Liftech
LIFTECH CONSULTANTS INC.

Crane Innovations – The Past, The Present, The Future
起重机创新-过去、现在、未来

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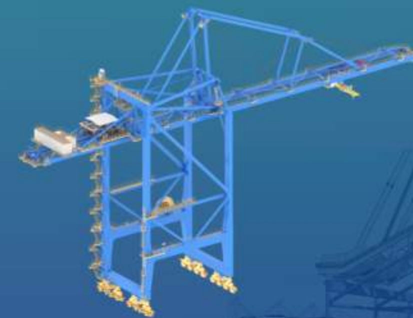
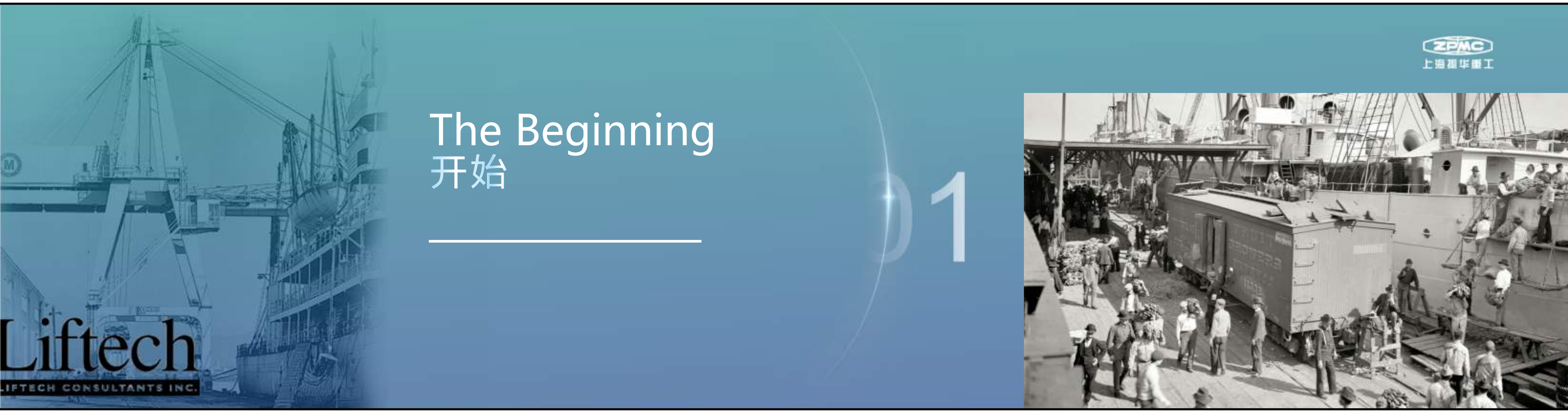


Liftech Consultants Inc. is a consulting engineering firm, founded in 1964, with special expertise in the design and procurement of dockside container handling cranes and other complex structures. Our experience includes structural design for wharves and wharf structures, heavy lift structures, buildings, container yard structures, and container handling equipment. Our national and international clients include owners, engineers, operators, manufacturers, and riggers. We provide structural, mechanical, and electrical engineering services.

Mr. Soderberg is Liftech's president and a structural engineer with over 29 years of experience in the design, review, and modification of a variety of structural systems including hundreds of container cranes, over a dozen bulk loader structures, and over two dozen wharves and piers. Other structures include crane lift and transfer systems and concrete and steel floats. Mr. Soderberg is presenting some of the historical ship-to-shore crane and related innovations from the beginning of the first dockside container cranes through some expected future innovations.



The photograph on the right shows bananas being offloaded in New Orleans in 1903.

As most of us know, before containerization, loading cargo was dangerous, time consuming, expensive, and there was significant theft.

Containerization changed all that…

Visionaries and Stakeholders
远见卓识者和利益攸关方

Malcolm McLean,
McLean Trucking,
SeaLand Service Inc.

Les Harlander,
Matson Shipping

Dean Ramsden,
Pacific Coast Engineering
Co. (PACECO)

Michael Jordan,
Liftech Consultants Inc.

Four key people at the beginning of containerization are shown here. Many others also played pivotal roles.

