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.

Erik Soderberg is a Liftech vice president with over 15 years of experience in the design, review, and modification of a variety of structures, including container cranes, wharves, buildings, heavy lift equipment, and various rigging structures. He has consulted on hundreds of cranes, participated in the design of several wharf structures, and has designed many crane transfer systems ranging from curved rails to shuttle systems. He has engineered repairs for dozens of container crane structures and for several bulk loaders. His field skills include an understanding of heat straightening techniques and the ability to develop repair procedures on site.

Topics

Procurement & Commissioning Best Practices

Life Extension & Upgrades

Impact of Panama Canal Expansion

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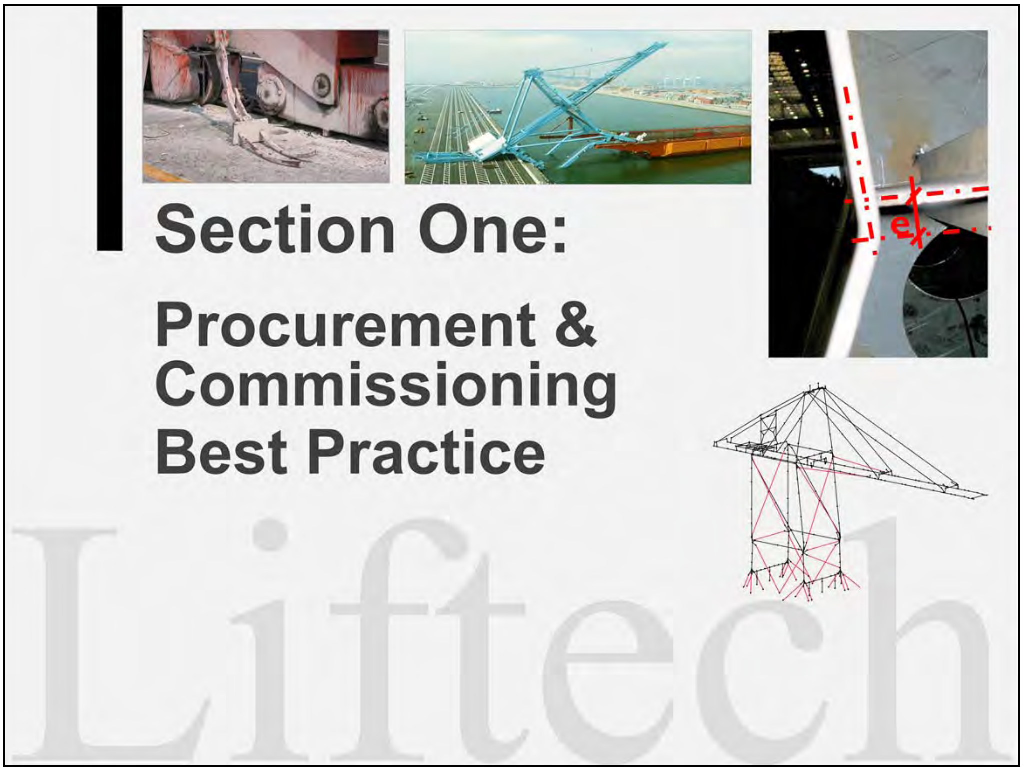
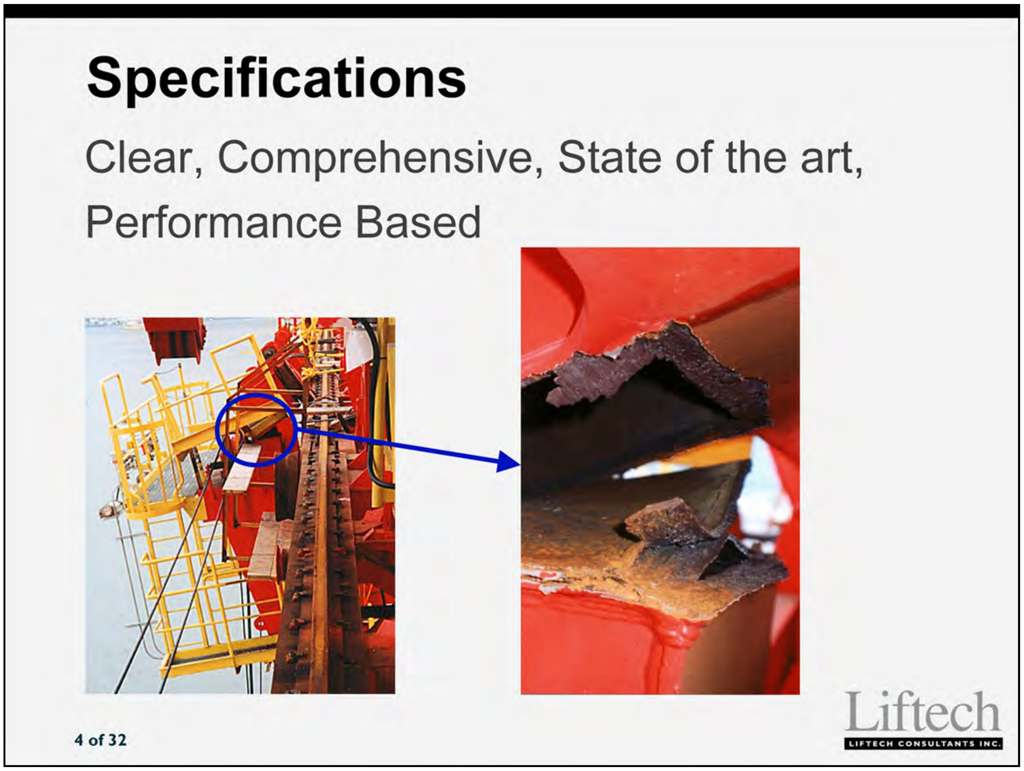
I will be discussing a variety of topics in this presentation.

Due to the breadth of each topic, I will be focusing on particular topics that I believe will be most worthwhile to the audience.



The best way to have a well-performing crane is to get the right crane in the first place.

Again, this topic is broad and only select topics are covered.



Specification content that is state of the art is continually changing. For example, Liftech's specification content for seismic performance has changed considerably in the past four years to address recently discovered performance issues.

As much as practical, let the specification requirements be performance based so that suppliers can use their own practices and suggest alternatives.

The specification should cover all aspects of the procurement. Seemingly small issues sometimes become big problems. On the crane shown, excessive sulfides in the steel combined with many through-thickness connection details resulted in a fracture-prone structure that nearly resulted in the loss of life. Repairs were required at many locations of the crane resulting in significant costs. This could easily have been avoided by specifying proper material and testing during fabrication.

