer honestly

2. The questions were simple and easy to understand.

3. The time necessary to complete was minimal.

4. Participants were qualified and experienced data center employees.

The study was conducted in May of 2012, at Interop Las Vegas, a large national technology tradeshow, to determine the number of injuries and damaged equipment that occurs in data center facilities. This event was chosen because it brings together IT professionals from a broad range of industries from all over the world.

Out of the 113 participants, 89 answered that they have worked or interfaced within a data center in the past five years. Out of the 89 relevant participants, 58 were able to provide information regarding injuries and 67 were able to provide information regarding dropped equipment.

Survey Questions:

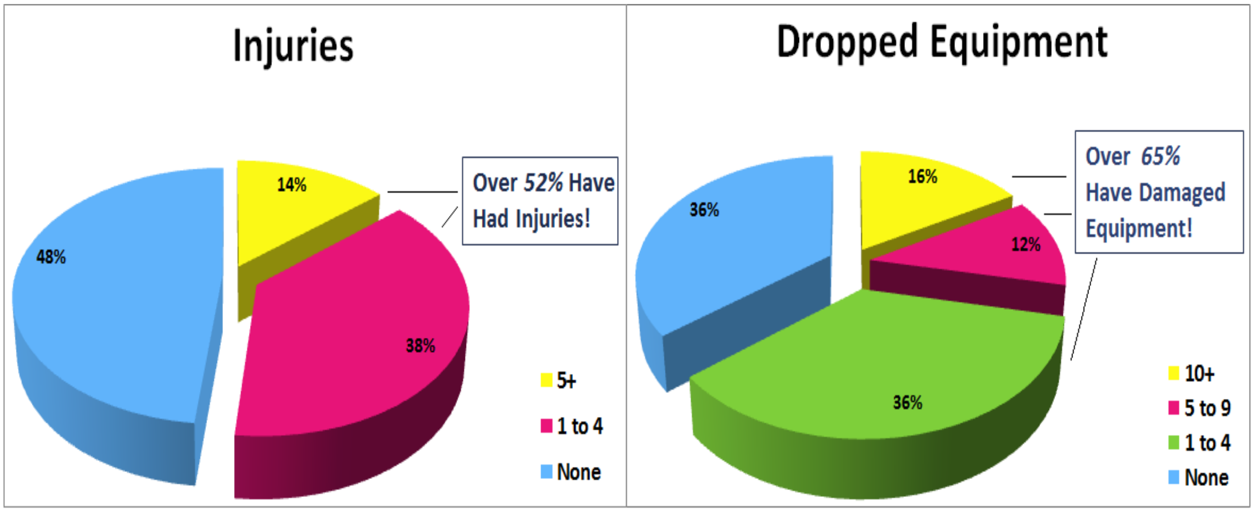
In the past 5 years…

1. Have you worked in or interfaced with a data center?
2. How many injuries are you aware of in your data center?

3. How many times has rack-mounted equipment been dropped in your data center?

Key Findings Included:

- **52%** were aware of injuries in the data center
- **65%** were aware of dropped equipment in the data center



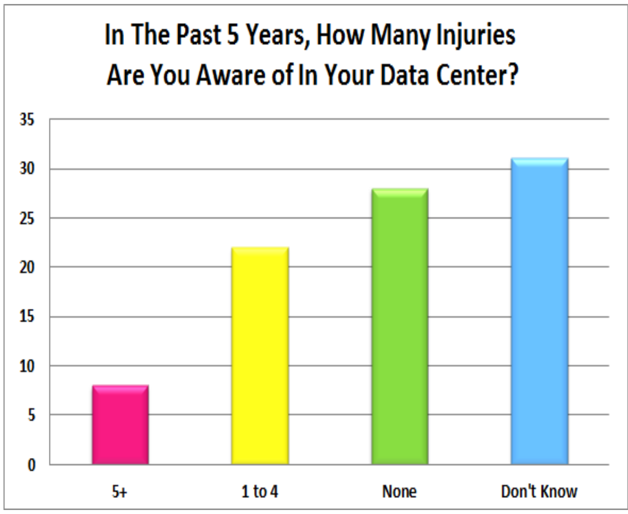
Detailed Findings:

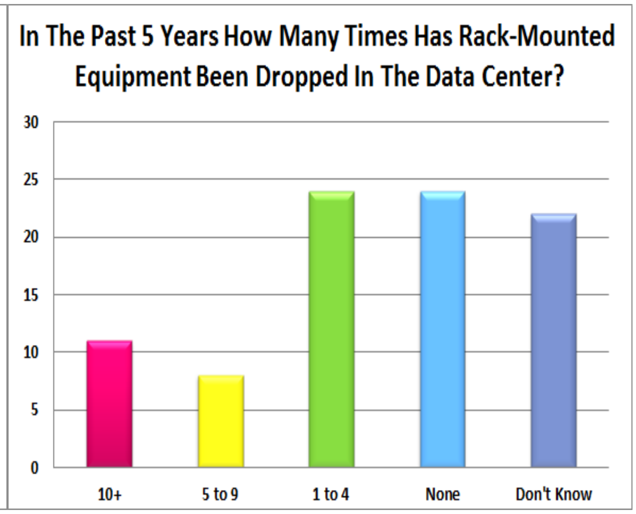
Of the participants who were aware of injuries:

- **38%** reported 1 - 4 injuries
- **14%** reported 5 + injuries

Of participants who were aware of damaged equipment:

- **36%** reported 1 - 4 instances of damaged equipment
- **12%** reported 5 - 9 instances of damaged equipment
- **16%** reported 10 + instances of damaged equipment





Conclusion:

In spite of its small sample size, the study's results confirm that existing data center operational methods are fraught with physical and financial risk. It is expected that subsequent study's will further validate the conclusions and possibly even reveal other losses, such as inefficiencies and repetitive stress injuries that may not be directly attributed to one particular incident.