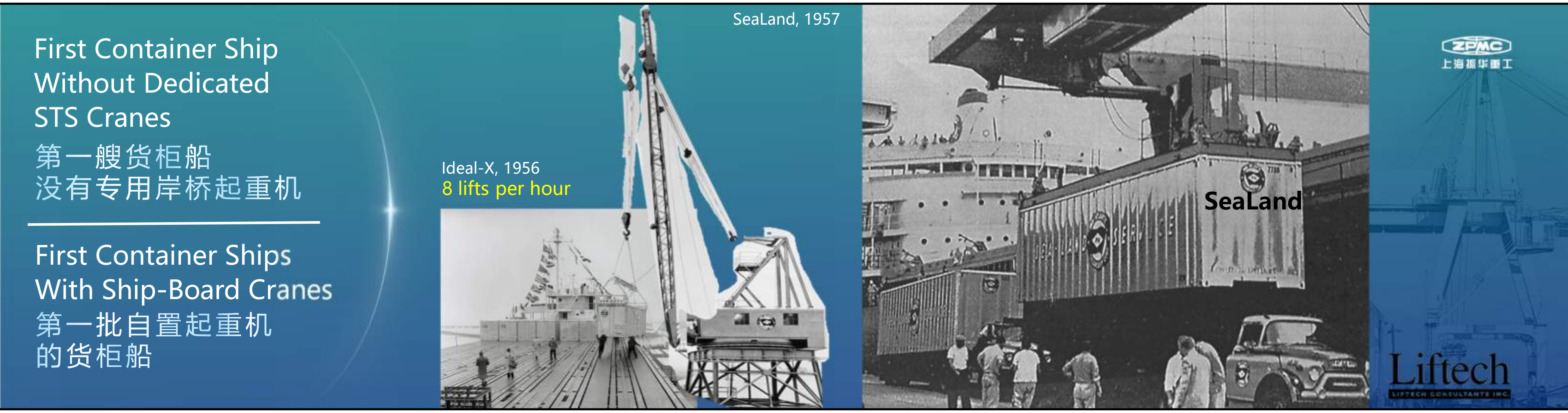
Malcom McLean is known as the “Father of Containerization.” He was the founder of McLean Trucking, conceived of and developed containerized shipping, and founded SeaLand Service Inc.

Les Harlander was the Matson Engineering Development Manager, a Naval Architect from Oakland, CA.

- He helped design and test the modern shipping container (24 ft) and later helped develop international container standards.
- He and his brother Don helped develop requirements for the first dockside (STS) container crane and pier-to-ship requirements.
- He was also part of Matson’s team for developing contract plans for converting their first C3 vessels for container shipping.

Dean Ramsden was the Paceco President and played an important role in designing the first dockside container crane and the first wave of container cranes.

Michael Jordan was a structural engineer at Hugh M. O’Neil Co. and later founded Liftech Consultants. Mike helped design the structure for the world’s first dockside container crane and was involved in thousands of other crane designs.



Some of the early containerization efforts are shown here.

In 1956, the Ideal-X vessel, an idea by Malcolm McLean, began operating being serviced by revolver cranes. Productivity was about 8 containers per hour. In 1957, vessels with shipboard cranes began operating but became less popular compared to land-based cranes, due to vessel motion, added vessel weight, shipping costs, difficulty maintaining the cranes while still using the vessel, and other reasons.

[MORE DETAILS – NOT PRESENTED]
In 1956, the Ideal-X vessel was made by converting an oil tanker to support containers. The first shipment was from the Port of Newark, New Jersey, to the Port of Houston, Texas. This was an idea of Malcolm McLean* (McLean trucking and later founder of SeaLand). The vessel carried 58, 33-ft containers, loaded in about 8 hr using a revolver crane with a productivity of about 8 min per container. Workers on deck were needed to control the container sway and rotation. The 33-ft container was based on a standard trucking size in the US. At that time, Matson estimated that nearly 50% of the company's costs were for loading and unloading ships.

In 1957, early vessels with ship-board cranes emerged, with the Gateway City being the first true containership, from Mobile, Alabama, first sailing from Newark, New Jersey, to Miami. These offered some advantages, as no specialized infrastructure was needed, but they became less popular compared to land-based cranes, due to vessel instability issues, added vessel weight, shipping costs, difficulty maintaining the cranes while still using the vessel, and other reasons.

The first shipping containers were from Matson, circa 1940, with wooden boxes 6 ft x 6 ft x 4 ft, with a hinged door with seals, to prevent pilferage.

In 1950, 8 ft x 8 ft x 30 ft containers were used on ocean-going ships and barges between Seattle and what would soon become Alaska, mainly for perishable foods. McLean was aware of those early efforts. SeaLand later purchased some of those vessels and started service to Alaska.

First Dedicated "A-frame" Dockside, Container Cranes
首台专用 "A型架" 码头集装箱起重机

1958 Matson PACECO Crane

Outreach	23.8 m
Gage	10.4 m
Lift height	15.5 m
Rated load	25 ST
Container	24 ft

12 to 15 lifts per hour

The first dedicated dockside container crane was built by Paceco for Matson. The first A-frame dockside crane started operation on January 7, 1959, at the Encinal Terminals in Alameda, California, for shipping between Alameda, CA, and Honolulu, HI, achieving 12 to 15 lifts per hour, about 400 tons of cargo per hour.