Design Review

Criteria Compliance

Key Items:

Strength and Fatigue

Stability, Stowage systems, and Wheel loads

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Design review is often worthwhile. Factors to consider are the experience of the supplier, the experience of the plant, and how similar the crane is to what the supplier regularly supplies.

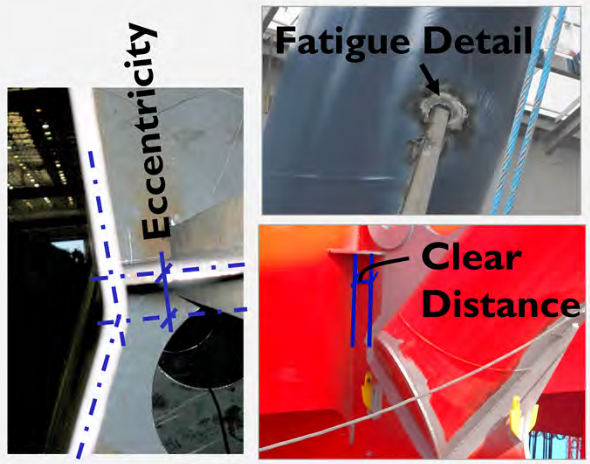
The major issues to address in the review include verifying the items listed on this slide. In our reviews it is common to improve fatigue details to significantly improve the structural reliability of the crane. While a submitted crane design may technically meet the specification, making small changes to the details during the design stage has no impact on costs but a big impact on fatigue performance.

Wind design codes vary significantly by region and are often misunderstood. Therefore, the wind loading on cranes can be underestimated and may have a significant impact on the required stowage systems and future performance in severe winds. Wheel loads are less critical but are also often miscalculated.

Fabrication Review

Design intent

NDT: Audit of the quality control



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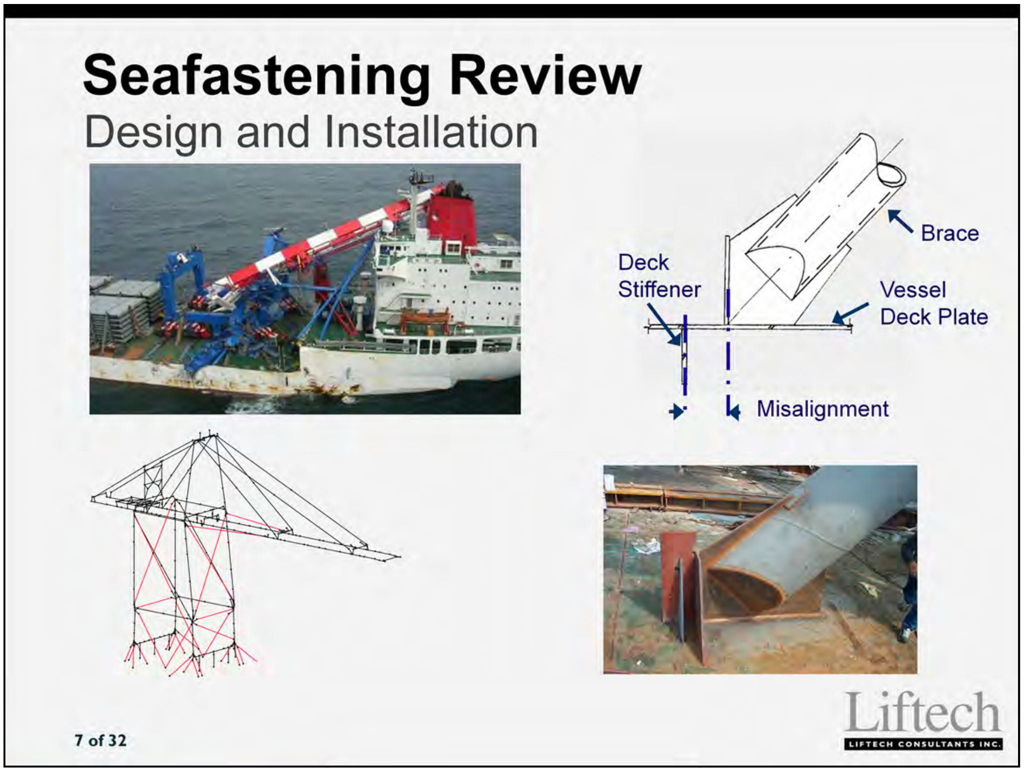
Fabrication review should consist of a review by an engineer who understands the design intent, as well as by inspectors to provide welding oversight. An engineer familiar with the design will notice problems that are not obvious to an inspector.

Plate eccentricities, rough surfaces, and inadequate clear distances are common and have a major impact on structural reliability.



Since most voyages rarely experience the design forces, suppliers can be tempted to use designs that have worked in the past rather than designs that will work for the specified forces. Accidents during crane delivery occur more frequently than many people realize.

Issues we have encountered include:

1. Not including the crane structure in the analysis of bracing forces and bracing design. For example, wire strands are more flexible than the crane structure. If not properly designed, the crane will resist most of the load and yield while the wire ropes are still stretching.
2. Not considering load paths into the vessel structure and reviewing the vessel strength. The load does not stop at the deck of the vessel.
3. Installation problems with bracing alignment, particularly with the vessel structure. Misalignment will result in significant bending stresses in both bracing and the vessel structure.

Offload Plan Review

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Many things can go wrong during an offload. We recommend reviewing the offloading plan and having an engineer on site during offloading to help ensure minimal risks during the offload.

Commissioning

Review structure for voyage damage including fatigue cracking

Perform comprehensive structural inspection in first year of operation to detect "infant" failures

