Developing World Prosthetics

SP.713 Lecture 1 2/3/10

Original Project

Vac-cast winner of IDEAS competition 2006

History of the class

Vac-Cast -> IDEAS -> India -> SP.714->SP.718

Class Overview

SP.~~714~~ 718 Developing World Prosthetics

W 3:00-5:00 4-402

9 Units (U) ~~P/F~~ A/B/C/D

http://stellar.mit.edu/S/course/SP/sp10/SP.7148

Team meetings TBD

Course Description

DWP is a collaboration between MIT and Jaipur Foot Organization (JFO) to improve the design, manufacture, and distribution of rehabilitation devices in the developing world.

In addition, we have tried to reach other countries collaborating with Community in Nicaragua, Fablab, and Northwestern Univ. this year.

Goal

Course Goals

- Gain awareness of communities in the developing world and the technical challenges they face.
- Learn about useful and appropriate prosthesis technologies for developing communities, their impact, and how they can be conceived, designed and implemented.
- Learn the hands-on skills.

Grading

Project work and class participation	15%
Homework assignments	15%
Mid-term Presentation	30%
Final Presentation/Report	40%

People

Lectures

- Ken Endo
- Robert Emerson, Lifestyle P&O

TAs

- A lots

Syllabus

February 3	Class overview/Introduction	
		Ken Endo
February 10	Developing World Prosthetics/Projects	
		Ken Endo and TAs
February 17	TBA	
		Guest Lecturer
February 24	Anatomy & Biomechanics	
		Prof. Hugh Herr
March 3	Invited Talk	
		Dr. Pooja Sandeepan
March 10	TBA	
		Guest Lecturer
March 17	Mid-term Presentation	
March 24	– no class – SPRING BREAK	

Syllabus

March 31	Overview of Prosthetic Device	Bob Emerson
April 7	Foot/Ankle	Bob Emerson
April 14	Knee/Socket	Bob Emerson
April 21	Below Knee Amputee	Bob Emerson
April 28	Above Knee Amputee	Bob Emerson
May 5	Upper Extremity	Bob Emerson
May 8	MIT museum event	
May 12	Final presentation	

Projects Overview

- Teams of 3-5 students
- TAs meet for at least an hour a week
- Meet outside of class
- Lab space (TBD)

Contents for today

- Why international development at MIT?
- Jaipur Foot Organization
- Biomechanics of Human Walking
- Past Projects

Why international development at MIT?