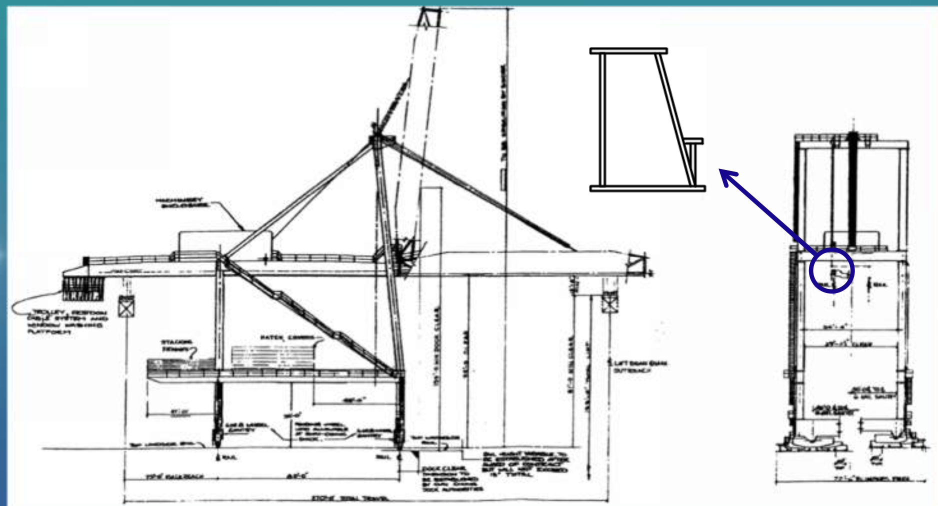
Similar cranes were soon delivered to Hawaii and Los Angeles, CA (in 1960). Revolver cranes were used for a short time prior to the first dockside crane being built and for use at other locations until all locations had dockside cranes.

[MORE DETAILS – NOT PRESENTED]
The crane was later modified and relocated. ASME "International Historic Mechanical Engineering Landmark."

The operator was in a fixed cabin at the waterside leg. Aesthetics were an important part of the design.

The crane design included numerous new features, such as a wire rope driven trolley, stepless DC variable voltage control system, high power for main hoist, trolley, gantry, and boom hoist, operating trolley and hoist simultaneously, or gantry and boom simultaneously, as required by the Matson team.

SeaLand SL-7,
Circa 1970



Integrated system approach

Modified A-frame

Box girder, lattice boom, rope driven trolley

Size

Outreach	35 m
Span	15.2 m to 30.5 m
Lift height	26 m

Load sway control

The next big milestone with containerization was the SL-7 program.

Sealand's SL-7 program was the breakthrough logistic concept that allowed door-to-door transport between the US and Europe within 7 days. The system was developed in the mid-1960s, with the first vessels in the early 1970s.

Three key components of this concept included very fast SL-7 vessels, enlarged terminals, and their STS cranes. The original A-frame configuration was replaced by a "modified A-frame" design.

The program was one of the largest investments by any shipping line, and total value of the program was more than 4 billion US 1970s dollars, about 30 billion today, a huge risk.

SeaLand bought their cranes with detailed performance specifications. This resulted in a generation of cranes suitable for heavy duty use, high reliability, and low maintenance. Many of these cranes were still in operation with 40 years of use.

[MORE DETAILS – NOT PRESENTED]

Spikes in oil prices later doomed the SL-7 shipping concept, as the fast ship speeds were no longer economical, and the vessels were sold to the US Navy, who also cared about speed, but was not as affected by the higher oil costs.

Rapid Evolution
快速发展

- Modified A-frame
  改良A型架
- Panamax / post-Panamax / Super post-Panamax
  巴拿马型/后巴拿马型 / 超级后巴拿马型
- Low Profile (Shuttle Boom) and Articulated Boom
  伸缩大梁和鹅颈大梁

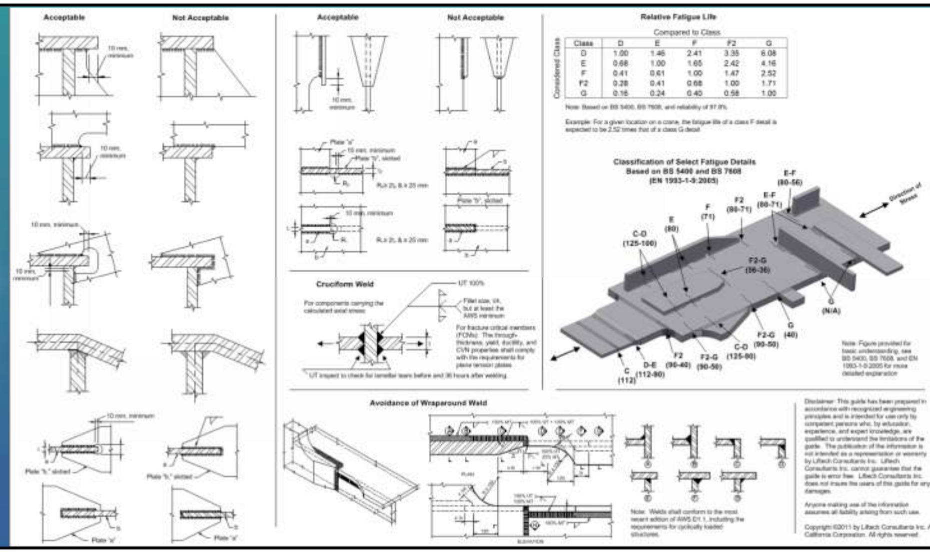
Numbers of cranes, designs, and sizes rapidly increased after the early cranes.