National Research, Case Studies, and Reports:

There are general studies and governmental guidelines in place for general lifting activities. The standards are not specific to the data center, these guidelines advise against or prohibit the lifting of heavy equipment, which is a category, in which most rack-mounted data center equipment would be included.

U.S Occupational Health and Safety Administration (OSHA):

OSHA's Technical Lifting Manual states that an employer should consider the principal variables when evaluating manual lifting tasks to determine how to safely lift a given load.

Some of these variables include:

- Mass of the load

- Horizontal distance from the load to the employee's spine
- Vertical distance the load will travel in handling
- Amount of trunk twisting the employee will be doing during the lifting
- Ability of the hand to grasp the load
- Frequency with which the load is handled

According to the manual "*acute back injuries can be the immediate result of improper lifting techniques and/or lifting loads that are too heavy for the back to support".*

While the acute injury may seem to be caused by a single well-defined incident, the actual proximate cause is often a combined interaction of the observed stressors coupled with years of weakening of the musculoskeletal support mechanism by repetitive micro-trauma. Injuries can arise in muscle, ligament, vertebrae, and discs, either singly or in combination.

The manual continues ***"…****manual materials handling is the principle source of compensable injuries in the American work force, and* ***4 out of 5*** *of these injuries will affect the lower back*." As informative and well-meaning as these guidelines intend to be they are often disregarded and not followed.

OSHA recommends using mechanical means to avoid injury while lifting equipment heavier than 50 pounds**.**

OSHA 300 Logs - Mandatory Injury Reporting:

Federal regulations require that all companies and businesses use the OSHA 300 Log to, classify, report, and analyze all work-related injuries. This is especially important with injuries in the data center environment because it assists management in appreciating the risks and costs of handling servers manually. Most injuries that are reported and documented in an OSHA 300 Log in data center facilities are due to the manual lifting and maneuvering of servers and other IT equipment.

National Institute for Occupational Safety and Health (NIOSH):

The National Institute for Occupational Safety and Health (NIOSH) states that *"back disorders are one of the leading causes of disability for people in their working years and afflict over 600,000 employees each year with a cost of about* ***$50 billion*** *annually."*

The costs of employee injury and/or damaged equipment are substantial, and compounded by the downtime of mission critical data centers. The NIOSH created the "lifting equation" to provide an accurate method for employers and employees to assess the level of physical stress associated with a specific set of lifting conditions, and assist in identifying the contribution of each job-related factor. They applied this equation-based analysis to some average lifting situations and found that there were several hazards associated with each example at particular points of the required lifting motion.

Even with a lift load of only 35 lbs., they were able to mathematically conclude that elimination of the manual lifting component of the job may be more appropriate than job redesign to avoid physical hazards. Refer to Appendix A for a full genesis of the equation, working examples, and conclusions of the analysis.

Department of Labor:

In 1982 the Department of Labor's Bureau of Labor Statistics [DOL(BLS)] published a report entitled *Back Injuries.* "The DOL's conclusions are consistent with current workers' compensation data indication that "injuries to the back are one of the more common and costly types of work-related injuries."(National Safety Council, 1990). According to the DOL report**,** *back injuries accounted for nearly 20% of all injuries and illnesses in the workplace, and nearly 23% of the annual workers' compensation payments*. A more recent report by the National Safety Council (1990) indicated that overexertion was the most common cause of occupational injury, contributing to 31% of all injuries. The back, moreover, was the body-part most frequently injured (22% of 1.7 million injuries) and the most costly to workers' compensation systems." (U.S. Dept. of Health and Human Services, 1994)

Health and Safety Center:

The Health and Safety Center, under governance by the Workers' Compensation Board of British Columbia in Canada, released a Musculoskeletal Injury (MSI) Prevention Guidance Sheet and a Push / Pull/ Carry Force Calculator. Both tools were designed to help employers and employees accurately identify and assess the risks associated with pushing, pulling, and lifting activities.

According to the Push/ Pull/ Carry Force Calculator, 75% of men with hands at a height of 44 inches, while carrying an object for a distance of seven feet, for a duration of only 12 seconds, should be able to carry the maximum weight of 41lb. under the conditions just described.

The suggested maximum carry weight decreases as the distance and duration of the carry increase. WorkSafeBC suggests that, in order to reduce MSI risk, workers should:

1. **Eliminate the need to push/pull/carry:**
   a. Automate pushing, pulling, and carrying tasks (examples include using mechanical rollers/conveyors and gravity feed systems).
   b. Use mechanical aids such as carts, dollies, lift trucks, or pallet jacks.
   c. Avoid carrying wide or tall (bulky) loads.
2. **Reduce the forces required to push/pull/carry:**
   a. Reduce the weight or size of load.
   b. Maintain the wheels on carts in good working order.
   c. Where practicable, provide handles.
   d. Ensure that friction between the floor and the cart wheels is low.
   e. Minimize the distances over which objects are to be pushed, pulled, or carried

Research Summary and Conclusion:

All available ergonomic guidelines advise against manual lifting of more than 40lb. in the workplace. The guidelines recommend using mechanical means and proper lifting techniques to reduce injury. Servers, UPS, and other rack mounted equipment typically weigh 35 - 500lb. Assuming four persons lifting equally, a 300lb.server would require each person to lift 75 lbs.; putting every person at risk of injury according to the above research.

