Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.
Integrated Design Building
University of Massachusetts, Amherst
University of Massachusetts Building Authority

The First Composite CLT Building in United States

Tom S. Chung, AIA, LEED BD+C, NCARB
Principal
Leers Weinzapfel Associates
LEERS WEINZAPFEL ASSOCIATES

- 2007 AIA Firm of the Year
- Top Ten_Architect 50_2015
- Over 65 National and Regional Design Awards
- 5 LEED Gold Projects
- Over 100 National and International Publications

UPenn Gateway Building
LEERS WEINZAPFEL ASSOCIATES

- 2007 AIA Firm of the Year
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MGH Museum of Innovation and Medical History
LEERS WEINZAPFEL ASSOCIATES

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- Over 100 National and International Publications
EQUILIBRIUM
VANCOUVER, CANADA
How Change of Building Systems was possible?

INTRODUCTION
- Background & Context
- Design Concept

PROCESS
- Mass Timber Structure Design
- Steel & Concrete Systems vs Wood Systems
- Assuring the Client: Budget and Procurement
- Code Review and Variance

DESIGN DETAILS & CONSTRUCTION
- Central Commons and Courtyard Design
Introduction

Regional Context
Regional Context
Concept Model
Wood Structure and Landscape
Program Organization

- Studios
- Classrooms
- Mechanical
- Learning courtyard
- Skylights & green roofs
- Offices
- 2 Story Commons
- Shops
- Workyard

2 Story Commons with Learning Courtyard Above
Stacked Studios/Stacked Offices
Sectional Perspective
View from Stockbridge Way
Process: Timber Structure Design

Predominance of Steel in MA
Massing Options Considered

Clark Addition

Lot 62 N_Linear E-W

Lot 62 S_Courtyard

Lot 62 S_Linear N-S
Concept Model
Preliminary Central Space Views
Steel vs. Timber: Schematic Design
Steel vs. Timber: Schematic Design
Steel vs. Timber: Schematic Design
Steel vs. Timber: Design Development
Steel vs. Timber: Design Development
Structural Framework

Revit Model
Structural Framework

Revit Model
CHANGE IS POSSIBLE EVERYWHERE

Steel Post & Beam  ➔ GL Post & Beam

Concrete/Masonry Shafts  ➔ CLT Shafts

Steel/Concrete Floors  ➔ CLT/Concrete Floors

Steel Deck Roof  ➔ CLT Roof

Steel Braces  ➔ Glulam Braces
GL Post and Beam

Beam to column Connections
Concrete

CLT

Shafts
CLT/Concrete Floors
Holz-Beton-Verbund-System™ (HBV) Composite floor
Holz-Beton-Verbund-System™ (HBV) Composite floor
CLT/Concrete Floors
CLT/Concrete Floors
Process: Assuring the Client

Project Team

- **Client:** University of Massachusetts Building Authority
- **User:** University of Massachusetts, Amherst Architecture & Design, LARP, Building Construction & Technology
- **Architectural / Structural Design Team:**
  - Architect: Leers Weinzapfel Associates
  - Structural Design Engineer: Equilibrium Consulting
  - SER: SGH
- **AHJ:**
  - MA State Building Inspector
  - MA Board of Appeals
- **Construction Team:**
  - Construction Manager
  - Timber Fabricator and Installer
Process: Assuring the Client

Energy Performance
Energy performance of a wood structure is by far superior to other material options. Steel columns are the most typical load-bearing structures and are a major contributor to localized long-term mold damage and low energy performance. The most efficient large-scale wood buildings use the glulam post and beam system as proposed in this report. Current examples include Norwich Academy in the UK, Earth Sciences Building in Vancouver, BC and Wood Innovation and Design Centre in Prince George, BC.

Based on conversations with the owner group for the CB project, energy performance is an important topic that will be taught in the building. Thus, the building should reflect best practices in this regard and use wood which is thermally insulating.