Prosthetic/Orthotic Technology

Material Science

Physiology

Pathology

Dynamics

Rehabilitation Engineering

Mechanical Engineering

Anatomy

Orthopedics

Biomechanics

Electrical Engineering

Neuroscience

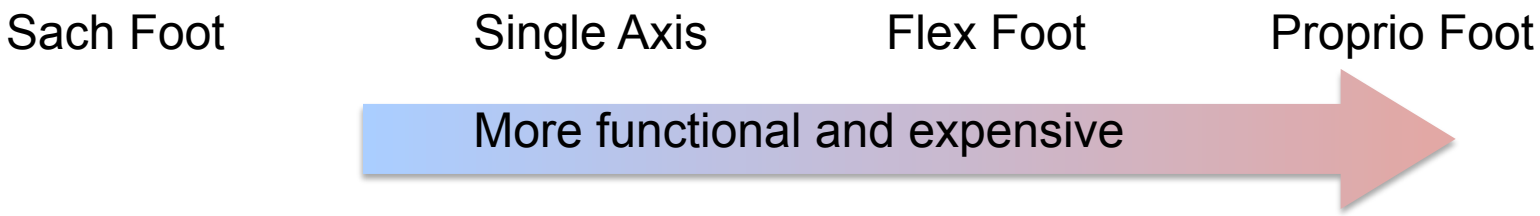
Computer Science

Biology

Control

R&D Focus

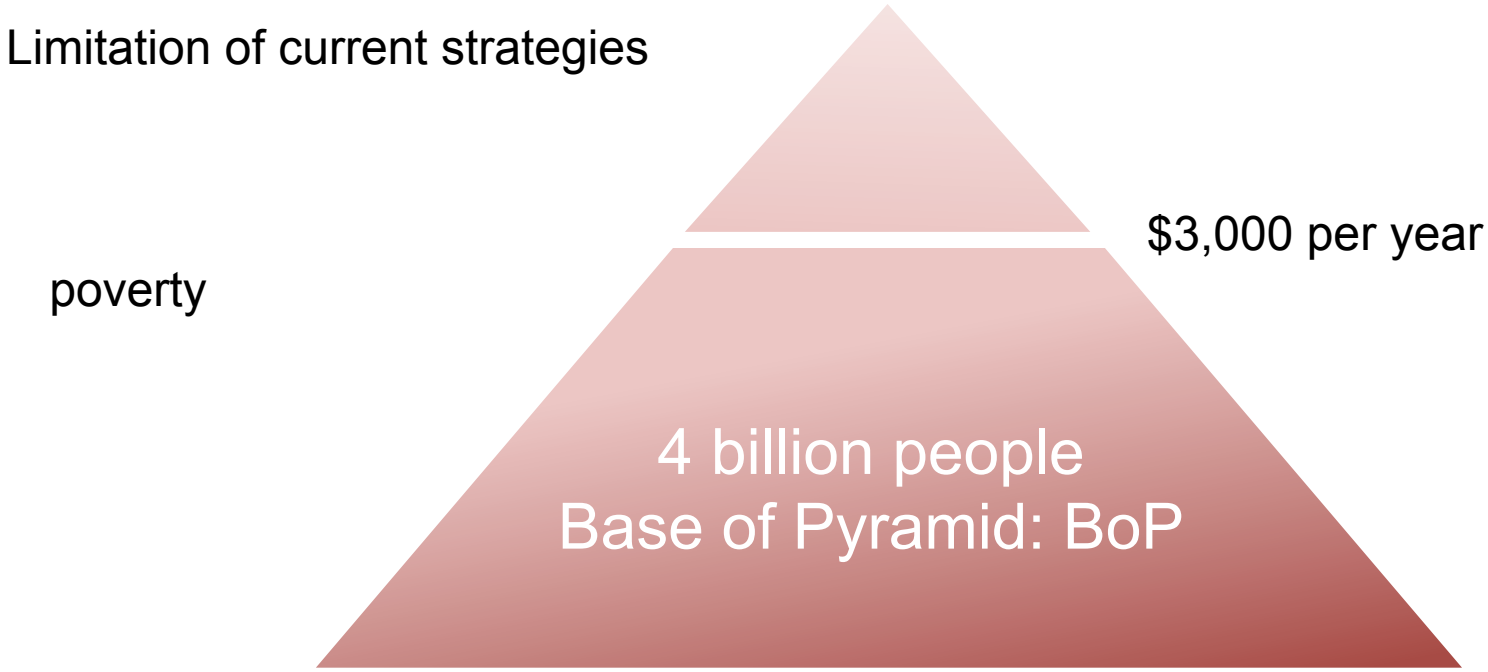
- Researchers in universities and companies tend to emphasize state-of-art technologies
  - Publication
  - Funding/grant
  - Tenure
  - Market (not needs)



Millennium Development Goals

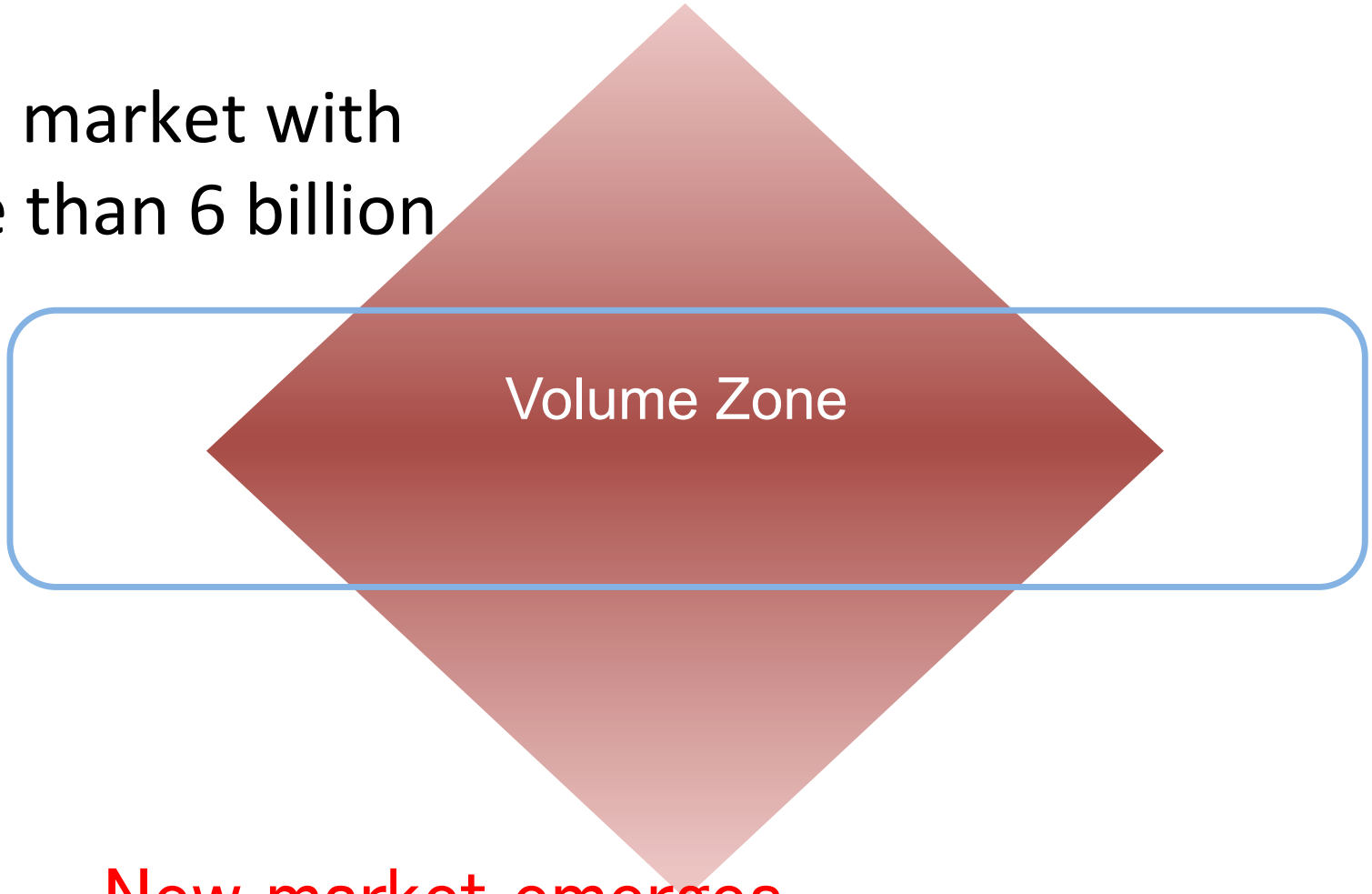
1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

Base of Pyramid



In the Future….