By the end of the 1970s, there were over 700 STS container handling cranes operating in over 200 ports around the world. In the 1980s and 1990s, other manufacturers in Japan, Korea, and Europe were also building cranes of similar design. Crane size continued to grow, to keep pace with larger vessels. Vessel size was often limited by various seagoing obstacles, such as the Panama Canal ("Panamax" vessels and cranes), the Suez Canal (Suezmax), the Malacca Straight (Malaccamax), etc.

In the left image, the first crane is superimposed near a 2005 crane for Norfolk International Terminals, approximately to scale.
In addition to size changes, different types were developed.
In the right image, a low profile crane and an articulated boom crane are shown. These crane types were developed for use near airports, where the overall height is restricted.

Early Innovations
早期创新

- Fatigue Details, Structural Maintenance
  疲劳细节，结构维护
- Trapezoidal Girder Section
  梯形大梁截面
- Machinery-on-Trolley (MOT)
  载重式小车(MOT)
- ... Many Others!
  还有很多很多!



As an early leader in the development of container cranes, some of Liftech's innovations included:

Improved structural fatigue details to reduce fatigue cracking.
Structural maintenance programs to increase structural reliability.
The trapezoidal girder section to improve structural reliability.
Wire rope dampers that, at little cost, eliminated wind induced vibration of cylindrical members.

There were many other innovations.

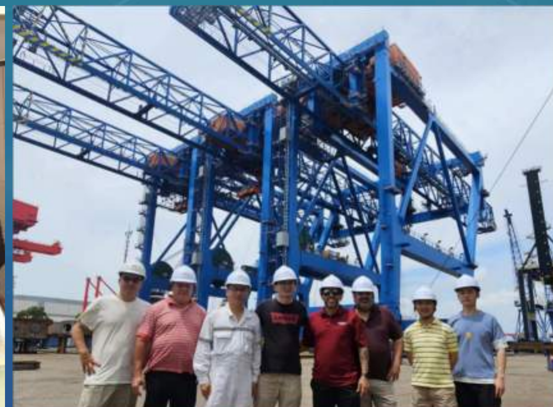
Another key innovation by others shown in the bottom right is the machinery-on-trolley which reduced rope lengths, reduced maintenance, and improved trolley drive characteristics, but presents other issues.

Structural modifications to allow the stiff machinery-on-trolley structure to warp and avoid fatigue cracking issues is shown on the bottom right.

Next, the recent era.

In the 1990s, ZPMC began designing and building cranes. Under the leadership of Mr. Guan, ZPMC grew rapidly. In addition to competitive construction, ZPMC innovations included shipping of completed cranes crosswise on their own fleet of ships and a standardized on and offload procedure. ZPMC has had a willingness to act on a variety of ideas including tandem and triple lift systems, super-capacitor energy systems, and prototype of automated container terminal system shown in the 2007 image.

Collaborators and Supporters
合作者和支持者


As Liftech founder Mike Jordan once said, innovations happen because we have great clients who are willing to take risks and try new things.

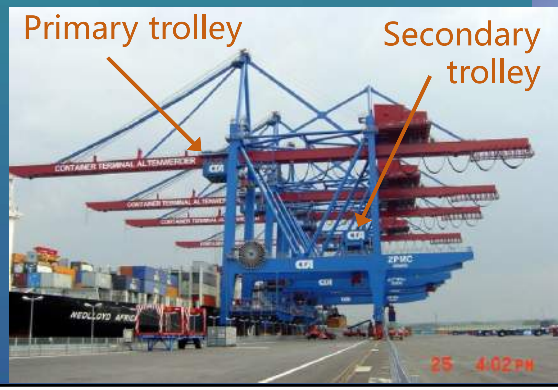
ZPMC's success is due to the support and collaboration of many clients, for example, those in the 1990s were willing to work with a new crane supplier like ZPMC.

The container industry's success is due to the support of the many clients and supporters willing to try new ideas like those shown in this presentation.

The size of the industry is now so large that even small innovations can have a tremendous impact.

Automated terminals are a major innovation with reduced operating costs and improved logistics, and they are the future. Their impact merits their own presentation. Three large automated terminals in Europe, Asia, and North America are shown here.

Dual Trolley Crane
双小车岸桥



Mostly used on automated terminals, the dual trolley crane has a primary waterside trolley and a secondary landside trolley along the portal tie beam girder with access to the landside extension. The secondary trolley is typically fully automated.