Structural Advantages of the Wood System
1. Open plan of the building can be easily achieved with the proposed system. It also provides the lightest dead load which limits seismic forces and size of foundations.
2. All timber elements are rated Heavy Timber and provide the required fire resistance.
3. Prefabrication of all timber elements together with the ease of electrical and mechanical installation in a timber structure ensures the shortest possible construction time.
4. Use of Wood/Concrete composite allows large spans with a minimum structural depth.
5. Wood structures are typically the easiest to accommodate any future changes in plan for new building layouts.
6. Ease of carefully detailed prefabricated Mass Wood Elements enables the erection of all timber members at all weather conditions.
8. Superior energy performance of wood members that eliminates heat bridges.
The Benefits of Sustainable, Structural Wood
7006 Integrated Design Building, April 11, 2014

The UMass ISB design team is actively considering the use of engineered wood as the primary structural material for the building. Engineered wood products — generally referred to as glue-laminated beams (Glulam) or cross-laminated timber (CLT) — are gaining popularity for rapid sustainability, physical and aesthetic attributes, and low-cost to grave sustainability properties. While concrete and steel have long been the primary structural material choice for large-scale buildings, engineered wood products are becoming equal for reliability, strength, and effectiveness. Wood products can now match or exceed the thermal, resiliency, and structural properties of concrete or steel and are increasingly cost-competitive especially when measured on a life cycle basis for performance, embodied energy, and comfort.

A comprehensive evaluation of wood as a viable sustainable construction material can be approached through a life cycle analysis. This takes into account all aspects of a materials usability, including extraction, transportation, modification, construction, reuse, and disposal. Other than mill work to adjust its dimensions, wood essentially needs no additional processing after its harvesting. Wood construction methods generally use glue-laminated beams (Glulam) or cross-laminated timber (CLT) that require minimal further alterations.

Concrete is the combination of multiple materials from just as many extraction sources. The cement in concrete is largely limestone, which needs to be mined and heated to extreme temperatures to produce cement in the powder form required for mixing. Concrete also contains aggregate and water, combined either on-site, or pre-mixed and delivered. The combination of these ingredients requires increased transportation for each material cost, and embodied energy (discovered later). When a concrete building or site is to be demolished, the concrete needs to be crushed for reuse. However, the cement is not extractable, new concrete requires fresh materials and manufactured cement.

When a wood structure is to be removed or torn down, it can be used as-is, or remilled to necessary specifications. Steel begins as iron ore, extracted from a mine, then smelted into steel. Smelting involves the removal of impurities like silica, phosphorus, and sulphur, along with the addition of alloys to create steels of different physical properties. This post-processing requires vast amounts of energy and labor. Steel is a very strong building material, but has its weaknesses. Moisture can cause rust, and if left untouche can cause failure. At a corrosion rate of 160 μm/yr, this does not accumulate too much over the lifetime of a large steel beam. However, thinner steel, such as that used in rebar, can cause cracks in concrete, or bending under strain. Though, with an 80% recycling rate, it is one of the most reused materials, this does not mean the demand, resulting in more mining and processing.

The initial extraction of any product will affect the environment. Concrete requires quarries for limestone, steel needs iron ore mines, each irreversibly and adversely, changing the natural landscape. Timber requires deforestation, which destroys natural habitats, as well as changing the landscape. However, these affect can be limited given responsible forest management. Quarries and iron ore mines are effectively irreplaceable, and irreplaceable, given the long span prior to their harvesting for the products to accumulate.

The Forest Stewardship Council (FSC) provides guidelines and rules for responsible forest management. Through the FSC, wood can be tracked from forest to site via Chain of Custody (CoC) documentation, ensuring that those wood products were grown and extracted from a properly managed sustainable forest. Following FSC strategies, timber extraction and regrowth can close to match the carbon sequestration of an untouched forest. The graph displays the amount of carbon stored in a statistically average FSC-regulated forest. Each through of the red, orange, and blue lines represent timber extraction events, followed by regrowth and proportional carbon sequestration. The green line represents a forest with no harvesting.

The overall carbon sequestrated is lost for those forests that are managed, not included in the graph are the effects of wood products, which retain the carbon they absorbed before they were cut down, increasing the overall relative sequestration of the forest.

