SEMINAR: HUMANITARIAN ENGINEERING

Aaron Brown PhD
Colorado State University
Department of Systems Engineering
• Designed Semi Conductor Testing Equipment

• Worked at NIST on Superconductor Test Equipment

• Worked in Aerospace Mechanism Design

• Hubble Robotics

• GMI (Global Precipitation Measurement Instrument)

• Molniya Orbitor

• Mars “Curiosity” Lander (a.k.a. Mars Science Laboratory and also deployed on “Perseverance”)
Mars Curiosity/Perseverance
My motivation this context
Engineers Without Borders
Humanitarian Engineering is a method of problem solving directed at cultivating the wellbeing of underserved people.

It often merges engineering technical skills with other areas of knowledge to derive appropriate solutions that are sustainable, participatory and aimed to improve the resilience and capacity of vulnerable communities.
A LARGE GAP REMAINS BETWEEN TODAY’S TECHNOLOGICAL ADVANCES AND THE NEEDS OF THE WORLD’S MAJORITY

- Engineering Focus: 90%
- Population Benefitted: 10%

GAP
- WATER & SANITATION
- ENERGY
- SHELTER
- HEALTH
- EDUCATION
- RESILIENCY TO CRISES
Why incorporate this into curriculum?

• “The majority of the world’s designers focus all their efforts on developing products and services exclusively for the richest 10% of the world’s customers. Nothing less than a revolution in design is needed to reach the other 90%.”

• Dr. Paul Polak, International Development Enterprises
Why Humanitarian Engineering?

- 2 billion people around the world do not have access to clean and safe drinking water
- 3.6 billion people – 46% of the world's population – lack adequate sanitation services
- Malaria poses a risk to approximately 3.3 billion people or approximately half of the world's population.
- Each day, 25,000 people, including more than 10,000 children, die from hunger and related causes
- 1.6 billion people around the world lack adequate housing and basic services, with projections that this could rise to 3 billion by 2030
- the number of people around the world who live without electricity is nearly 776 million
- 773 million adults in the world (around 14% of the population) cannot read or write.
- Two billion people, or a quarter of the world's population, now lives in conflict-affected areas
“Human Development is about creating an environment in which people can develop their full potential and lead productive, creative lives in accord with their needs and interests. “ (UNDP)
World Bank income groups, 2022

The World Bank's income classifications split countries into one of four categories determined by the country's gross national income (GNI) per capita. The GNI thresholds between income groups have changed through time based on World Bank definitions.

Data source: World Bank (2023)
Global Population
8.1 Billion!
In April 2024 (and growing)
Increased Population equates to Increase Energy Demand

Demand for energy dominated by:

- USA: we consume 10 times the global average
- China and India: Have growing economies and standards of living which means increased industrialization. China has surpassed the US in carbon emissions.
- Developing countries are increasing their energy use
Developed Countries disproportionately contribute to greenhouse emissions
Nuclear energy saw the largest decline, 4% year-over-year, driven largely by shutdowns to perform critical repairs in France's nuclear fleet.

Non-renewable: 85.6%
- Coal: 35.4%
- Natural Gas: 22.7%
- Nuclear: 9.2%
- Oil: 2.5%
- Hydroelectric: 14.9%
- Wind: 7.2%
- Solar: 4.5%
- Other: 0.9%

Renewables: 14.4%
- Wind: 13.3%
- Solar: 24.2%
- Other: 2.7%

Renewables experienced an impressive 15% growth rate in 2022, compared to oil, natural gas, coal, and hydro, which together mustered an anemic 0.4%.
Oil consumption by Nation
Evidence of Change

chasing ice
More Extreme Weather
A 2020 World Bank paper estimated that between 32 million and 132 million additional people will be pushed into extreme poverty by 2030 due to climate change.
40% of world’s inhabitants reside in coastal zones of this, 67% are low income by WB metrics.
The countries most vulnerable to climate change

The Notre Dame Global Adaptation Initiative index gauges countries’ vulnerability based on their exposure, sensitivity and ability to adapt to the negative impacts of climate change.

Vulnerability to climate change

| Low | High |

Darker colors reflect greater vulnerability; gray indicates no data available.
Engineers’ role

Sustainable solutions that build capacity and resilience.
Humanitarian Engineering = Building Capacity and Resilience
Creating Secure and Stable Communities

“... a community that allows all of its members to enjoy a quality of life where basic human needs and rights and meaningful work are fulfilled. It is a community that has access to resources and knowledge, thus capable of sustaining itself economically, socially, and environmentally. “
Does the process used in the framework help community users generate information to solve problems they have identified, using methods that increase their capacity to solve similar problems in the future?
Technology’s role
Why has development aid so often failed?