Huge market with
more than 6 billion



New market emerges
by pushing up the base of pyramid

For Solving Problems

- Religion
- Gender Issue
- Culture
- Environment
- Economy

Twelve Steps to Practical Problem Solving

1. Go to where the action is.
2. Talk to the people who have the problem and listening to what they say.
3. Learn everything you can about the problem's specific context.
4. Think big and act big.
5. Think like a child
6. See and do the obvious.
7. If somebody has already invented it, you don't need to do so again.
8. Make sure your approach has positive measureable impacts that can be brought to scale. Make sure it can reach at least a million people and make their lives measurably better.
9. Design to specific cost and price targets.
10. Follow practical three-year plans
11. Continue to learn from your customers.
12. Stay positive: don't be distracted by what other people think.

[Out of Poverty, Paul Polak]

What's D-lab?

- D-lab (http://d-lab.mit.edu)
  - A series of academic offerings for undergrad students in MIT
  - 'D' for Development though Dialog, Design, and Dissemination

Dialog
Introduction to international development

Internship
local field trip

Design
Hand-on experience under constraints

Internship
local field trip

Dissemination
Explore possible idea of international development for business plan competitions and ventures

Courtesy of Alfinio Flores. Used with permission.

D-lab Course list

Dialog	Design	Dissemination
•D-lab Development	•Cycle ventures •D-lab Design •Developing World Prosthetics (DWP) •Wheelchair Design •ICT •Health •Energy	•D-lab Dissemination •Development Venture

http://d-lab.mit.edu/courses

Jaipur Foot Organization(JFO)

Jaipur Foot Organization (JFO)

- Bhagwan Mahaveer Viklang Sahayata Samiti (BMVSS) is a non-governmental, Non-profit, Non-Political, Non-religious, Voluntary Society helping the Physically Challenged persons particularly the resource less.
- BMVSS is running 15 Centres and 3 Sub-centers in India other than Jaipur as head office. Reach-out to patients through Camps.

Greddy named them JFO.

About JFO

- World's Largest Artificial Limb Fitting Society
  - 20,000 limbs & 50,000 other aids & appliances in a year have annual budget of appx. 10 Crore INR (US $ 2.5 Million)
- Special Consultative status with the Economic & Social Council of the United Nations Organization

- Cost is only US $ 35 per Limb, which is good for 3-5 years rather the patient gets it FREE, all subsequent repairs & replacements are also FREE.

Goal of JFO

- Physical & Social Rehabilitation of the Physically Challenged Persons.
- Enabling them to regain their self respect and human dignity.
- Become normal and useful member of the society.

Statistics

Pie charts showing high prevalence of locomotor-related morbidities in both rural and urban India removed due to copyright restrictions.

Products

Jaipur foot

Transfemoral Prosthesis

Courtesy of Dr. Pooja Mukul, Bhagwan Mahaveer ViklangSahayata Samiti - Jaipur Foot Organization, Jaipur, India. Used with permission.

JAIPUR FOOT FITMENTS IN FOREIGN COUNTRIES

Afghanistan	3,051
Bangladesh	1,000
Dominican Republic	500
Honduras	400
Indonesia	869
Kenya	500
Lebanon	145
Malawi	250
Nigeria	500
Nepal	200
Pakistan	989
Panama	400
Philippines	3,000
Papua New Guinea	170
Rwanda	500
Somalia	1,000
Sudan	1,800
Trinidad & Tobago	200
Uganda	250
Vietnam	600
Zimbabwe	250
Zambia	121
Total	**16,445**

Courtesy of Dr. Pooja Mukul,
Bhagwan Mahaveer Viklang
Sahayata Samiti - Jaipur
Foot Organization, Jaipur, India.
Used with permission.