As such, one might expect to commonly find injuries related to lifting rack mounted equipment in Data Centers. ServerLIFT Corporation's blind study and the OSHA 3000 reports validate this conclusion in general, although further study would be required to quantify data with a higher degree of statistical significance.

Given the rapid expansion of the industry and the growing weight of equipment, there is a need for a broad implementation of procedures that include device-based lifting to mitigate future injury and damage.

The Impact and Importance of a Specialized Server Handling Solution

A specialized server handling solution significantly increases efficiency, reduces risk of injuries and lowers operating costs in any data center environment. In mild to large sized companies, small improvements can have a substantial impact. Constantly applied across an entire network, with a level of consistency, these changes can significantly improve data center efficiency and reduce operating costs.

Productivity and Cost Savings in the Data Center:

Cost Savings by Implementing a ServerLIFT:

The following average annual savings can be presumed when savings are based on, two salaried employees, at a salary rate of $70,000 per year, with an average needed time of 30 minutes to manually install rack-mounted equipment, at a weight of 75+ lbs., with the understanding that the task can be completed 50% faster with the help of an SL-500X Electric ServerLIFT.

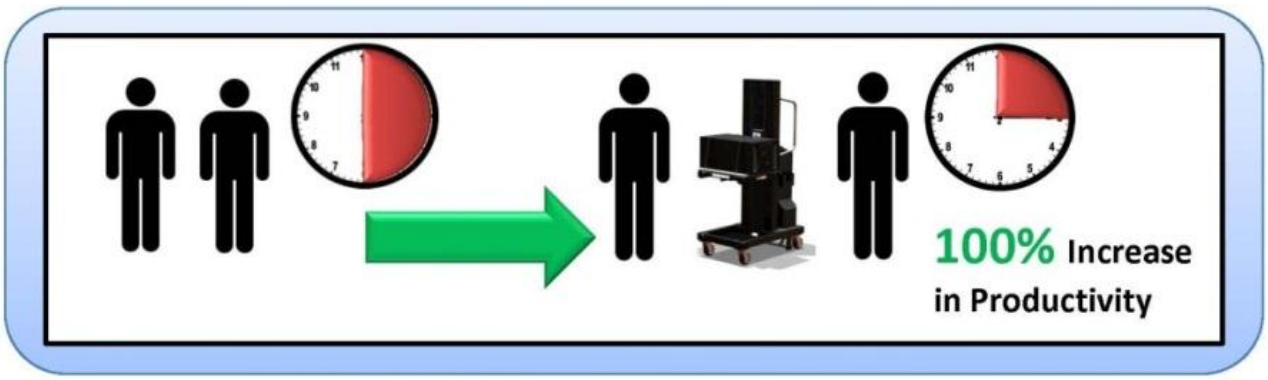
Rack-Mounted Equipment Moves	Annual Savings*
5 moves per week	$4,550
10 moves per week	$9,100
30 moves per week	$27,300

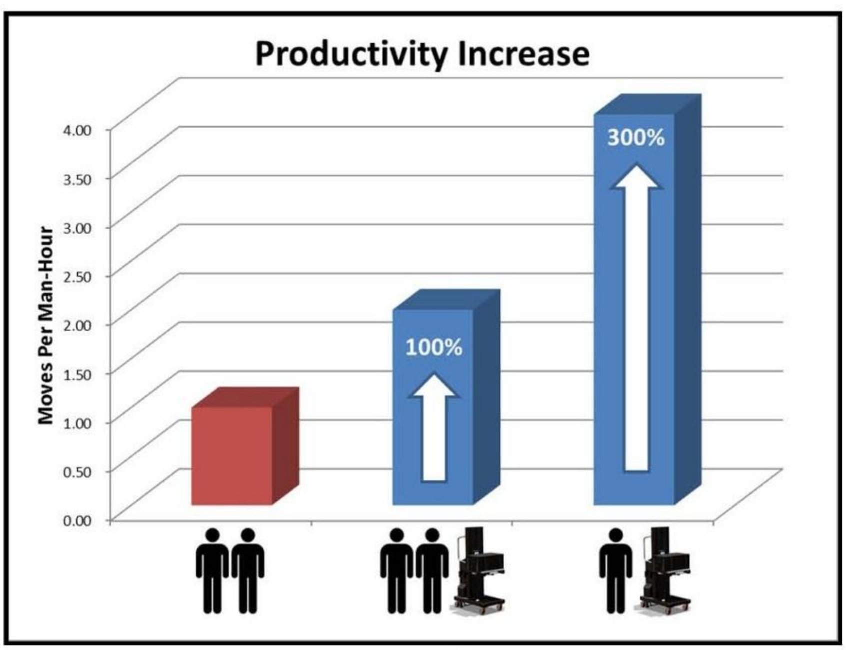
*Average annual savings based on 2 salaried employees ($70,000/year each) with an average time of 30 minutes to manually install rack-mounted equipment (75 + lbs.). The task can be done 50% faster with the help of a ServerLIFT SL500.

Improved Data Center Efficiency with ServerLIFT:

It normally takes at least 20 - 30 minutes for two or more IT technicians to manually install a piece of heavy rack-mounted equipment. With the help of an SL-500X Electric ServerLIFT, the time needed is typically reduced by at least 50%, increasing productivity by 100%.