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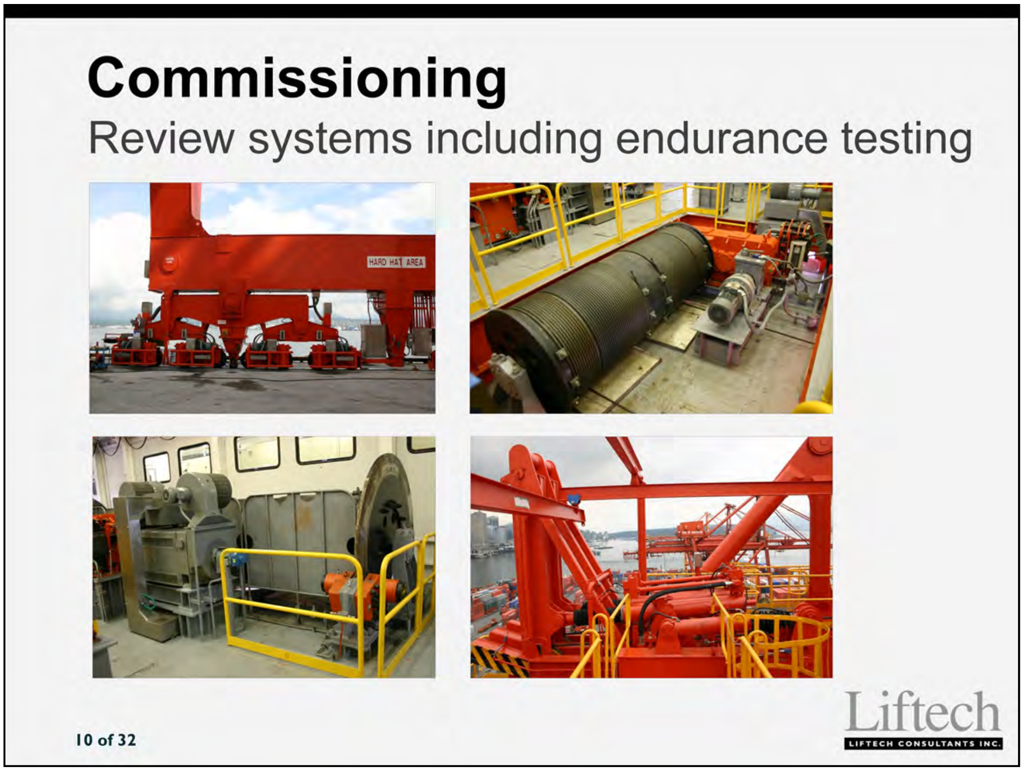
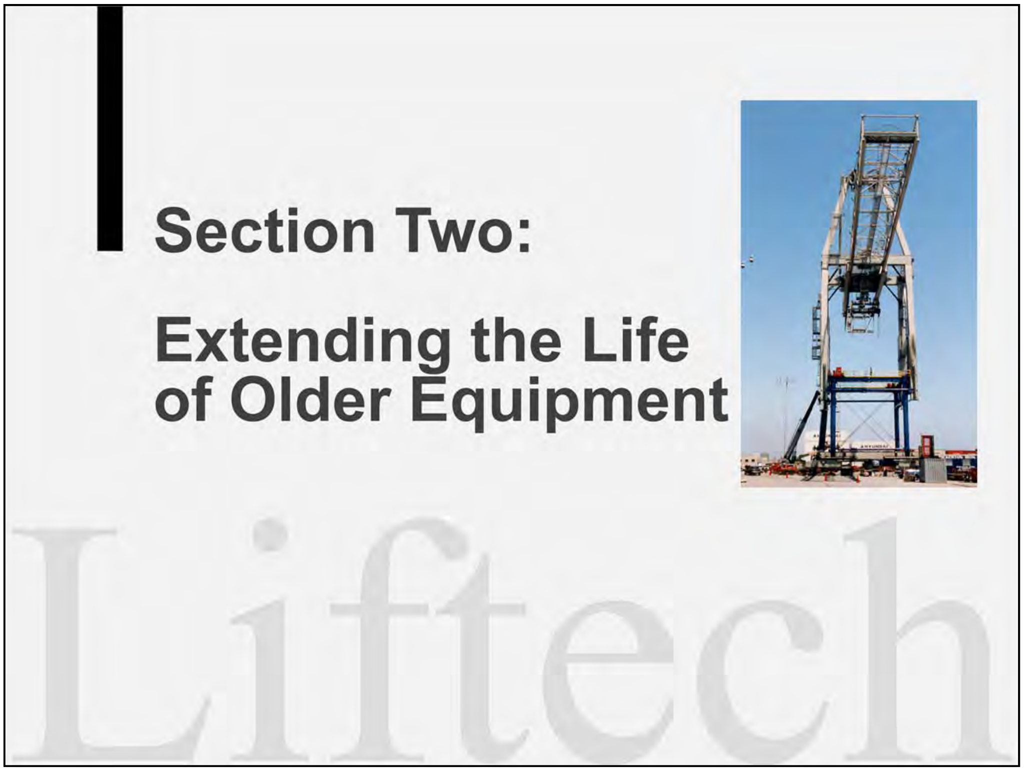
Cranes sometimes experience large forces during their voyage resulting in damage. Inspect the crane upon arrival for damage.

After a year of operation, inspect the crane again to detect infant failures. An infant failure is a failure due to fabrication or design defects that went undetected during the procurement process.



Test the various crane systems to verify reliable performance.

Specify endurance test programs including acceptance criteria.



I will now talk about extending the life of older equipment.

Extending Life - Topics

Extending life without upgrades – maintaining reliability

Upgrades – Changes to structure or machinery to improve usefulness

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Two topics will be covered: (1) extending the life of existing equipment by maintaining an acceptable reliability and (2) extending the life by modifying the usefulness of the equipment.

Background: Design Philosophy

Damage tolerant design
Inspection and repair required

Safe life design
No inspection

Reference: BS 7608 (and *EN 1991-1-9:2005*)

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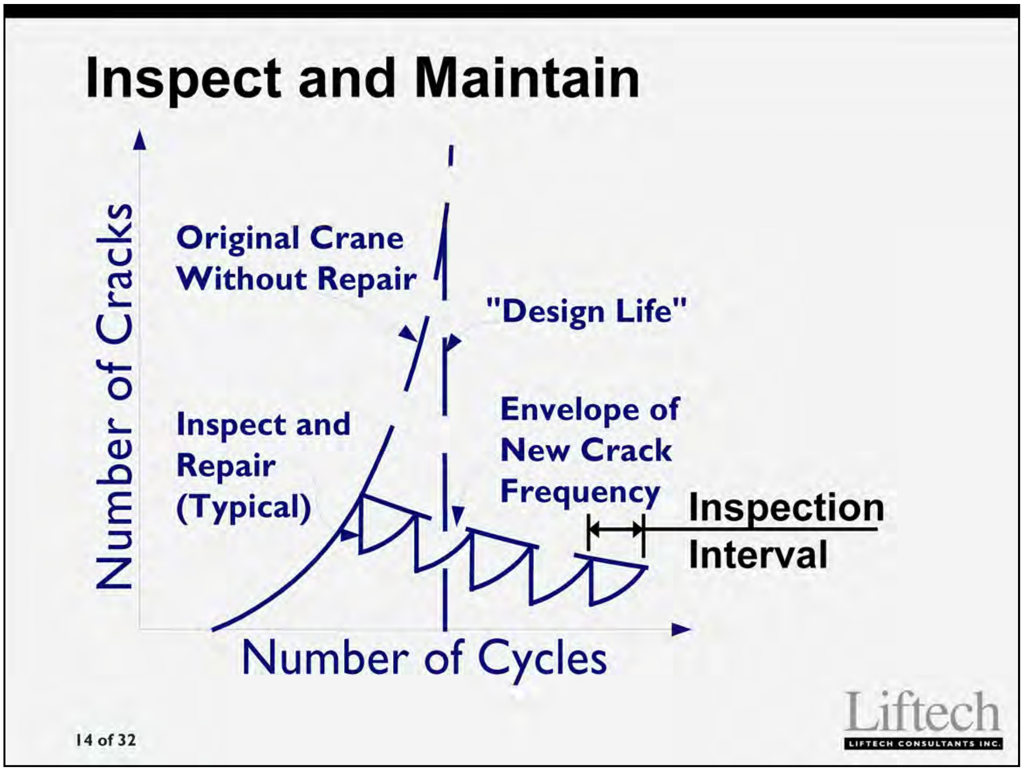
To understand the risks and reliabilities of crane structures, one must understand the design basis of these structures.