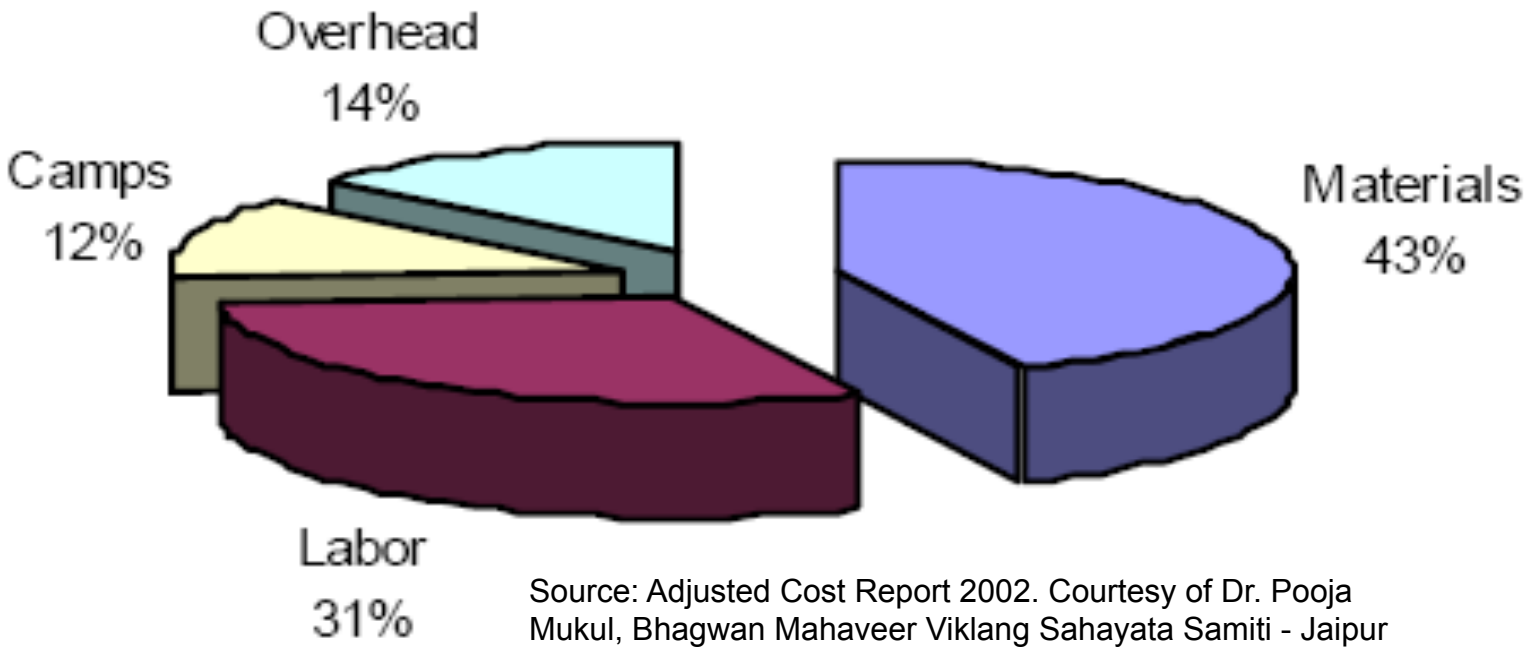
TOTAL ASSISTANCE PROVIDED IN INDIA AND ABROAD

In 1975, the society began with a very modest fitment of 59 artificial limbs but is now fitting about 20,000 artificial limbs and about 30,000 Polio Calipers, and other Aids and Appliances every year in our centres and through mobile camps in India and abroad. Till 31st March 2007, the BMVSS has provided assistance as follows:-

Artificial Limbs	3,10,220
Calipers	2,63,150
Tricycles	58,971
Crutches & Other Aids	3,18,217
Hearing Aids	11,963
Polio Corrective Surgery	6,366
Total	**9,68,887**

Courtesy of Dr. Pooja Mukul, BhagwanMahaveer Viklang Sahayata Samiti - JaipurFoot Organization, Jaipur, India.Used with permission.

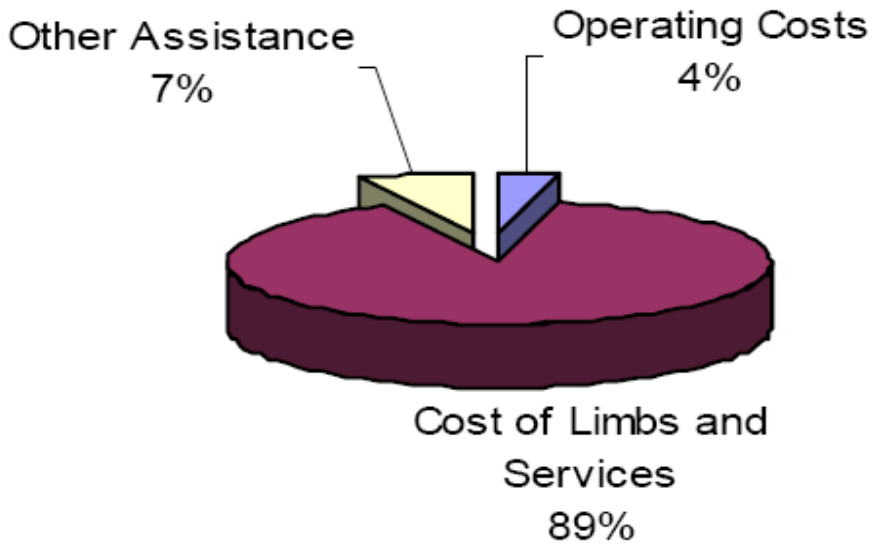
Cost of Typical Jaipur Foot Below Knee Limb



Source: Adjusted Cost Report 2002. Courtesy of Dr. Pooja Mukul, Bhagwan Mahaveer Viklang Sahayata Samiti - Jaipur Foot Organization, Jaipur, India. Used with permission.

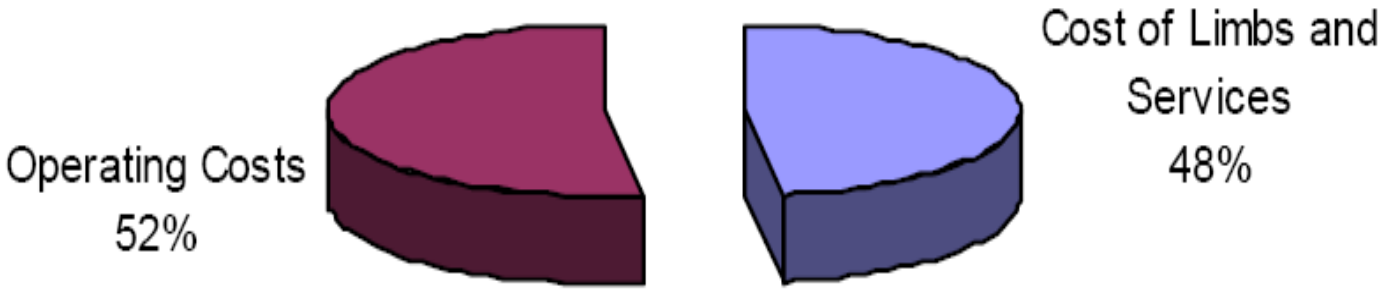
Jaipur Foot 2002 Expense by Classification

(overhead costs of camps are included in Cost of Limbs and Services)



Source: Adjusted Cost Report 2002. Courtesy of Dr. Pooja Mukul, Bhagwan Mahaveer Viklang Sahayata Samiti - Jaipur Foot Organization, Jaipur, India. Used with permission.