In most cases, a job that used to require multiple employees only requires one with the assistance of a ServerLIFT solution. In some instances, a task that originally took 20 - 30 minutes with at least three employees manually handling IT equipment can now be completed by one employee in half the time, thus increasing productivity by 300%.





14 Specifications for Choosing a Specialized Data Center Server Handling Solution

As critical as deploying a server lifting solution is, it is equally as important for a data center to understand what the key points are to consider when choosing the right device for their unique needs. Below you will find 14 key points that are essential in considering when purchasing a server lifting solution.

1. **Design Intent**

Question: Was the lifting machine designed to be used in a data center?

Importance: Lifts that handle general materials in a variety of environments (like warehouses and loading docks) are designed to operate in spaces and aisles regulated by commercial architectural standards and local codes.

Data centers are built with much tighter spaces than commercial environments and have strict policies against products that use hazardous materials.

To effectively handle and install rack-mounted equipment in compact data center aisles, a lifting machine must be designed with the functionality and configuration to suitably maneuver in the specific space and accurately position the equipment. Further, the use of hydraulics or other hazardous materials by the lifting device risks a code violation in the data center.

2. **Load Capacity**

Question: Is the lift’s rated capacity able to handle the weight of the IT equipment you need to lift or may need to lift in the future?

Importance: The servers, switches, and power supplies used in modern data centers can weigh hundreds of pounds and some trends indicate they will only get heavier. It is important to plan ahead and spec a lifting device that is designed to handle your rack-mounted equipment.

3. **Platform Stability**

Question: How rigid and stable is the machine under load and when in use?

Importance: Lifting and moving servers, is unlike handling any other type of load. IT equipment can be sensitive to jarring movements and needs to be kept level and secure for proper alignment installation into data center racks.

When selecting a lifting machine for this purpose, the more rigid and stable it is under load and during operation, the better. If the platform sags, the equipment won't remain level and installation will become more difficult. If the unit is unbalanced, shakes, or is wobbly, the server is at risk of falling or being damaged.

4. Equipment Positioning

Question: In which orientation does the lift position equipment?

Importance: In data center aisles, space is tight and equipment may be populated on both sides of the aisle.

Front loading units severely restrict the space and maneuverability available to the operator because the lift needs to be turned to face one side. Also, repositioning is very difficult when the unit is facing the rack.

Lifting devices that position equipment from the side allow for racking on either side of narrow aisles. Side loading makes it easy for the operator to make precise position adjustments.

5. Compliance

Question: Does the lifting device comply with local regulations and is it certified as such?

Importance: All data center devices, including servers, switches, and power supplies must be certified to ensure that maximum levels of radio-frequency disturbance are not exceeded and minimum safety standards are met. The certifications are based on compliance with local regulations such as **FCC/IC** (North America) and **CE** (European Union). Devices that are not in compliance can cause a danger to data center employees and equipment.

6. Operating Controls

Question: Are the controls easily accessible from a variety of operator positions?

Importance: Maintaining line of sight with the rack is critical in making the height adjustments necessary to precisely align equipment for an easy install. Operating controls that are easily accessible from any position ensure that a clear line of sight can be achieved in any situation.

7. Adjustment Scale

Question: Is the lift capable of making very small, incremental up/down movements?

Importance: Precise alignment of the equipment is essential for successful installs and is especially important in populated racks. Only lifts that can move up and down in very fine steps are able to achieve the positioning necessary to precisely match up the equipment and rack mounting points.

8. Lifting Speed

Question: How quickly can a maximum load be lowered or raised?

Importance: Time is money. Lifts that can move equipment up or down very quickly and efficiency better support data center operating goals. The ultimate solution for data centers are lifts that can:

a. Move servers quickly up or down for efficient vertical positioning, AND
b. Make slower, precise positioning adjustments for efficient horizontal racking or un-racking.

9. Platform Range

Question: What is the vertical range (lowest to highest position) of the lift's equipment platform?

Importance: To operate efficiently, data center racks must be populated from bottom up. Heavy IT equipment needs to be supported and installed into all available rack positions. Lifting devices selected for data center applications should have the operational range necessary to deliver equipment at the bottom or up to the top of any rack.

10. Securing Equipment

Question: Can the equipment be secured to the platform?

Importance: Servers and switches can shift during transport. A device with straps and attachment points for equipment to be tied down or secured in place is essential to a data center lift in order to prevent damage to sensitive equipment.

11. Overhead Safety

Question: Does the unit have safety measures to prevent damage to data center facilities and equipment?

Importance: Low ceilings, overhead cable trays, cold/hot aisle containment areas and seismic re-enforcement structures are often found in data centers. Catastrophic damage to these facilities and equipment can occur due to operator inattention when raising servers with a lifting machine. By protecting against costly accidents, lifts that have built-in, dynamic safety measures are better suited for data center environments.

12. Braking System

Question: Does the lift have a braking system that effectively prevents twisting and rolling during lifting and install?

Importance: When supporting equipment during an install, lifts must remain stationary for safety and functionality. Braking systems with only a single point of contact to the floor may prevent directional motion, but can still rotate about the single braking point. Mechanisms with multiple locking points, like individual wheel locks, are more time consuming to use and risk the operator neglecting to engage one or all of the locking points.

A braking system with exactly two points of contact to the floor and a single point of activation for the operator is the best choice for data center applications.