It is not economically practical to design cranes to an extremely high reliability such that cracking will not occur.

Crane design is based on damage tolerant design. When fatigue cracking occurs in service, the remaining structure can sustain the load until the damage is detected. This means cranes will develop cracks. The criteria require that cracks be found and repaired. This means the structure must be inspected periodically and cracks repaired.

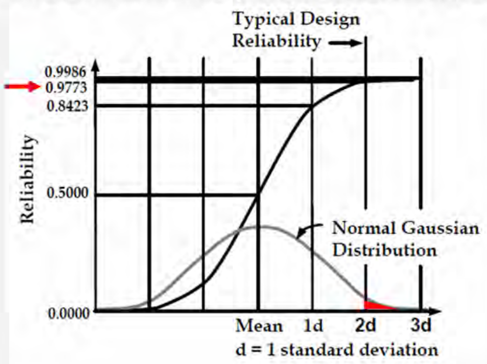


The number of cracks increases with the number of cycles. Without inspection and repair, the number and size of cracks will increase and eventually one may cause a catastrophic failure. With inspection these cracks can be found and repaired. The repair can make the detail better than it was before. The envelope of new crack frequency may decrease with time, or may increase, but typically the number of cracks will accelerate.

Theoretically, a properly maintained structure can last forever; in practice it can last well beyond its original design life.

Extending Useful Life

Useful Life: Duration for operating the crane with a tolerable risk of failure due to fatigue cracking. Not related to corrosion, mechanical failure, or obsolescence.



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The useful life is extended by maintaining an acceptable reliability.

Approach

Evaluate existing condition

Estimate repairs and maintenance effort

Stakeholder decision

Repairs

Structural maintenance program

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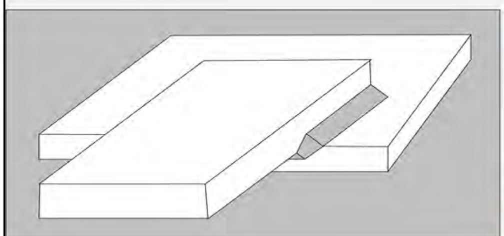
The steps associated with extending the useful life of an older structure are provided here.

Evaluate Existing Condition

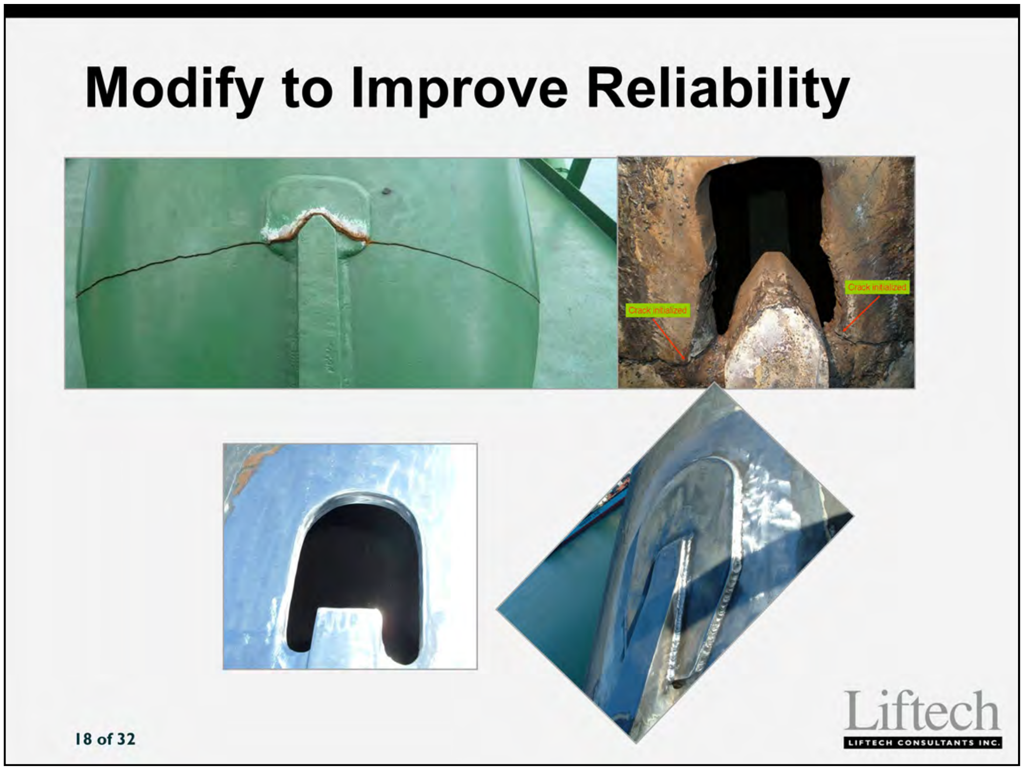
Condition survey by engineer
- Distress and damage
- Suspect details
- Post fabrication attachments