Ossur 2002 Expense by Classification

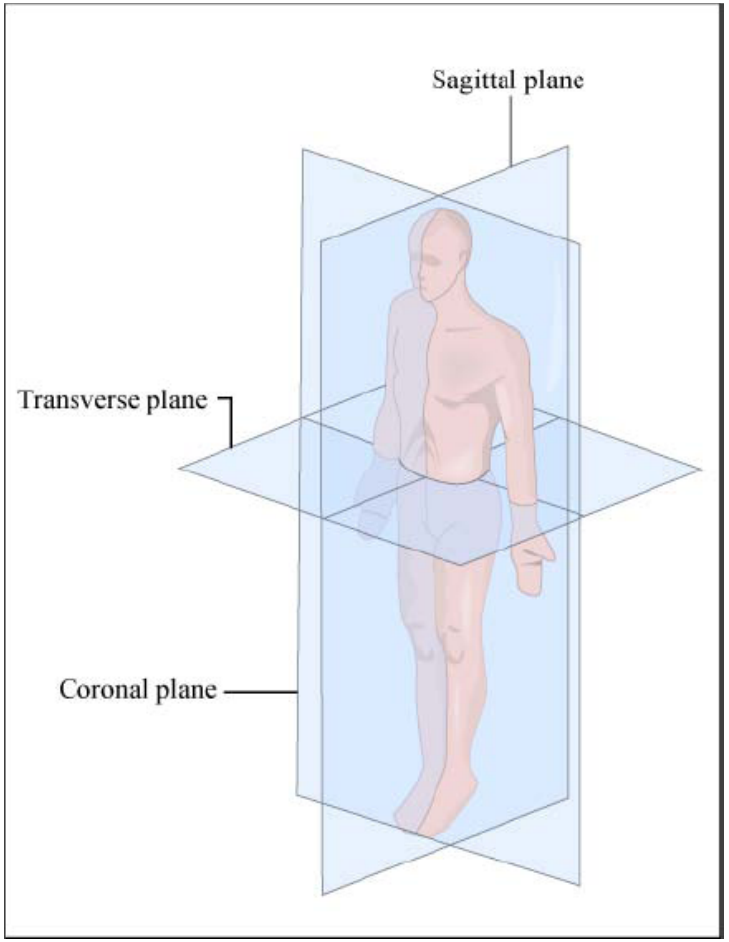


Source: Adjusted Cost Report 2002. Courtesy of Dr. Pooja Mukul, Bhagwan Mahaveer Viklang Sahayata Samiti - Jaipur Foot Organization, Jaipur, India. Used with permission.