13. Wheels

Question: Are the casters or wheels of the lift adequate for traversing across your data center's flooring?

Importance: Data centers with raised flooring are commonly made up of grated tiles. Wheels that are thin, small and made of metal can damage flooring. Only large (minimum 4"-5" or 10-12cm) diameter wheels that are made of non-scuffing material are able to navigate smoothly and safely over this type of terrain when carrying heavy loads.

14. Containment

Question: Does the lifting mechanism have components that contain hazardous fluids or compounds that are restricted from use in your data center?

Importance: Over time, hydraulic systems and lead acid batteries are prone to failure and will eventually leak. These fluids are extremely dangerous and can cause major damage to data center facilities/equipment, leading to significant downtime. Only hydraulics-free machinery that use leak-proof batteries are suitable for the data center. <u>Standard automotive batteries are not acceptable.</u>

Streamlining of Data Center Server Lifts

ServerLIFT Corporation was founded in 2002 in response to a growing demand for a safe and efficient way to handle servers and other IT equipment in the data center. With a strong focus on the integration of design and manufacturing across the value chain, we have grown to become the premier provider of IT equipment handling solutions.

Creating exceptional value and a competitive advantage for our clients is what has made ServerLIFT the choice of leading data centers around the world. From the beginning, extensive research was conducted to identify the key features required to move servers and peripheral equipment safely and efficiently in the modern data center. This market intelligence endeavor was meticulously integrated with top engineering and design talent to create a product portfolio that exceeds the highest standards in the industry. This effort is ongoing, as we continue to innovate and respond to clients' needs.

ServerLIFT Corporation has forever changed the way IT equipment is handled. We have changed it in the way that data center experts want and need it to be done. By taking a holistic view of evolving demands, IT processes, and industry trends, our product roadmap ensures that ServerLIFT will continue to be the IT professional's safest data center decision.

ServerLIFT Product Line:

- SL-500X Electric ServerLIFT
- SL-350X Manual ServerLIFT
- LE-500X Lift Extension
- RL-500 Platform RISER

SL-500X ServerLIFT:

The SL-500X Electric ServerLIFT promotes a safer work environment and improves overall data center efficiency. The SL-500X has a slim 24 inch frame which sits on 4 oversized swiveling castors, allowing it to easily maneuver through and around data center aisles. The unit is designed to load IT equipment from the side rather than the front for easier alignment and install. It features a side-shifting shelf which supports equipment during the transition from the platform into the rails of the rack. With an overall elegant and sleek design, the rugged platform is capable of lifting 500 lbs. of IT equipment to a height of eight feet.

SL-500X ServerLIFT Base Specifications:

	US	Metric
Height (Lowered)	5′ 10″	1.76 m
Height (Raised)	9′ 4″	2.85 m
Length	3′ 8″	1.12 m
Width	2′ 5″	0.625 m
Platform Height-Extended	8′	2.44 m
Platform Height-Stowed	5.3″	13.5 cm
Load Capacity-Platform Center	500 lbs.	226.8 kg
Load Capacity-Edge	300 lbs.	136.08 kg
Platform Movement / side	6″	15.24 cm
Movable Platform-Width	14 3/4″	37.6 cm
Platform Length	24″	61 cm
Total Platform Width	21″	53 cm
Rear Caster Diameter	5″	12.7 cm
Front Caster Diameter	3″	10.2 cm
Caster Width	2″	5.08 cm
Total Unit Weight	428 lbs.	194 kg

SL-350X ServerLIFT:

The SL-350X manual ServerLIFT features the durable design you have come to expect from ServerLIFT, in an economy class unit for any data center, including small server rooms and satellite locations. The slim 24" footprint allows for easy access down narrow data center aisles, while the oversized swiveling casters give it the ability to turn around sharp corners. The unit is designed to load server and other rack-mounted equipment from the side for optimum alignment and installation in even the narrowest data center aisles. The ultra-rigid platform has little to no deflection making it easy to lift and align equipment. The platform also features a unique gliding shelf that supports equipment into the rack, for a more seamless installation process. With a powerful hand crank, an operator can effortlessly lift 350 lbs. up to a height of 8 feet.

SL-350X ServerLIFT Base Specifications:

	US	Metric
Height (Lowered)	5′ 8″	1.73 m
Height (Raised)	9′ 2.75″	2.81 m
Length	3′ 8″	1.12 m
Width	2′ 5″	0.625 m
Platform Height-Extended	8′	2.44 m
Platform Height-Stowed	5.3″	13.5 cm
Load Capacity-Center	350 lbs.	176.9 kg
Load Capacity-Edge	300 lbs.	136.08 kg
Platform-Movement/Side	6″	15.25 cm
Movable Platform-Width	14 3/4″	37.6 cm
Platform Length	24 in	61 cm
Total Platform Width	21″	53 cm
Rear Caster Diameter	5″	12.7 cm
Front Caster Diameter	3″	10.2 cm
Caster Width	2″	5.08 cm
Total Unit Weight	350 lbs.	176.9 kg

Conclusion

The growing performance demands placed on data centers are increasingly affecting IT hardware maintenance requirements. A facility will run at its best efficiency with the proper tools and innovative solutions. Deploying a specialized server handling solution significantly decreases risk, increases efficiency and lowers operating costs.