Complex systems

Approaches have often been reductionary

Technology alone cannot solve pressing issues in vulnerable communities

Projects need to recognize local conditions and be inclusive of cultural considerations

Successful projects need to be participatory
Social problems are complex and sometimes hard to define.

Often a perfect or singular solution does not exist.

Traditional problems are often "tame" problems. Social problems are often what we can call “Wicked Problems”
Sustainable Community Development

A sustainable community manages its human, natural, and financial capital to meet current needs while ensuring that adequate resources are available for future generations.

- Multidisciplinary approach...
  People, Planet, Prosperity...the triple bottom line
SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD

1. No Poverty
2. Zero Hunger
3. Good Health and Well-being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation and Infrastructure
10. Reduced Inequalities
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace, Justice and Strong Institutions
17. Partnerships for the Goals
WASH

Water Sanitation and Hygiene
Clean water and Sanitation
GOAL #6
Food Security
2

Zero Hunger
Energy
7 Affordable and clean energy
The UN goals are global which has merit as a unifying strategy, but local context is important and too often ignored.
Participatory methods

- Stake Holder input
- Understanding local conditions
- Allowing communities to develop their own solutions
- Assist
A different engineering challenge

VS

ΣF
Systems thinking applied to many scenarios
Pillars of Sustainability: A System Perspective
A systems framework: food & nutrition security

[Diagram showing relationships between environmental system, pollution/clean water availability, health/disease system, individual decision-making, individual outcomes, and various factors such as pollution, soil degradation, climate, income/prices/marketing, sustainability of food production, labor availability, food availability/quality, nutrient absorption, susceptibility, immune response.]
Appropriate technology
Appropriate Technology

- Holistic Design
- Considers local context
- Sustainable Practices ➔ Systems Thinking
- Interconnections, Stocks, Flows etc
- Participatory Methods
- Local Context important
Human Centered Design

- Human-centered design is an approach to problem-solving commonly used in design, management, and engineering frameworks that develops solutions to problems by involving the human perspective in all steps of the problem-solving process.
Some Projects
Humanitarian Engineering Study Abroad

COSTA RICA
Mexico Collaborative Project (funded by 100k Strong for Americas Initiative)
Humanitarian Technology for Emergency Disaster Response in Nepal

The Ghorka Earthquake
Basic Biosand Filter for Disaster Response in Nepal

पानी फिल्टर गर्ने उपकरण बनाउने तरिका

विशेष ध्यान दिन पर्ने कुराहर

- यो उपकरणबाट दुबै हुन्छ र भागमती तपाईले राख्ने पाटका काफी जनित्तक किदलो मुख्यतम हुन्छ जसलाई पाटका फिल्टर गर्ने गर्नुभएको जागी र त्यसका राख्नु लागुरुङको व्यवस्था हुन्छ ।

- यो उपकरण बाट फिल्टर गर्नेछ र भागमती पाटका मुख्यतम हुन्छ ।

- त्यसै तिने किदलोदुवै गर्ने पाटका तपाईले अपनै रोटिहरू राख्ने र बोटताल सघ रोटिहरू 5-6 मिनेट मत्सामा राख्ने पाटका नयै पनि होस् ।

- पाटका उपस्थापना बाटल्याँ १ मिनेट उम्नालो मात्र, किदलो बाट 5000 पीट (5000 मीट्र) ताल हामीले अपनै कानौं उम्नालो बाटल्याँ ३ मिनेट उम्नालो मात्र ।

- यी राख्ने कुराहर ध्यान दिन पर्ने नियम र दुलो मुख्यतम पाटका मुख्यतम हुन्छ ।
AT Assessment tool
“Engineers often have failed to understand the social dimensions around technology transfer and implementation.”
- Murphy et al., 2009

“‘Appropriate technology is simply not appropriate,’ said a senior USAID official commenting on a small-scale hydro scheme...”
- Ellis & Hanson

1989

“This highlights the need to develop a decision support tool that can help decision-makers to select appropriate technology.”
- Kalbar et al. 2012
Evaluation using MCDA

✓ Multiple considerations

✓ Systematic

✓ Well-suited to AT
Indicators of Appropriateness from a Literature Meta-Analysis
**STEP 1:**
Indicate the TOTAL NUMBER of indicators you are scoring today.