Some of the design challenges for this system include:

- Secondary trolley accommodating crane deformations.
- Crane stiffness required for the automation positioning.
- Complex interaction of motions and loadings due to two simultaneously operating trolleys.
- Container transfer platform with protection and isolation for workers.

Indented Berth
嵌入式码头

In the 1990s, Ceres Amsterdam built an indented berth, permitting cranes on both sides of the vessel and allowing servicing of adjacent vessel hatches, potentially doubling the number of cranes per vessel, and halving the time at berth.

Despite working well functionally and technically, the project was terminated due a combination of factors unrelated to the concept.

Floating terminal ideas are similar and permit varying vessel widths.

Tandem 40 Hoist System
双四十起升系统

The introduction of tandem hoist systems allowed lifting multiple containers.

This was achieved by dual hoist systems as shown on the left and by single hoist systems with special tandem headblocks as shown in the middle. As shown on the right, a dual hoist with a tandem lift spreader can lift more than two full length containers at a time.

The use of aerodynamic member sections, and even machinery houses, reduces the wind loading on cranes, providing structural, mechanical, wheel load, and energy advantages.

PACECO tubular leg cranes in Seattle are shown on the left.

ZPMC crane with semi-circular boom and trolley girder with round frame members is shown in the middle.

Kunz yard cranes with elliptical leg and boom sections is shown on the right.

Elevating Girder Crane
升降大梁岸桥

The elevating girder crane was promoted by Dave Rudolf of Virginia International Terminal. Virginia Port Authority (VPA) purchased one elevating girder crane that was jointly designed by ZPMC, Liftech, and McKay International Engineers. The entire upper works can be raised or lowered to a variety of elevations, which results in shorter cycle times when servicing smaller vessels, while still maintaining capacity to serve the large vessels.

Modern Large Size Low Profile Cranes
现代大型伸缩大梁岸桥

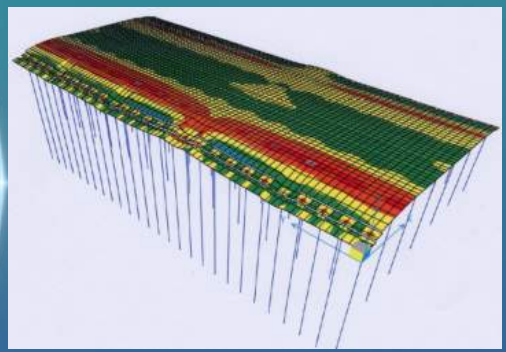
Recent low profile cranes, in addition to having much larger outreaches and being much heavier, are also more advanced including:

- More advanced anti-racking and crane anti-collision controls
- Removal of the traditional boom trolley house
- Trolleys designed to maximize lift height
- Complex fabrication challenges for camber and meeting standard tolerances

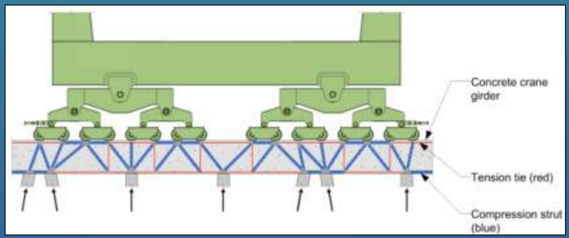
Note: There is a trolley house on the boom of the PED cranes shown, but new VIT/VPA cranes will not have a trolley house.

Next are select crane-wharf innovations that have occurred associated with the rise and increase in size of the dockside container crane and other special requirements.

Justifying Additional Capacity
验证额外承载力



3D Finite Element Analysis



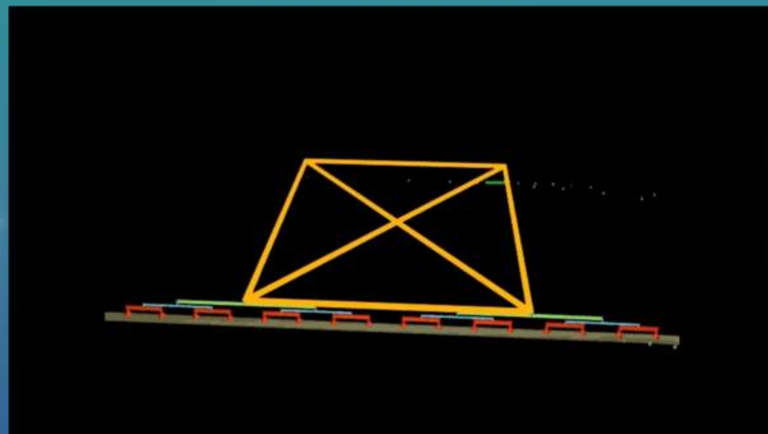
Strut-and-Tie Analysis

Load Testing, Pile Testing

Often, new equipment with larger loads is desired, but existing structures with inadequate rated capacity poses a challenge. There are a range of innovative methods to try to justify increased capacity. Three key innovative methods are shown here. The finite element analysis is a relatively new analysis tool that is particularly worthwhile in justifying girder capacity, particularly when wharves have transverse beams. Strut-and-tie analysis is favorable if additional shear capacity must be justified. Load testing using reasonable criteria is another method that can be applied after confirming the girders probably have the required capacity.