Thorough NDT inspection



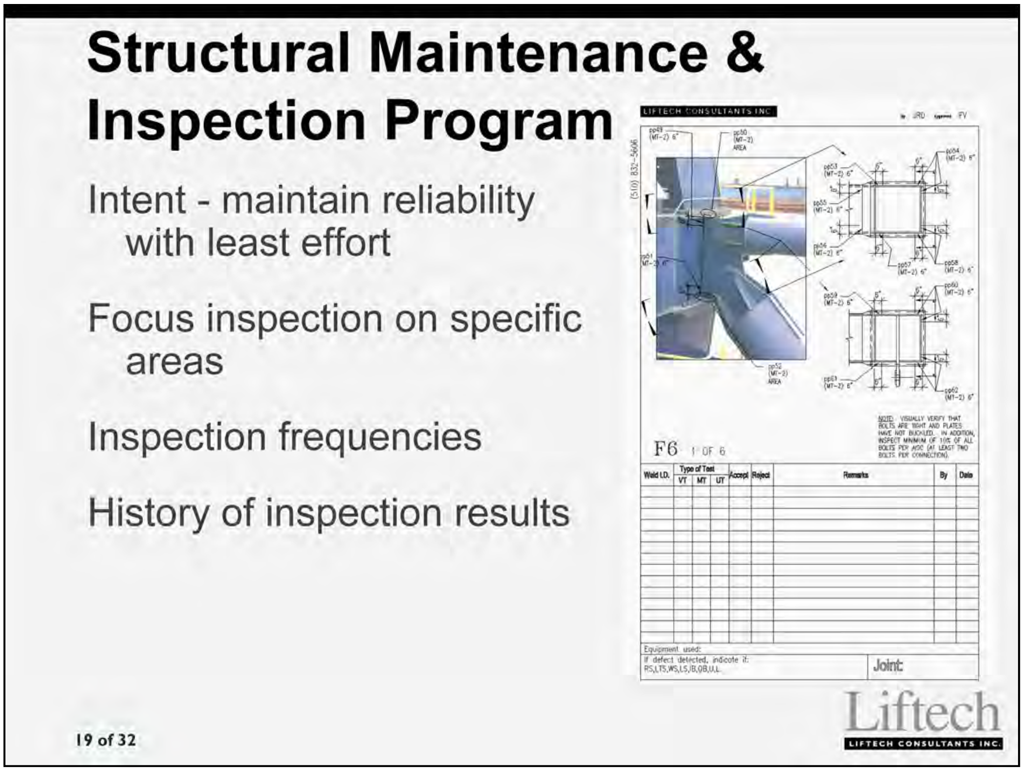

The structural condition survey will identify areas of concern including damage, differences in the as-built drawings, and locations that require additional attention during the weld inspection. Wraparound welds like the one shown can shorten the fatigue life by 2.5 times.

A thorough NDT inspection should be performed to identify the extent of cracking and necessary repairs.



Simple modifications can often be made to improve reliability and reduce maintenance costs.

On this crane, a poorly fabricated stress relief hole at the end of a slotted plate resulted in fatigue cracking.



The inspection manual describes:

connections needing NDT inspections
when and how to inspect
who can inspect
reporting procedures

Not all joints need to be inspected at the same interval frequency. It depends on how critical the connection is and the rate of fatigue damage at that connection.

Inspection frequency is based on a cumulative damage analysis of the crane and the fatigue load spectrum.

An inspection history is useful in identifying chronic problems, and provides a preview of cracking that may develop on similar, less used cranes.

Extending Life - Topics

Upgrades – Changes to structure or machinery to improve usefulness

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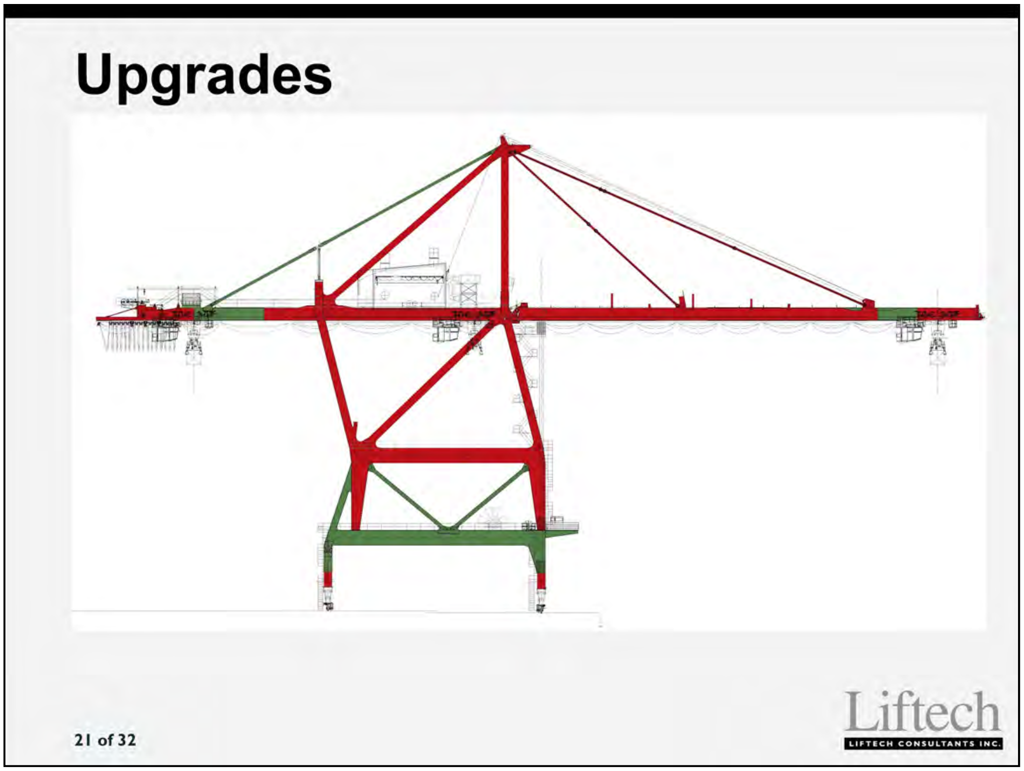
Now we will talk about extending the life by modifying the usefulness of the equipment.



Many times the life of a crane can be extended by changing the geometry to serve different ships, or modifying the mechanical/electrical systems to work faster, at greater capacities, and/or more reliably.

Some typical upgrades:

Geometry
- Increase lift height
- Increase outreach
- Elevator supports and walkways

Reinforcement
- Frame
- Boom
- Forestays

Mechanical and Electrical
- Main hoist, boom hoist, and trolley drums
- Relocate and upgrade sheaves