How many indicators today?  8

**STEP 2:**
Rank your indicator from most to least important (top to bottom)

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Rating</th>
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<tbody>
<tr>
<td>Locally available raw materials</td>
<td>4</td>
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<tr>
<td>Resource efficiency</td>
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<tr>
<td>Job creating</td>
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<td>Simplicity</td>
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<td>Ease of Use</td>
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<td>Uses renewable resources</td>
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<td>Adaptability</td>
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<tr>
<td>Autonomy</td>
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</table>

**STEP 3:**
Rate this technology for each indicator

PRESS HERE to Calculate Score

This is your AT's "Appropriateness" Score

4.21
Westwood
<table>
<thead>
<tr>
<th>Main Data Sources</th>
<th>Type (Primary/Secondary)</th>
<th>Community Demographic Data</th>
<th>General Community Needs or Problems</th>
<th>Specific Community Food Problems</th>
<th>Specific Community Housing Problems</th>
<th>Information to help partner with Re:Vision</th>
<th>Community Strengths</th>
<th>How to Connect to Community</th>
<th>Additional Resources</th>
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<td>Re:Vision's Files or Data</td>
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Westwood residents paid $689 average rent. This equated to 95% the average rent price in Denver of $725.

Westwood household had 3.3 people. The greater Denver area had an average of 2.3 people per household.

21.1% of Westwood spoke “English not well or not at all” vs. 7.6% for the rest of Denver.

WESTWOOD HOUSEHOLDS HAD A MEDIAN HOUSEHOLD INCOME OF $31,886, WHICH WAS 57% THE MEDIAN HOUSEHOLD INCOME FOR DENVER OF $55,129.
<table>
<thead>
<tr>
<th>Rank</th>
<th>Community Needs</th>
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<tr>
<td>1</td>
<td>Economic needs (jobs and income)</td>
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<td>2</td>
<td>Violence or negative influencers (Gangs, drugs, alcohol, pornography, robberies)</td>
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<tr>
<td>3</td>
<td>Educational needs (better schools for children, more education for adults including about good food)</td>
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<tr>
<td>4</td>
<td>Poor housing stock (Windows, insulation, safety, expense of repairs)</td>
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<tr>
<td>5</td>
<td>Poor food options (No local grocery stores, expensive healthy food, limited space or time to garden)</td>
</tr>
<tr>
<td>6</td>
<td>Lack of sense of community (trash on streets, graffiti, abandoned buildings, stray dogs)</td>
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<tr>
<td>7</td>
<td>Health concerns (diabetes, high blood pressure, lack of insurance or adequate care)</td>
</tr>
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</table>
Problem:

• Expensive monthly energy bills for residents of Westwood
Six Potential Options

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<th>ScorexWeight</th>
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</tbody>
</table>
Focused Strategy: Solar Furnace
• How It Works
Performance Prediction
Furnace Modeling and Testing
Data Logging
customized Arduino controlled data logger
Actual and Test Output

- Outlet Temp

Predicted Outlet Temp
Community focus group with the pilot solar furnace at Re:Vision
Installing Demonstration Units
Fogg Behavior Model

For permission to publish this, contact BJ Fogg
Ability

Affordable

Community have the skills to construct the devices.

Materials needed were readily accessible
TRIGGER

• First Demonstration Models Installed after First Cold Snap
Dear Heater

...

Love, Cat

FEEDBACK
Covid Ventilator Project
Innovation for Emerging Markets

• The emerging world, long a source of cheap labor, now rivals the rich countries for business innovation (Economist, April 17, 2010)

• Frugal or constraint based innovation

• Hand held EKG: $80 Cost

• Tata Swach (Clean) water filter: $22 initial investment (3,000 liters, 200 days for a family of 5)

• Improved cooking stoves

• “Little Cool” fridge runs on batteries: $70
Assistive Technology

- Dementia
- Memory Support
- Autism
- Knee
- Spinal Cord Injury
- Quadriplegia
- Tetraplegia
- Automatic Calendar Clock
- Knee Brace
- Therapeutic Footwear
- Exoskeleton
- Diabetes
- Stroke
- Hearing
- Elderly People
- Education
- Home Automation
- Distance Learning
- Mobile Help for Seniors
- Wheel chair
- Autism Connect
- Assistive Limb
- Hearing Aid
- Mobility
- Muscle Movement
- Exoskeleton
- Wearable Device
Ethics & Humanitarian Engineering

- Local context is Important
- Avoid the “White Savior Complex”
- Build Trust
- Sustainable Solutions to solve problems Community Identifies
Environmental Justice
Engineering For Peace
Systems Thinking is a useful tool

• Many problems with multiple variables are too complex for the linear thinking of traditional engineering methods.
• Systems Thinking can provide a tool to tackle these, avoid pitfalls and unintended consequences.
• While we often think of Systems Engineering being applied to areas like aerospace and computer engineering, it can also be useful as a tool to address complex sociotechnical problems….these are the biggest problems humanity is facing
And...

Our complex challenges need to be solved through a different paradigm
We cannot solve our problems with the same thinking we used when we created them.

Albert Einstein - www.quoteikon.com