Curved Rails
Optimized Geometry

弧形轨道优化
几何形状



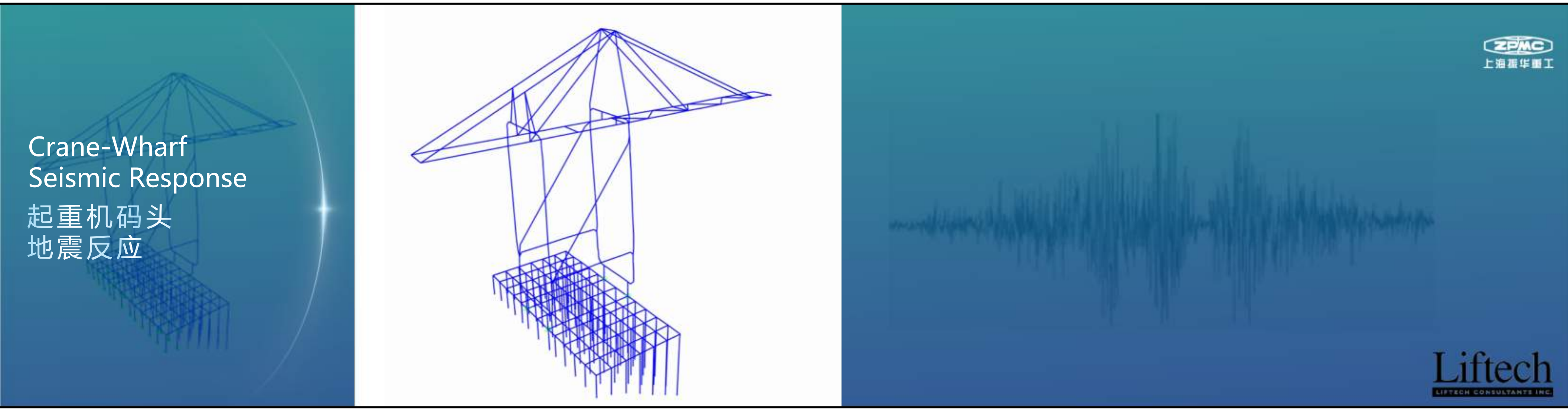
Optimize curved rail geometry

Gantry rotation to accommodate curve

Equipment running on rails must sometimes travel around curved rails.

As shown in this video, the leading and following wheels travel different paths. Notice the leading path in green and trailing in blue. If the difference in paths is large enough, expensive side shift mechanisms are required between the crane frame and main equalizer beams on one side of the crane.

Liftech developed an innovative method that calculates the optimal curved rail geometry and various travel paths. This method and analysis has allowed designing equipment to not have the expensive side shift mechanism and accurately locate power trenches.



STS cranes have become massive, and more significantly affect the wharf response in large earthquakes. This video is of a finite element time history analysis in which an Alaskan design earthquake ground motion is applied to a proposed future wharf structure and crane. Notice how the wharf and crane interact in an earthquake.

Using modern finite element software, it is practical to analyze this interaction behavior with reasonable accuracy and calculate the response of the crane and wharf, allowing for critical design decisions to be made.

Next are some of the newer and potential future innovations.

The articulated balance crane is a concept conceived by Liftech and jointly developed by ZPMC and Liftech.

This was presented in the morning section so we will focus on technical aspects.

To raise the boom, the boom rotates at pins at the waterside cross beam. The trolley girders, houses, and trolley remain horizontal using a “parallel linkage.”

Conventional systems are used for the main hoist, boom hoist, trolley drive, and gantry.