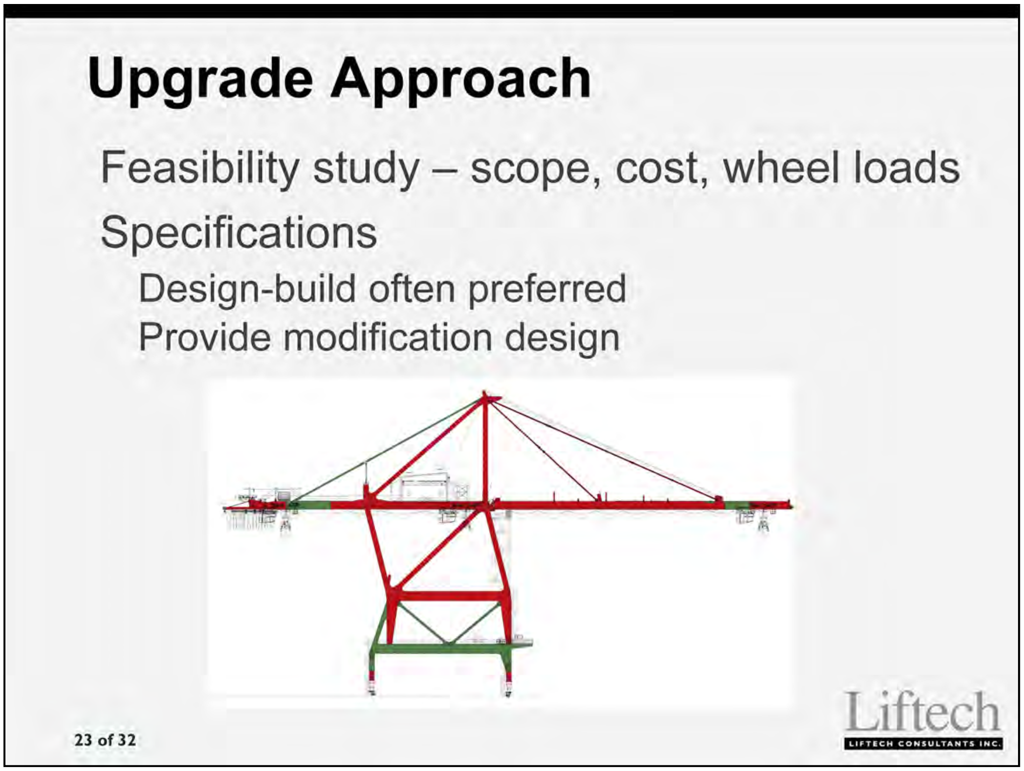
Upgrades are practical and, due to fuel and material costs, have recently become more competitive to procuring new cranes.

Some examples of upgrades are provided here and include:

boom extension, crane raise, and gage change

Crane raises have become less costly as contractors have developed a variety of efficient raising systems. The one shown here was the first one and it was designed by Liftech for Bickerton Iron Works back in the 1990s.

The gage change shown here was performed by supporting and slightly raising the landside of the crane and swinging the existing leg, sill beams, and gantrying components into position.



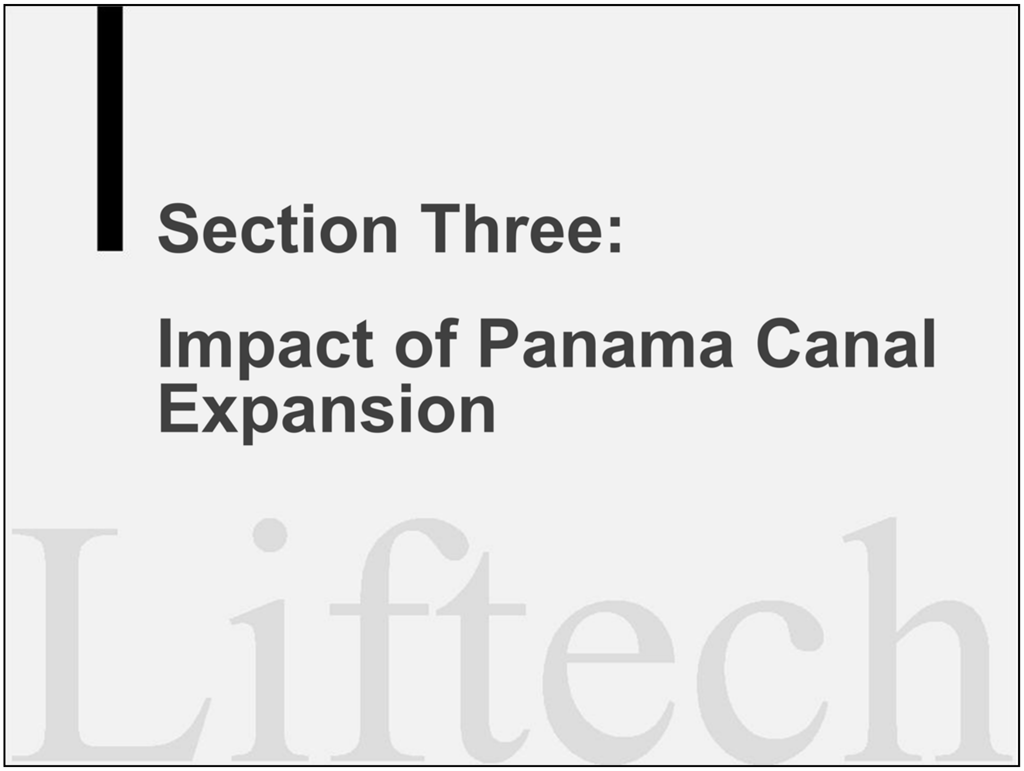
The first step is to see if it is economically feasible to upgrade the crane for the performance you want or determine how much performance can be gained for a given budget.

To start the study you need to establish the design criteria. The study will determine the needed modifications and cost, and evaluate wheel loads.

The next step is to decide if, and how to proceed. Design-build is a common method as the contractor is responsible for the design.

No matter how you proceed you need clear specifications. When taking the design-build approach, providing engineered design drawings is often beneficial. Even if a contractor chooses an alternate design, having an engineered design will reduce the contingency. The more complete the bid document, the more uniform and lower the bids.

The image on this slide is a modification design developed by Liftech provided with the recent ECT modification bid specification.