For more information, products videos and pricing please visit: http://www.serverlift.com

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Appendix A

The NIOSH Lifting Equation

The lifting equation is used as a calculation to determine a recommended weight for specific two-handed, symmetrical lifting tasks. In 1991, NIOSH issued a revised equation for the design and evaluation of manual lifting tasks. It uses six factors that have been determined to influence lifting difficulty the most, combining the factors into one equation. Two of the factors which are new to the revised equation include twisting (asymmetry) and the quality of the worker's grip on the load (coupling).

Using the equation involves calculating values for the six factors in the equation for a particular lifting and lowering task, thereby generating a Recommended Weight Limit (RWL) for the task. The RWL is the load that nearly all healthy employees (90% of the adult population, 99% of the male and 75% of the female workforce) can lift over a substantial period of time (i.e., up to 8 hours) without placing an excessive load on their backs. (OSHA)

The revised lifting equation for calculating the **Recommended Weight Limit (RWL)** is based on a multiplicative model that provides a weighting for each of six variables. The RWL is defined by the following equation:

RWL = LC × HM × VM × DM × AM × FM × CM

Where:

		METRIC	U.S. CUSTOMARY
Load Constant	LC	23 kg	51 lb
Horizontal Multiplier	HM	(25/H)	(10/H)
Vertical Multiplier	VM	$1-(.003\|V-75\|)$	$1-(.0075\|V-30\|)$
Distance Multiplier	DM	.82 + (4.5/D)	.82 + (1.8/D)
Asymmetric Multiplier	AM	1-(.0032A)	1-(.0032A)
Frequency Multiplier	FM	From Table 5	From Table 5
Coupling Multiplier	CM	From Table 7	From Table 7

Terminology and Data Definitions:

Lifting Index (LI): The LI is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of the level of physical stress is defined by the relationship of the weight of the load lifted and the recommended weight limit.

The LI is defined by the following equation:

$$LI = \frac{\text{Load Weight}}{\text{Recommended Weight Limit}} = \frac{L}{RWL}$$

Horizontal location of the hands (H): The horizontal location of the hands at both the start (origin) and end (destination) of the lift must be measured. The horizontal location is measured as the distance from the mid-point between the employee's ankles to a point projected on the floor directly below the mid-point of the hands grasping the object (the middle knuckle can beused to define the mid-point). The horizontal distance should be measured when the object is lifted (when the object leaves the surface). See Figure 1.

VM = Vertical Multiplier (1 - (0.0075|V-30|))

Vertical location of the hands (V): The vertical location is measured from the floor to the vertical mid-point between the two hands (the middle knuckle can be used to define the mid-point). See Figure 1.

DM = Distance Multiplier (0.82 + (1.8 / D)

Travel Distance of the load (D): The total vertical travel distance of the load during the lift is determined by subtracting the vertical location of the hands (V) at the start of the lift from the vertical location of the hands (V) at the end of the lift. For lowering, the total vertical travel distance of the load is determined by subtracting the vertical location of the hands (V) at the end of the lower from the vertical location of the hands (V) at the start of the lower.

AM = Asymmetric Multiplier (1 - (0.0032A))

Asymmetry Angle (A): The angular measure of the perpendicular line that intersects the horizontal line connecting the mid-point of the shoulders and the perpendicular line that intersects the horizontal line connecting the outer mid-point of the hips. See Figure 2.

FM = Frequency Multiplier (Table 5)

Lifting Frequency (F): The average lifting frequency rate, expressed in terms of lifts per minute, must be determined. The frequency rate can be determined by observing a typical 15 minute work period, and documenting the number of lifts performed during this time frame. The number of lifts observed is divided by 15 to determine the average lifts per minute. Duration is measured using the following categories: Short (Less than one hour); Moderate (1 to 2 hours); Long (2 to 8 hours).

CM = Coupling Multiplier (Table 7)

Object coupling (C): The classification of the quality of the hand-to-object coupling (rated as Good, Fair, or Poor).

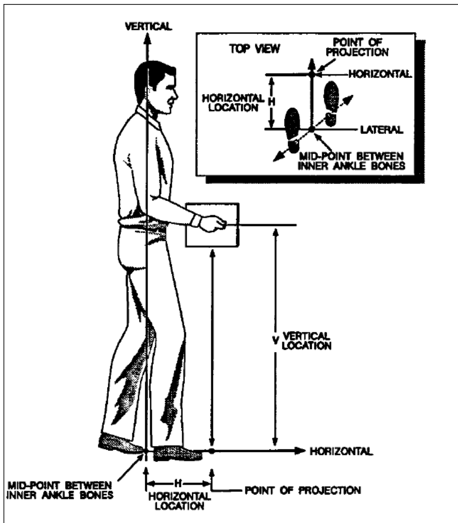

Figure 1 Graphic Representation of Hand Location

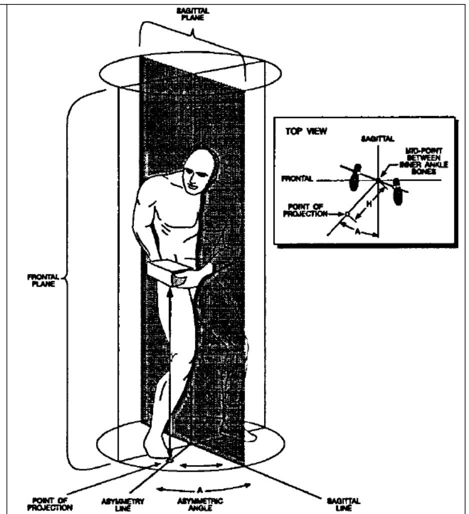

Figure 2 Graphic Representation of Angle of Asymmetry (A)