Perhaps the greatest argument for wood as a sustainable building material is its comparatively low embodied energy and closely related carbon footprint. During its life in a forest, a tree will absorb CO2; and release it only when burned or white rotted. Over 40 years, a tree, on average, can sequester 1 ton of CO2. When harvested, this carbon dioxide storage is not lost, it remains within the piece of timber. Carbon storage capacity accumulates as more wood is used in a construction project. Throughout its manufacture, a piece of framing timber will result in the emission of 0.65 tons of carbon/ton of material, compared to 0.034 for concrete, and 0.694 for single steel.

The potential of having an initial net-zero below net-zero carbon footprint increases with the volume of wood products. Inclusion of the sequestered CO2 within the products themselves, wood construction projects can have an initial negative carbon footprint. The footprint slowly increases back to zero and above, as the CO2 production associated with energy needed for electricity, heating and other processes, is required. Of course, if renewable energy sources are the supplier, then the rate is slowed, or even halted.

The engineered wood products industry has successfully addressed concerns for using it in medium-to-large scale building such as ISB. These concerns include structural integrity, moisture resistance, durability, and fire suppression. The industry has also demonstrated that wood has superior performance with regard to thermal conductivity, construction flexibility, and occupant appeal. With regard to structural integrity, CLT and Glulam beams are competitive with steel and concrete. CLT is constructed by layering panels of boards of wood on top of, and orthogonal, to each other, then glued together. This gives both shear and compressional strength due to the alternating grain directions.
Key Issues

• Danger of “Over Estimating Contingency” by Construction Managers or Cost Estimators due to the “Unknown”

• Importance of multiple Bidders

• Coordination of Fabricator and Installer Team

• Proper scoping of work for Bids. Especially if based on Progress Drawings

• Consideration of Contractor Reputation and History. It’s a small world!
Process: Assuring the Client
### Timber vs Steel Budget Comparison

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Qty</th>
<th>Unit</th>
<th>Cost</th>
<th>EST'D Cost</th>
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<tr>
<td><strong>Alternates</strong></td>
<td></td>
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<tr>
<td>Wood frame option</td>
<td>1</td>
<td>10'</td>
<td>$3,500,000.00</td>
<td>$3,500,000.00</td>
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<tr>
<td>Wood frame option</td>
<td>1</td>
<td>10'</td>
<td>$3,750.00</td>
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<tr>
<td>Metal deck @ basement</td>
<td>10,790</td>
<td>sf</td>
<td>$4,900.00</td>
<td>$4,900.00</td>
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<tr>
<td>Filled @ deck @ basement</td>
<td>10,790</td>
<td>sf</td>
<td>$5,500.00</td>
<td>$5,500.00</td>
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<tr>
<td>Concrete topping to all upper floor slabs</td>
<td>10,790</td>
<td>sf</td>
<td>$52,368.00</td>
<td>$52,368.00</td>
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<tr>
<td>Additional steel beams, columns and framing (per Le Meuser)</td>
<td>85</td>
<td></td>
<td>$4,250.00</td>
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<tr>
<td>Additional sprinkler heads</td>
<td>1</td>
<td>1</td>
<td>$100,000.00</td>
<td>$100,000.00</td>
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<tr>
<td>Insulation @ upper slabs</td>
<td>52,368</td>
<td>sf</td>
<td>$1.50</td>
<td>$1.50</td>
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<tr>
<td>Add hinging to CLT</td>
<td>15,040</td>
<td>sf</td>
<td>$3.50</td>
<td>$3.50</td>
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<tr>
<td>Allowance for pred. of finished wood structure during construction</td>
<td>52,368</td>
<td>sf</td>
<td>$0.75</td>
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<td><strong>Total Wood frame cost</strong></td>
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<td>$30,529.00</td>
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<td><strong>Steel option</strong></td>
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<tr>
<td>Steel, decking &amp; wall</td>
<td>1</td>
<td>1</td>
<td>$3,203,385.00</td>
<td>$3,203,385.00</td>
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<tr>
<td>Add CMU shadwalls at stairs &amp; elevators</td>
<td>5,520</td>
<td>sf</td>
<td>$30.00</td>
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<tr>
<td>Add hinging to shadwalls at stairs &amp; elevators</td>
<td>15,040</td>
<td>sf</td>
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<tr>
<td>GMD acoustical barrier</td>
<td>2,200</td>
<td>sf</td>
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<tr>
<td>Wood grille ceiling @ 2nd Floor Central Space</td>
<td>5,000</td>
<td>sf</td>
<td>$20.00</td>
<td>$20.00</td>
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<tr>
<td>Wood grille ceiling @ Cafe/EmbLib</td>
<td>2,080</td>
<td>sf</td>
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<td>Paint exposed ceilings/dec</td>
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<td><strong>Total Wood frame cost</strong></td>
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<td></td>
<td></td>
<td>$344,834.00</td>
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<tr>
<td><strong>Delta Between Options</strong></td>
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<td>27.25%</td>
</tr>
<tr>
<td><strong>Total Add for Wood Structure Including Markups</strong></td>
<td></td>
<td></td>
<td></td>
<td>27.25%</td>
</tr>
</tbody>
</table>
## Fabricator/ Installer Bid Quotes