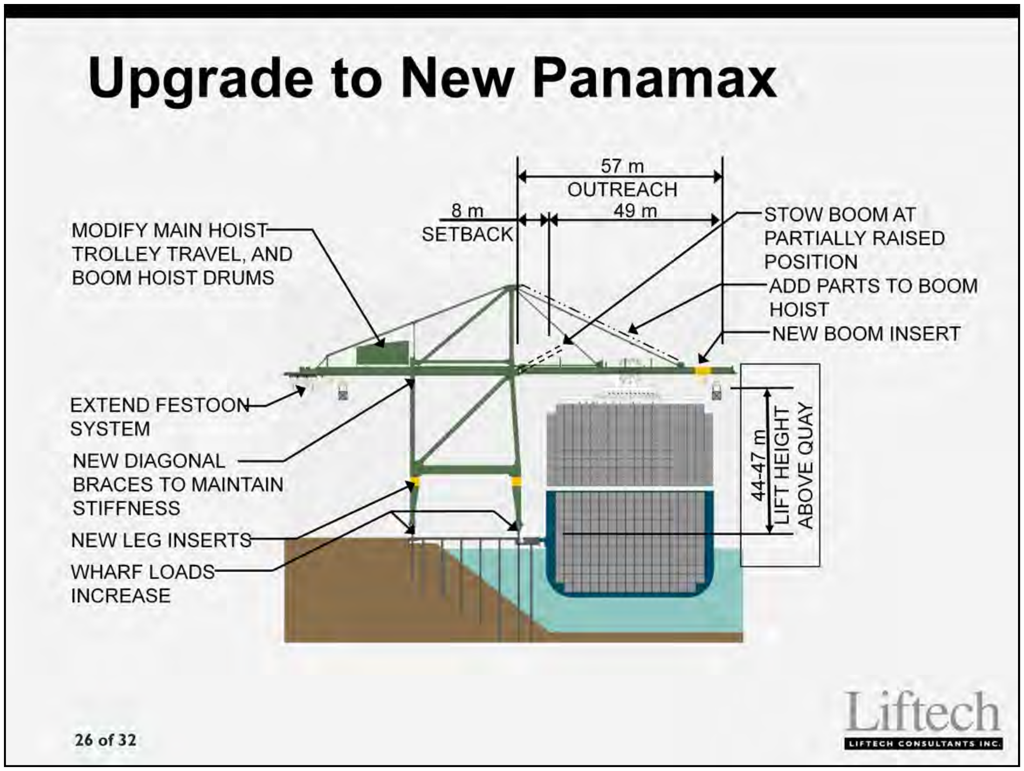
The widening of the Panama Canal has people wondering what vessels will come calling, and how they can accommodate those vessels.

Vessel Sizes

Ship Class	Panamax	New Panamax	Jumbo-23
# CONTAINERS WIDE	13	19	23
VESSEL WIDTH	32.3 m	49 m	59 m

At 19-wide, the New Panamax is 6 containers wider than the old Panamax. It is possible that wider vessels can be accommodated in special circumstances.

A Jumbo-23 vessel is shown for comparison.



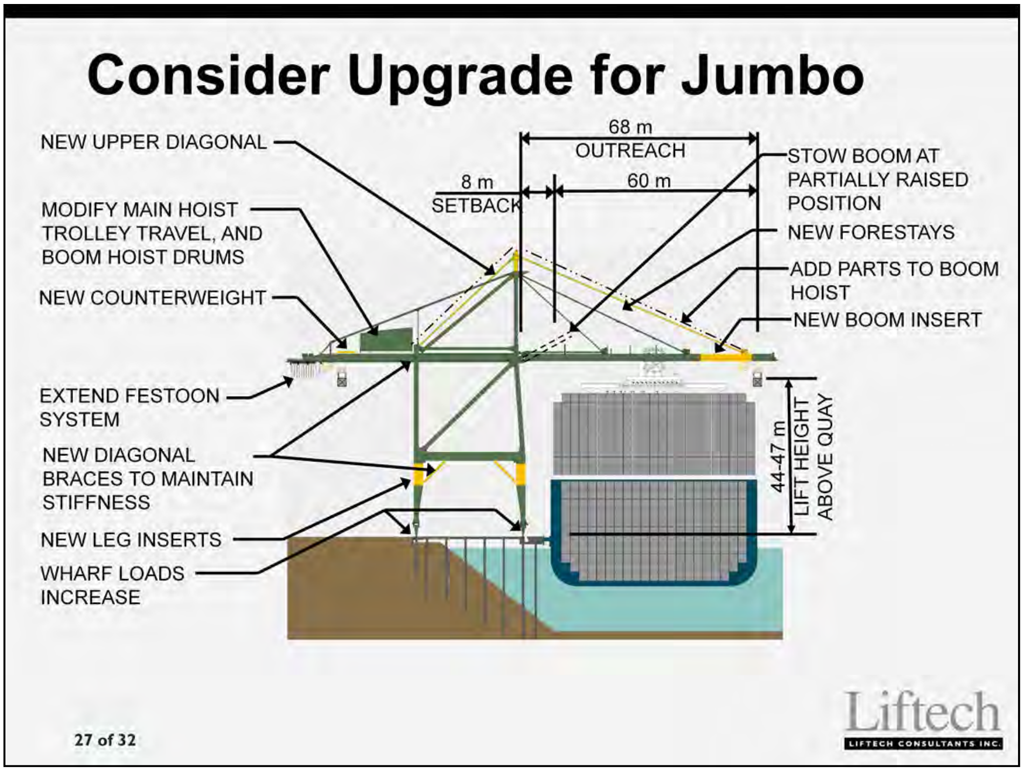
In many cases an existing post-Panamax crane (17-wide) can be modified for less cost and in less time than buying a new crane. The costs range from 25% to 60% of the cost of a new crane, and the time required can be about half that of buying a new crane.

Not all cranes are suitable for upgrading to 19-wide. It may be cost prohibitive to upgrade the crane for the size and performance needed.

While considering the upgrades required, you should investigate if there are other upgrades that can be made for minimal extra cost.

Larger cranes will impart larger loads on the quay. Fortunately, modern analysis techniques can often justify the larger loads.

Some common required upgrades are shown above to increase a 17-wide post-Panamax crane to a 19-wide New Panamax crane. The most obvious upgrades are increasing the height and outreach.

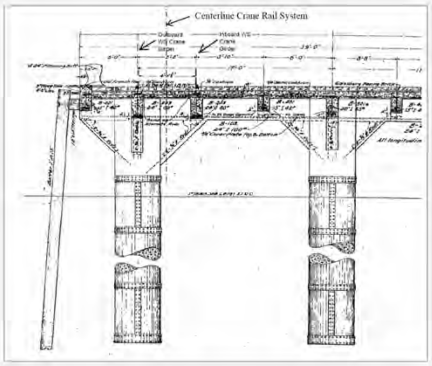


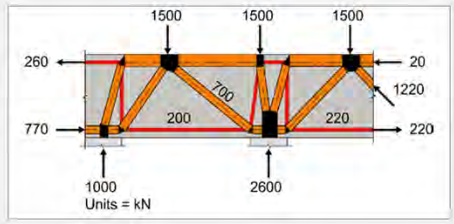
If you are already upgrading to 19-wide, you may want to consider something between 19-wide and up to 23-wide, as the difference in cost be reasonable.