Biomechanics of Human Walking

Anatomical Terminology

- Sagittal Plane
- Coronal/Frontal Plane
- Transverse / Axial Plane



Flexion vs extension

- Flexion: decreases angle between body segments
- Extension: increases angle

Abduction vs Adduction

- Abduction: away from midline
- Adduction: toward the midline

Plantarflexion vs. Dorsiflexion

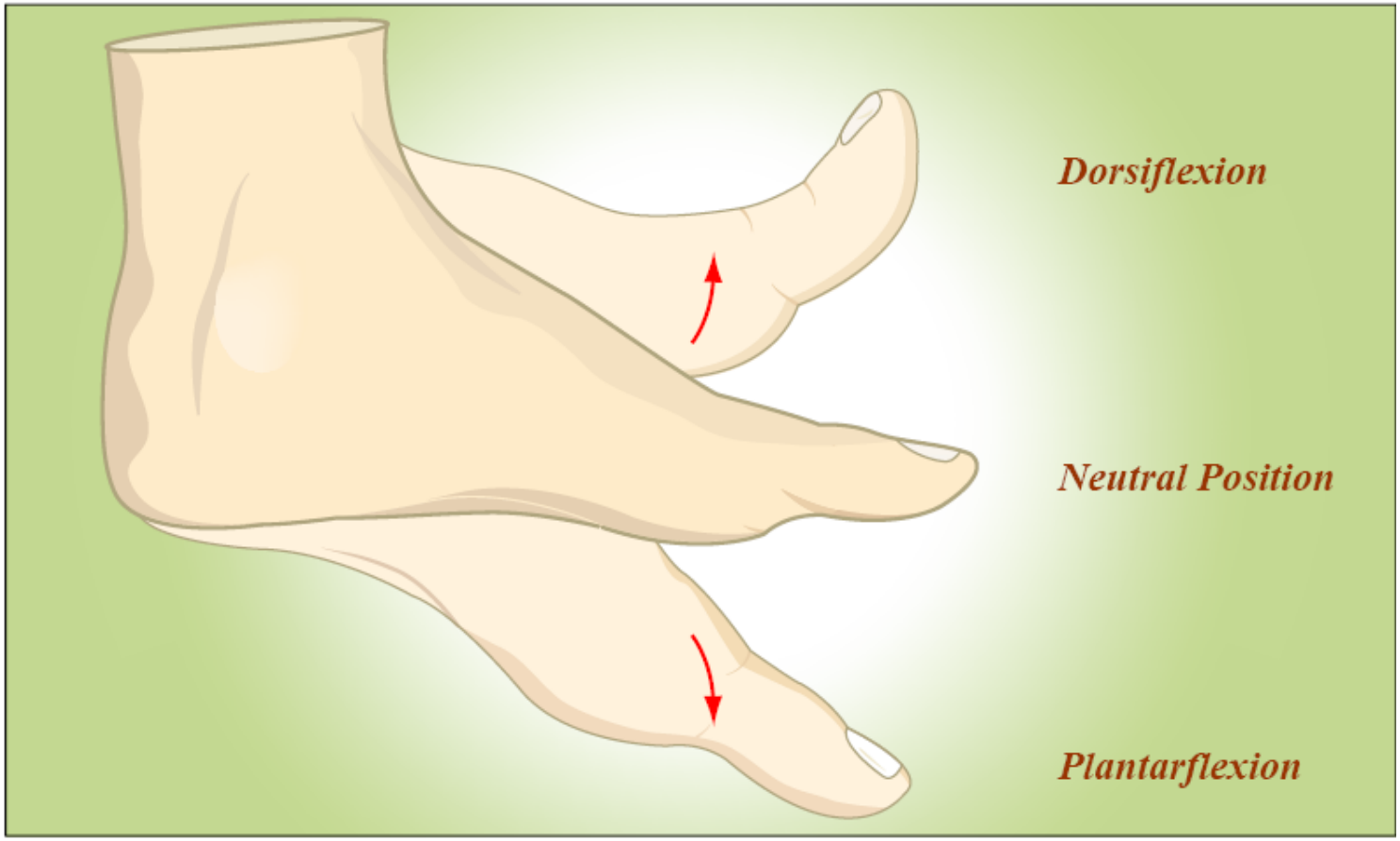


Image by MIT OpenCourseWare.

Walking: The phases of a stride

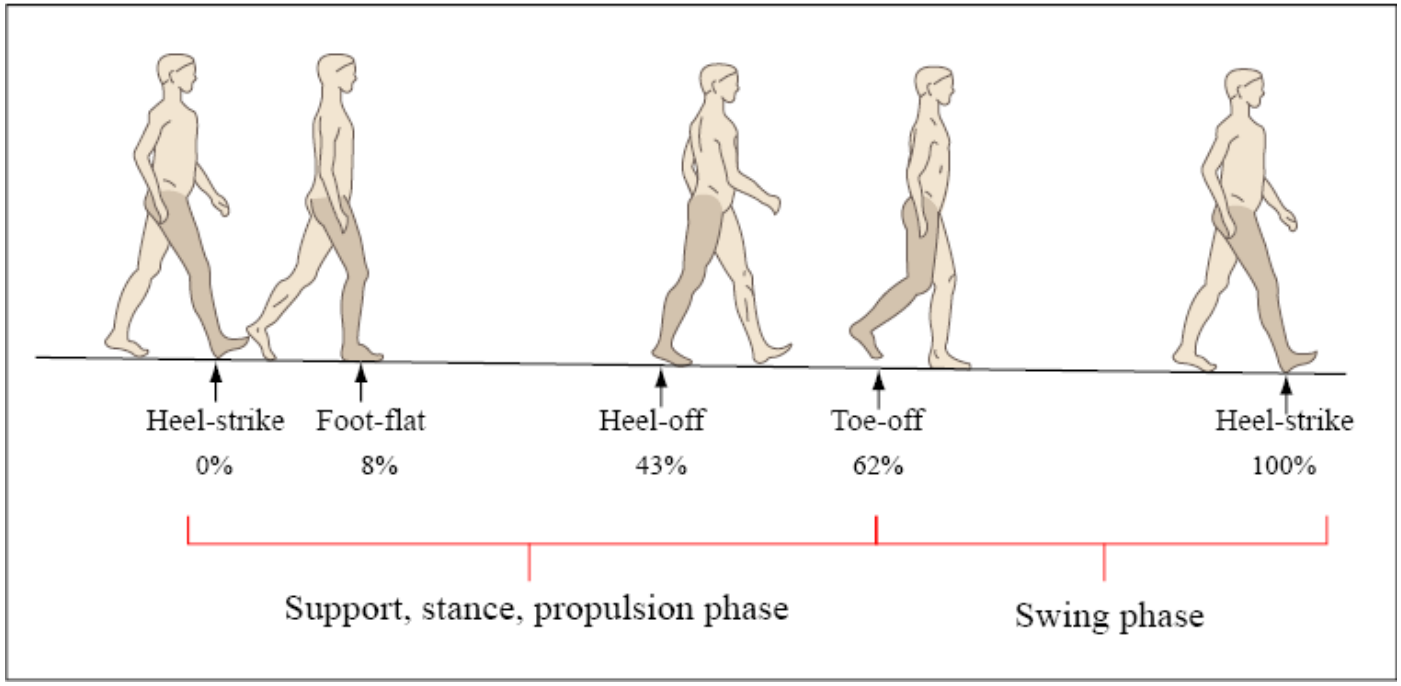
Stride: Complete cycle of locomotor movement

stride length: total cycle length

stride time: total cycle duration

stride frequency = 1/(stride time)

step length: distance traveled from heel-strike to heel-strike of adjacent legs



Joint angles

Figure from Journal of Motor Behavior (1983) removed due to copyright restrictions. See Winter, David A. "Biomechanical Motor Patterns in Normal Walking." *Journal of Motor Behavior* 15, no. 4 (1983).