Table 1
Horizontal Multiplier

H	HM	H	HM
in		cm	
≤10	1.00	≤25	1.00
11	.91	28	.89
12	.83	30	.83
13	.77	32	.78
14	.71	34	.74
15	.67	36	.69
16	.63	38	.66
17	.59	40	.63
18	.56	42	.60
19	.53	44	.57
20	.50	46	.54
21	.48	48	.52
22	.46	50	.50
23	.44	52	.48
24	.42	54	.46
25	.40	56	.45
>25	.00	58	.43
		60	.42
		63	.40
		>63	.00

Table 2
Vertical Multiplier

V	VM	V	VM
in		cm	
0	.78	0	.78
5	.81	10	.81
10	.85	20	.84
15	.89	30	.87
20	.93	40	.90
25	.96	50	.93
30	1.00	60	.96
35	.96	70	.99
40	.93	80	.99
45	.89	90	.96
50	.85	100	.93
55	.81	110	.90
60	.78	120	.87
65	.74	130	.84
70	.70	140	.81
>70	.00	150	.78
		160	.75
		170	.72
		175	.70
		>175	.00

Table 5
Frequency Multiplier

F lifts/min	DURATION					
	< 1 hour		1-2 hours		2-8 hours	
	V< 30 in	V ≥ 30 in	V< 30 in	V ≥ 30 in	V< 30 in	V ≥ 30 in
≤2	1.00	1.00	.95	.95	.85	.85
.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

Table 3
Distance Multiplier

D	DM	D	DM
in		cm	
≤10	1.00	≤25	1.00
15	.94	40	.93
20	.91	55	.90
25	.89	70	.88
30	.88	85	.87
35	.87	100	.87
40	.87	115	.86
45	.86	130	.86
50	.86	145	.85
55	.85	160	.85
60	.85	175	.85
70	.85	>175	.00
>70	.00		

Table 4
Asymmetric Multiplier

A	AM
deg	
0	1.00
15	.95
30	.90
45	.86
60	.81
75	.76
90	.71
105	.66
120	.62
135	.57
>135	.00

Table 7
Coupling Multiplier

COUPLING TYPE	CM	
	V < 30 in	V≥ 30 in
GOOD	1.00	1.00
FAIR	.95	1.00
POOR	.90	.90

Table 6
Hand-to-Container Coupling Classification

GOOD	FAIR	POOR
1. For containers of optimal design, such as some boxes, crates, etc., a "Good" hand-to-object coupling would be defined as handles or hand-hold cut-outs of optimal design [see notes 1 to 3 below].	1. For containers of optimal design, a "Fair" hand-to-object coupling would be defined as handles or hand-hold cut-outs of less than optimal design [see notes 1 to 4 below].	1. Containers of less than optimal design or loose parts or irregular objects that are bulky, hard to handle, or have sharp edges [see note 5 below].
2. For loose parts or irregular objects, which are not usually containerized, such as castings, stock, and supply materials, a "Good" hand-to-object coupling would be defined as a comfortable grip in which the hand can be easily wrapped around the object [see note 6 below].	2. For containers of optimal design with no handles or hand-hold cut-outs or for loose parts or irregular objects, a "Fair" hand-to-object coupling is defined as a grip in which the hand can be flexed about 90 degrees [see note 4 below].	2. Lifting non-rigid bags (i.e., bags that sag in the middle).

Table 8
General Design/Redesign Suggestions

If HM is less than 1.0	Bring the load closer to the worker by removing any horizontal barriers or reducing the size of the object. Lifts near the floor should be avoided; if unavoidable, the object should fit easily between the legs.
If VM is less than 1.0	Raise/lower the origin/destination of the lift. Avoid lifting near the floor or above the shoulders.
If DM is less than 1.0	Reduce the vertical distance between the origin and the destination of the lift.
If AM is less than 1.0	Move the origin and destination of the lift closer together to reduce the angle of twist, or move the origin and destination further apart to force the worker to turn the feet and step, rather than twist the body.
If FM is less than 1.0	Reduce the lifting frequency rate, reduce the lifting duration, or provide longer recovery periods (i.e., light work period).
If CM is less than 1.0	Improve the hand-to-object coupling by providing optimal containers with handles or handhold cutouts, or improve the handholds for irregular objects.
If the RWL at the destination is less than at the origin	Eliminate the need for significant control of the object at the destination by redesigning the job or modifying the container/object characteristics. (See requirements for significant control, p. 36, 43.)

Sample Equation:

NIOSH Example 2, Loading Supply Rolls:

Job Description-

With both hands directly in front of the body, a worker lifts the core of a 35-lb roll of paper from a cart, and then shifts the roll in the hands and holds it by the sides to position it on a machine, as shown in Figure 8. Significant control of the roll is required at the destination of the lift. Also, the worker must crouch at the destination of the lift to support the roll in front of the body, but does not have to twist.

Job Analysis-

The task variable data are measured and recorded on the job analysis worksheet (Figure 9). The vertical location of the hands is 27 inches at the origin and 10 inches at the destination. The horizontal location of the hands is 15 inches at the origin and 20 inches at the destination. The asymmetric angle is 0 degrees at both the origin and the destination, and the frequency is 4 lifts/shift (i.e., less than .2 lifts/min for less than 1 hour).