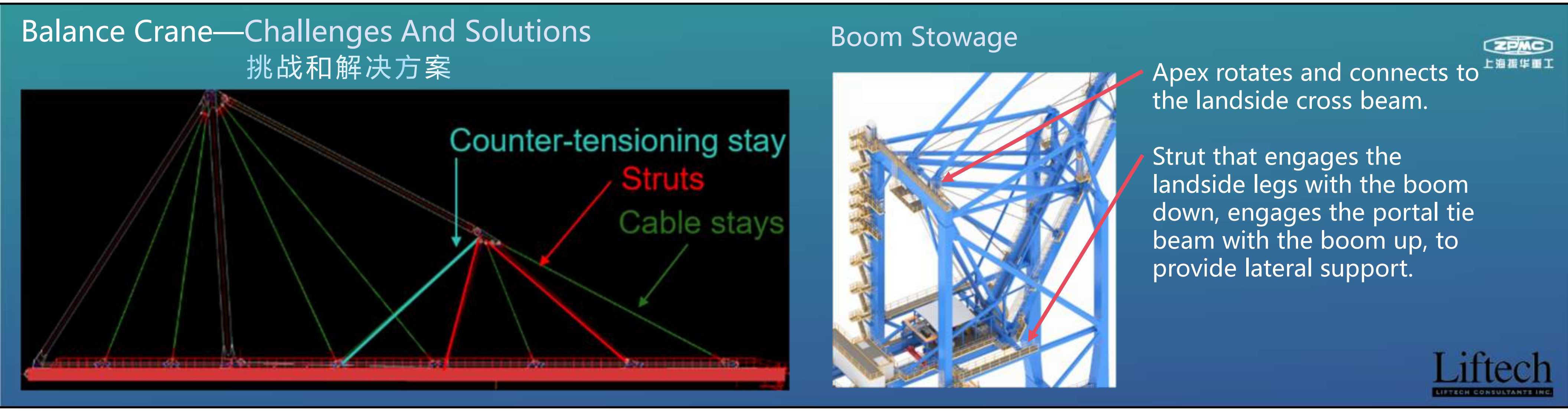
Advantages of this system include:

A lighter boom and reduced stowed wind wheel and tie-down loads.

Easier access and removal of machinery for maintenance, for example the entire trolley can be readily replaced on a machinery-on-trolley variant.

Fewer trolley cycles over the farther landside boom hinge resulting in reduced impact to operator, trolley rail wear, and rail maintenance.

Simplified boom hoist reeving with less rope and reduced hoist time.



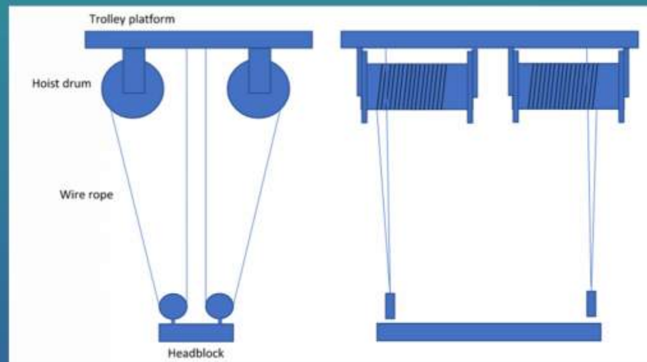
Key challenges with the balance crane design include adequate pre-tensioning of the boom stays, a difficulty due to the light-weight, raisable boom structure. The current concept includes struts to allow adequate stay pre-tensioning.

Tongji University of Shanghai helped with the wind-vibration analysis.

The right image shows how the raised boom is secured by the cross beam and portal beams, another design challenge.

[MORE DETAILS – NOT PRESENTED].
The cable stays shown in green will likely be fully locked coil cables for stiffness and corrosion resistance: common and proven in cable-stayed bridges.

Segment Hoist Motor
分段式起升电机

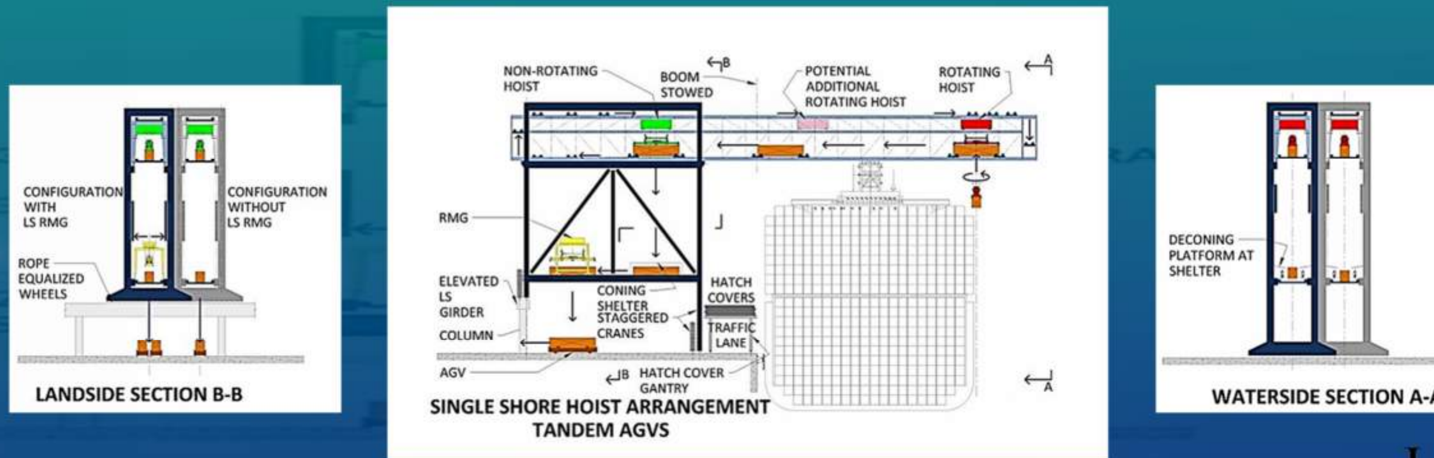


View of segment motor test stand with 9 segments 1FW6809-15N41-0AA0

The Segment Motor Hoist System is a new concept system conceived of by Liftech and developed with Siemens, made possible by the advances in motor technology. This system will result in significant improvements. Examples include not needing gear boxes or the snag protection system.