Walking Speed vs Angles

Figures from Journal of Motor Behavior (1983) removed due to copyright restrictions. See Winter, David A. "Biomechanical Motor Patterns in Normal Walking." *Journal of Motor Behavior* 15, no. 4 (1983).

Assignment 1

- Read winter's paper and answer the questions.

Team Projects

- Needs background about human biomechanics, anatomy, physiology et al.
- Hands-on

Term Project Flow

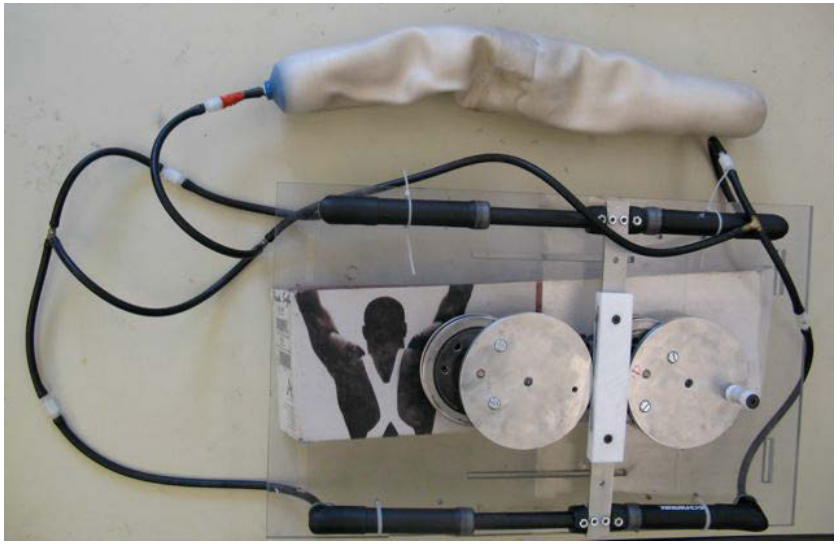
- Specify Projects
- Research existing designs
- Mid-term Presentation 3/17
- CAD model proposed design
- Manufacture Prototype
- Basic Test
- Final Presentation 5/8 and 5/12

Past Projects

- EZ-Unlock Knee
- Free-Swing Orthotic Knee
- Vac sock
- Exo knee

Vac-Sock

- Method for prosthetic fitment
- Accurate limb fit
- Reusable materials



Courtesy Goutam Reddy. Used with permission.

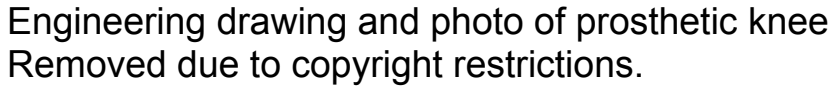
Exo-Knee

- Stance-lock prosthetic knee

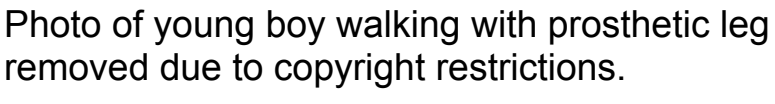
Jared Sartee

MIT Knee

- Mr. Sanjeev Kumar (JFO) offered this project.
- Transfemoral prosthetics with knee lock system.



Summer Internship



Shape & Roll Redesign

Improved Prosthetic Foot for the Developing World

Project Goals

- New attachment for exoskeletal socket
- Redesign support structure with material available in developing world
- Redesign to allow extreme dorsiflexion for squatting

Photo of Shape and Roll Foot from Prosthetics Research Laboratory and Rehabilitation Engineering Research Program at Northwestern University Feinberg School of Medicine has been removed due to copyright restrictions.

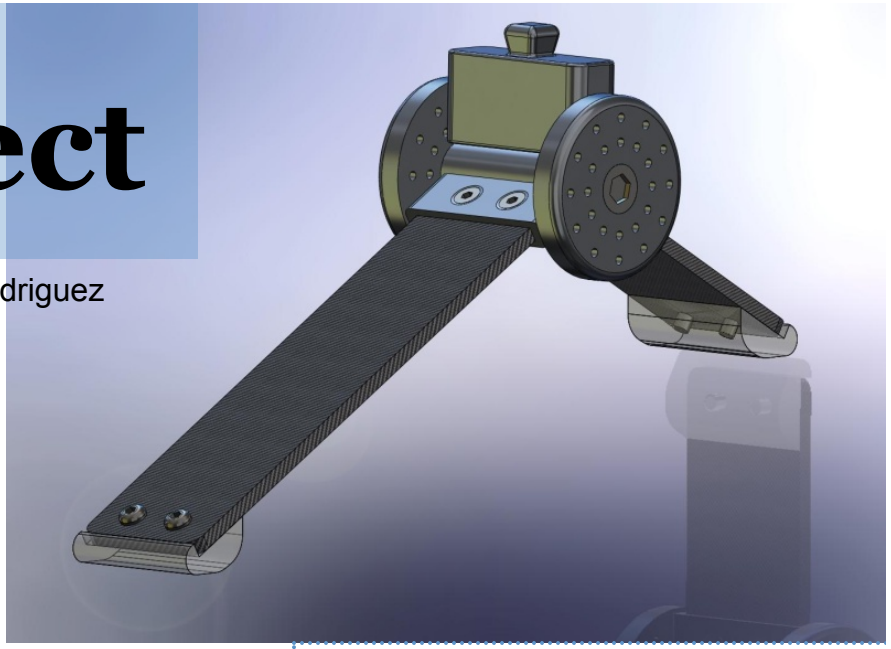
Solutions

- Attachment for exo similar to ICRC foot
- Rod cut longitudinally as nut for attachment

Engineering drawing of prosthetic foot removed due to copyright restrictions.