| Description | Vendor A | Vendor B | Vendor C | Vendor D | Vendor E | Vendor F | Vendor G | Vendor H | Vendor I | Vendor J | Vendor K | Vendor L | Vendor M | Vendor N | Vendor O | Vendor P | Vendor Q | Vendor R | Vendor S | Vendor T | Vendor U | Vendor V | Vendor W | Vendor X | Vendor Y | Vendor Z |
|-------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Item 1      | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 2      | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 3      | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 4      | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 5      | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 6      | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 7      | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 8      | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 9      | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 10     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 11     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 12     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 13     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 14     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 15     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 16     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 17     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 18     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 19     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |
| Item 20     | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       | ✔       |

*Note: ✔ indicates that the vendor meets the requirement.*
CLT roof/floor panels and shear walls

CLT floor panels and glulam beams with composite concrete
Proposed Alternate Structural Systems

Cross Laminated Timber (CLT) roof and floor decks and shear walls

- 20+ years in Europe, recent projects in Canada similar to IDB
- ANSI/APA PRG -320: current material fabrication requirements and stress grades
- Connections between CLT panels similar to traditional wood frame construction
- Employing high strength, ductile HSK connections as shear wall anchors

CLT floor decks and glued laminated timber beams with composite concrete deck

- 20+ years in Europe, extensive research and testing in Germany with HBV connector system
- CLT units provide required strength, concrete decks only counted on for stiffness
TESTING
Process: Code Review & Variance

Concealed Ceiling Areas
Process: Code Review & Variance

Concealed Ceiling Areas
Central Commons and Courtyard Design
(Opposing) Design Parameters

Maximum planting wanted but minimum maintenance desired
Heaviest weight on the longest span
Open atrium wanted with minimum structure height
Wet garden on a wood structure
No direct load path on one side

Did we do it?

Central Commons and Courtyard Design
Preliminary Courtyard Section
Central Commons and Courtyard Design
Central Space Structural Concepts
Zipper Truss Precedent
Zipper Truss Options
Zipper Truss Final Concept

- Option 3
  - Use goes 20% smaller than before
  - Rev. 2
Structural Loading Efficiency

Opti 2:
- Composite shear connection w/ glulam beams
- 4" wide
- Zone of 6" soil above glulam beams.

LWA - 7/0/13/14
Modified Final Courtyard Plan
Courtyard Model Views
Central Connector Studies
Central Connector Studies
Grasshopper Parametric Definition
CHANGE IS POSSIBLE EVERYWHERE!
CHANGE IS POSSIBLE EVERYWHERE!
CHANGE IS POSSIBLE EVERYWHERE!
CHANGE IS POSSIBLE EVERYWHERE!
CHANGE IS POSSIBLE EVERYWHERE!
CHANGE IS POSSIBLE EVERYWHERE!
CHANGE IS POSSIBLE EVERYWHERE!
CHANGE IS POSSIBLE EVERYWHERE!
CHANGE IS POSSIBLE EVERYWHERE!
THANK YOU!