Liftech SuperCrane

Liftech超级起重机



Innovations in crane systems are being studied to improve overall productivity and reduce vessel servicing time.
These systems are typically costly but may one day become worthwhile.
The Liftech SuperCrane concept was developed in the 1980s by Michael Jordan.

It involves rotating lifted containers so narrow cranes can be used, <u>permitting cranes at adjacent vessel hatches</u>.

- The waterside hoist lifts and rotates the container and sets it onto carts, one on either end of the container.
- The carts move the container along rails to the (non-rotating) landside hoist.
- The landside hoist lowers the container.
- The carts continue to the landside end of the boom and a system lifts them to an upper rail that they travel along to get to the waterside end of the boom where they are lowered.

The landside RMG crane is optional.
Multiple hoists can be provided both at the landside or waterside.
Hatch covers are stored over a waterside traffic lane.

The landside has fixed columns with elevated crane rail supports for improved traffic flow (similar to FastNet).

APMT FastNet

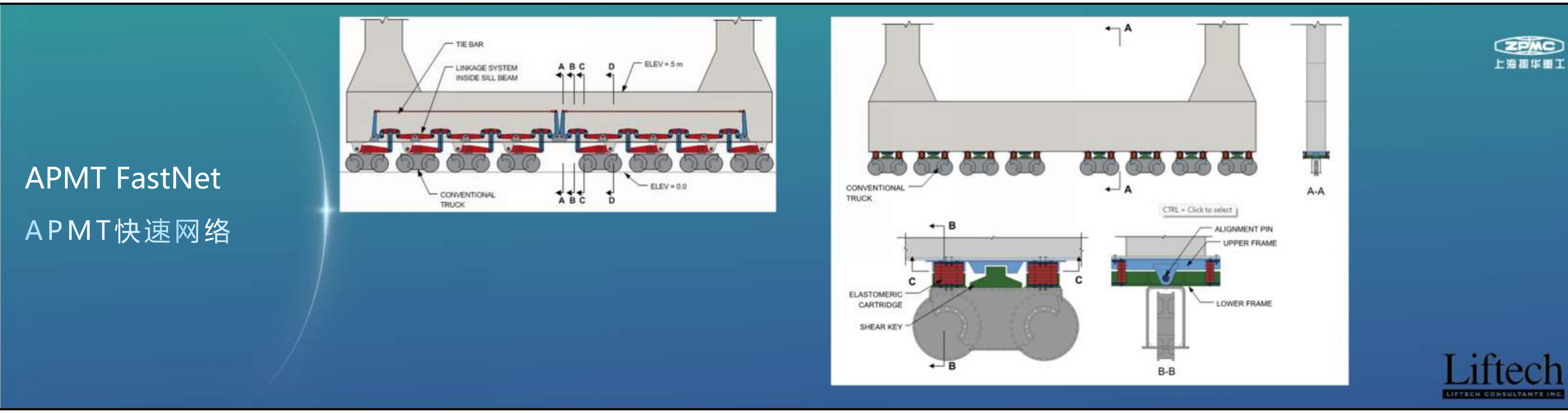
APMT快速网络

The APMT FastNet system is another elevated crane system allowing access to adjacent vessel hatches.

The development of this system resulted in other innovations including

- a special boom design to pass the movable waterside columns
- a simple wheel equalization system using ropes or linkages for any number of wheels, not requiring equalizer beams

Like the SuperCrane, the landside is on an elevated fixed girder for improved traffic flow.



The upper left is a simplified image of the wheel equalization system innovation developed by Liftech for the APMT FastNet System.

Notice:

1. This system can be used for any number of wheels. Such a system will be required when many wheels are required.
2. If there is a failure or if a truck needs to be removed, the vertical linkage for that truck can be locked and the remaining wheels will still be equalized.
3. A damper can be installed in the tie-bar system at a small cost to reduce earthquake forces.

A similar system but with elastomeric bearings was also developed by Liftech as shown on the right.

Innovations have significant impact on the world. Look at how far containerization has come in less than 70 years.

Innovations are the result of collaboration among clients (shipping lines, terminal operators, port authorities, etc.), crane suppliers, consultants, and workers.

The risk to develop an innovation is typically great, but the reward can be greater.

Thanks to the industry for taking risks by supporting innovation.

Thank you ZPMC for hosting this event and thank you to all attendees.

We look forward to working with all of you to innovate and advance the industry.