Crane Girder Strength

Crane girder capacity study:

- Most wharves have additional capacity
- Study is inexpensive compared to modifications





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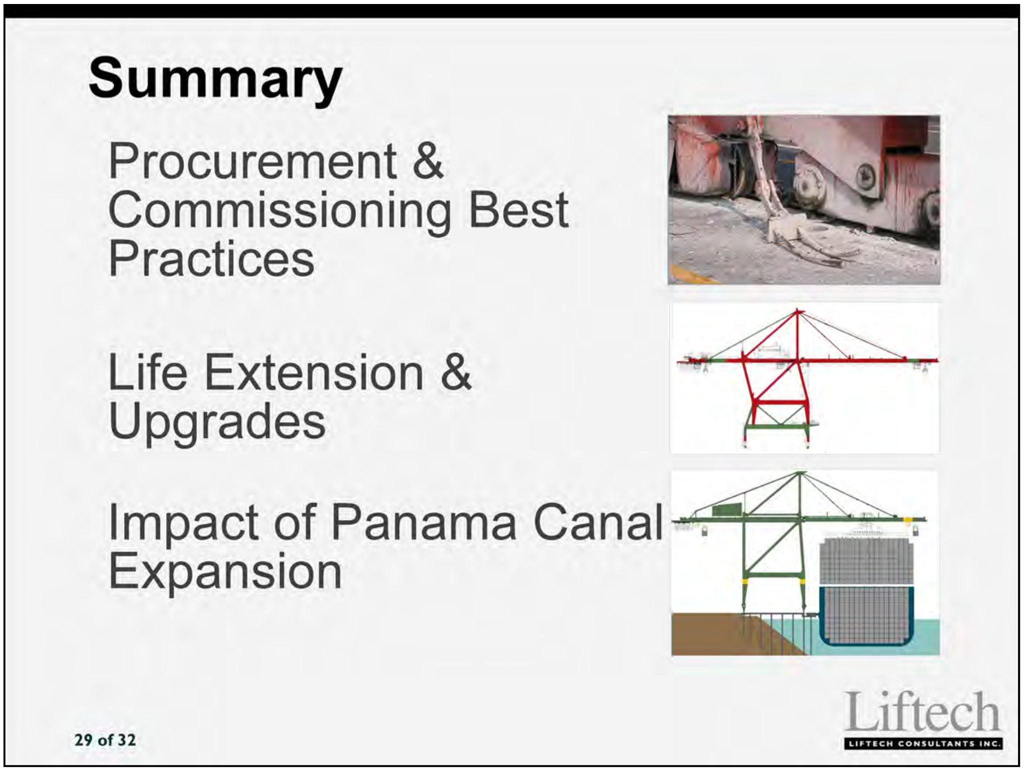
Increasing the crane size often results in wheel loads that exceed the stated capacity of the rail girders.

Many wharves, especially older wharves, have more capacity than was originally calculated.

Capacity studies that use modern structural analysis methods and geotechnical analysis nearly always justify additional capacity, sometimes significant capacity.

Finite element analysis programs are used that consider the contribution of other components of the wharf structure. Strut-and-tie analysis methods can be used to justify additional shear capacity. There are many methods that can be used. Which one is most appropriate depends on how much additional capacity is required and in which component, e.g., pile capacity, shear capacity, bending capacity, soil capacity.

Capacity studies are considerably less expensive than modifying the wharf and usually yield positive results.

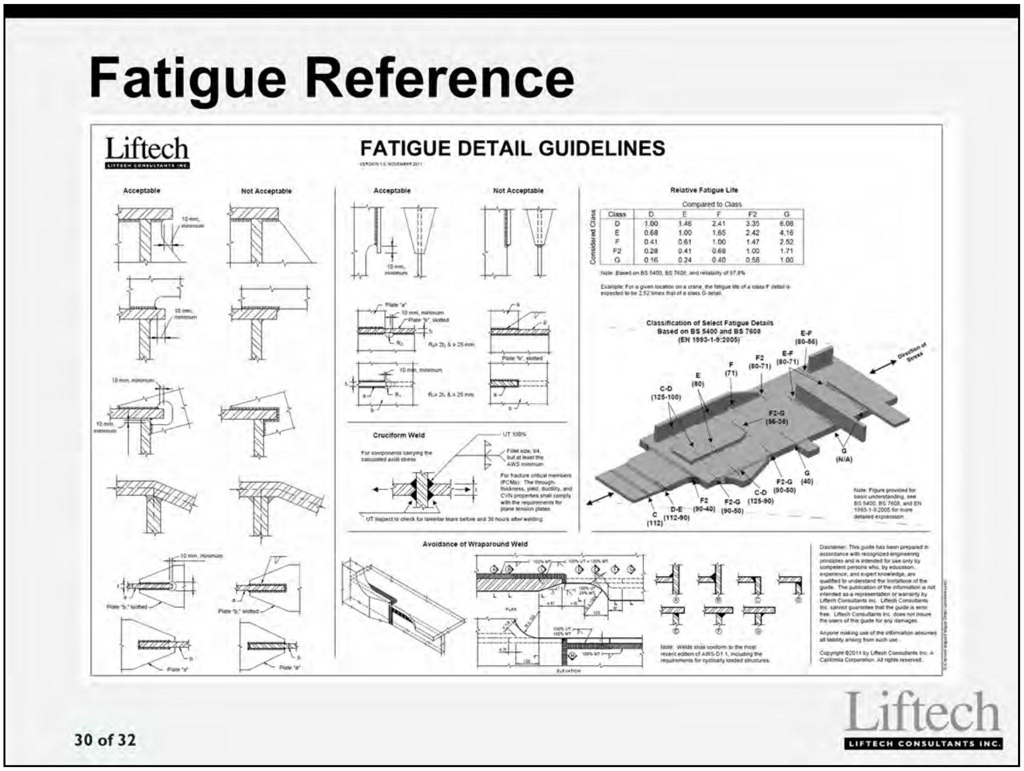


To summarize:

1. When procuring and commissioning new cranes, use a state-of-the art performance specification. Consider design, fabrication, voyage, commissioning, and offloading reviews. Design, fabrication, and commissioning reviews often pay off in the long-term performance. Voyage and offloading reviews reduce risks and have avoided catastrophic failures.

2. The useful life of an older crane can often be extended with little effort. Structural maintenance is critical to maintaining its reliability. Upgrades are practical to improving the usefulness of an existing crane and are often very competitive with procuring a new crane considering procurement costs and schedules.

3. The widened Panama canal will accommodate 19-container-wide vessels and possibly wider vessels. If these vessels will come calling at your port and your cranes are not large enough, consider modifying your cranes in addition to purchasing new cranes. If modifications are made, remember that the incremental cost of making the crane larger is small. If wheel load capacity is an issue, consider a crane girder capacity study.



The following 11”x17” handout provides some guidance on fatigue details was developed to supplement this presentation and is available on our website.


Thank You
This presentation is available for download
at www.liftech.net

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