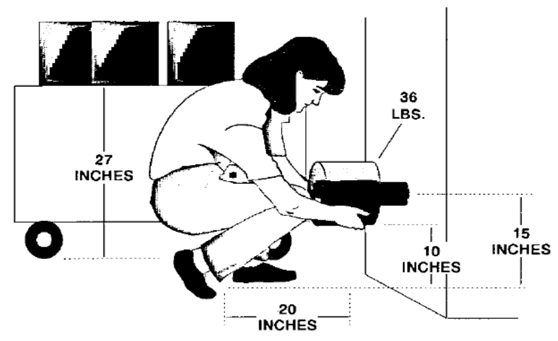

Figure 8 Loading Supply Rolls, Example 2

The coupling is classified as poor because the worker must reposition the hands at the destination of the lift and they cannot flex the fingers to the desired 90 degrees angle (e.g., hook grip). No asymmetric lifting is involved (i.e., A = 0), and significant control of the object is required at the destination of the lift. Thus, the RWL should be computed at both the origin and the destination of the lift. The multipliers are computed from the lifting equation or determined from the multiplier tables. As shown in Figure 9, the RWL for this activity is 28.0 lb. at the origin and 18.1 lb. at the destination.

Hazard Assessment-

The weight to be lifted (35 lb) is greater than the RWL at both the origin and destination of the lift (28.0 lb and 18.1 lb, respectively). The LI at the origin is 35 lb./28.0 lb. or 1.3, and the LI at the destination is 35 lb./18.1 lb. or 1.9. These values indicate that this job is only slightly stressful at the origin, but moderately stressful at the destination of the lift.

Redesign Suggestions-

The first choice for reducing the risk of injury for workers performing this task would be to adapt the cart so that the paper rolls could be easily pushed into position on the machine, without manually lifting them.

If the cart cannot be modified, then the results of the equation may be used to suggest task modifications. The worksheet displayed in Figure 9 indicates that the multipliers with the smallest magnitude (i.e., those providing the greatest penalties) are .50 for the HM at the destination, .67 for the HM at the origin, .85 for the VM at the destination, and .90 for the CM value. Using Table 8, the following job modifications are suggested:

1. Bring the load closer to the worker by making the roll smaller so that the roll can be lifted from between the worker's legs. This will decrease the H value, which in turn will increase the HM value.
2. Raise the height of the destination to increase the VM.
3. Improve the coupling to increase the CM.

If the size of the roll cannot be reduced, then the vertical height (V) of the destination should be increased. Figure 10 shows that if V was increased to about 30 inches, then VM would be increased from .85 to 1.0; the H value would be decreased from 20 inches to 15 inches, which would increase HM from .50 to .67; the DM would be increased from .93 to 1.0. Thus, the final RWL would be increased from 18.1 lb. to 30.8 lb., and the LI at the destination would decrease from 1.9 to 1.1.

In some cases, **redesign may not be feasible. In these cases, use of a mechanical lift may be more suitable**. As an interim control strategy, two or more workers may be assigned to lift the supply roll.

Comments-

The horizontal distance (H) is a significant factor that may be difficult to reduce because the size of the paper rolls may be fixed. Moreover, redesign of the machine may not be practical. Therefore, **elimination of the manual lifting component of the job may be more appropriate than job redesign. Reference the chart below for more detail.**

JOB ANALYSIS WORKSHEET

DEPARTMENT: Shipping
JOB TITLE: Packager
ANALYST'S NAME:
DATE:

JOB DESCRIPTION: Loading paper supply rolls

Example 2

STEP 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Frequency Rate lifts/min	Duration (HRS)	Object Coupling
		Origin		Dest.			Origin	Destination			
L (AVG.)	L (Max.)	H	V	H	V	D	A	A	F		C
35	35	15	27	20	10	17	0	0	<.2	<1	Poor

STEP 2. Determine the multipliers and compute the RWL's

RWL = LC x HM x VM x DM x AM x FM x CM

ORIGIN RWL = 51 x .67 x .98 x .93 x 1.0 x 1.0 x .90 = 28.0 Lbs

DESTINATION RWL = 51 x .50 x .85 x .93 x 1.0 x 1.0 x .90 = 18.1 Lbs

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFTING INDEX = OBJECT WEIGHT (L) / RWL = 35 / 28.0 = 1.3

DESTINATION LIFTING INDEX = OBJECT WEIGHT (L) / RWL = 35 / 18.1 = 1.9

Figure 9: Example 2, Job Analysis Worksheet

JOB ANALYSIS WORKSHEET

DEPARTMENT: Shipping
JOB TITLE: Packager
ANALYST'S NAME:
DATE:

JOB DESCRIPTION: Loading paper supply rolls

Modified Example 2

STEP 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Frequency Rate lifts/min	Duration (HRS)	Object Coupling
		Origin		Dest.			Origin	Destination			
L (AVG.)	L (Max.)	H	V	H	V	D	A	A	F		C
35	35	15	27	15	30	3	0	0	<.2	<1	Poor

STEP 2. Determine the multipliers and compute the RWL's

RWL = LC x HM x VM x DM x AM x FM x CM

ORIGIN RWL = 51 x .67 x .98 x 1.0 x 1.0 x 1.0 x .90 = 30.1 Lbs

DESTINATION RWL = 51 x .67 x 1.0 x 1.0 x 1.0 x 1.0 x .90 = 30.8 Lbs

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFTING INDEX = OBJECT WEIGHT (L) / RWL = 35 / 30.1 = 1.2

DESTINATION LIFTING INDEX = OBJECT WEIGHT (L) / RWL = 35 / 30.8 = 1.1

Figure 10: Example 2, Modified Job Analysis Worksheet