LegoLeg Project

Project by: Giovanni Talei Franzesi, Jacquelyn Kunkel, Matthew Rodriguez
Advisor: Ken Endo



- **Carbon fiber composites are ideal** for lower limb prosthesis
  - Light
  - Strong
  - Can store/return energy
    - Makes movement much less tiring, faster and more natural

- **High cost** (~1-5K) prevents wider adoption in other countries

- **Main cost is fabrication**, not the raw material

- **Goal**:

To design a **leg/foot** system that

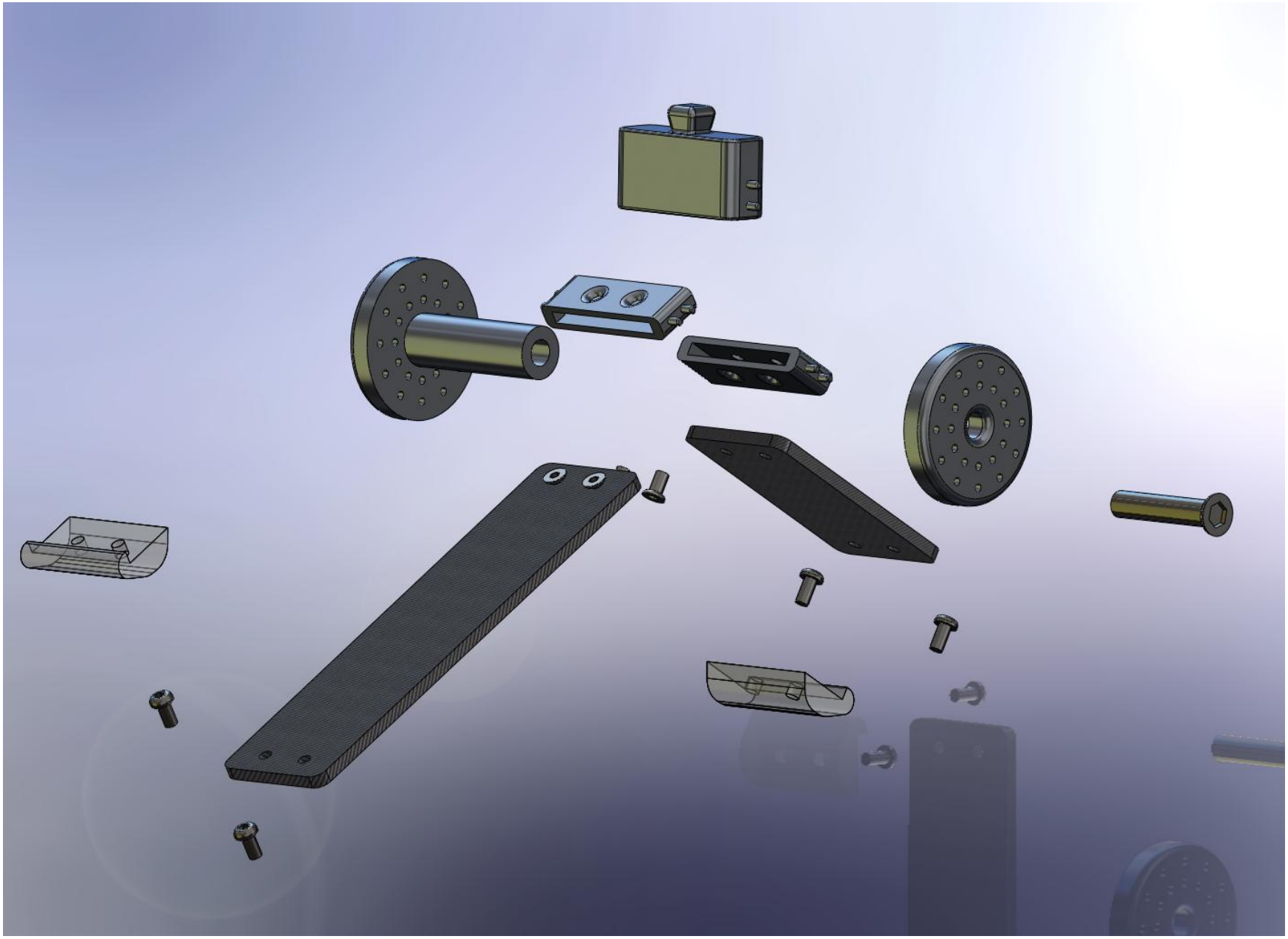
- can **match performance** of existing prosthesis but with greater modularity
- Can **easily manufactured** with the tools in the FabLab, resulting in **greatly decreased final cost, crucial to more extensive adoption**

Design:

- Intrinsically modular
- Easily fabricated
- Rationally designed for optimal biomimetic performance

-

Engineering drawings of LegoLeg courtesy of Giovanni Talei Franzesi, Jacquelyn Kunkel, and Matthew Rodriguez.
Used with permission.



Engineering drawings of LegoLeg courtesy of Giovanni Talei Franzesi, Jacquelyn Kunkel, and Matthew Rodriguez.
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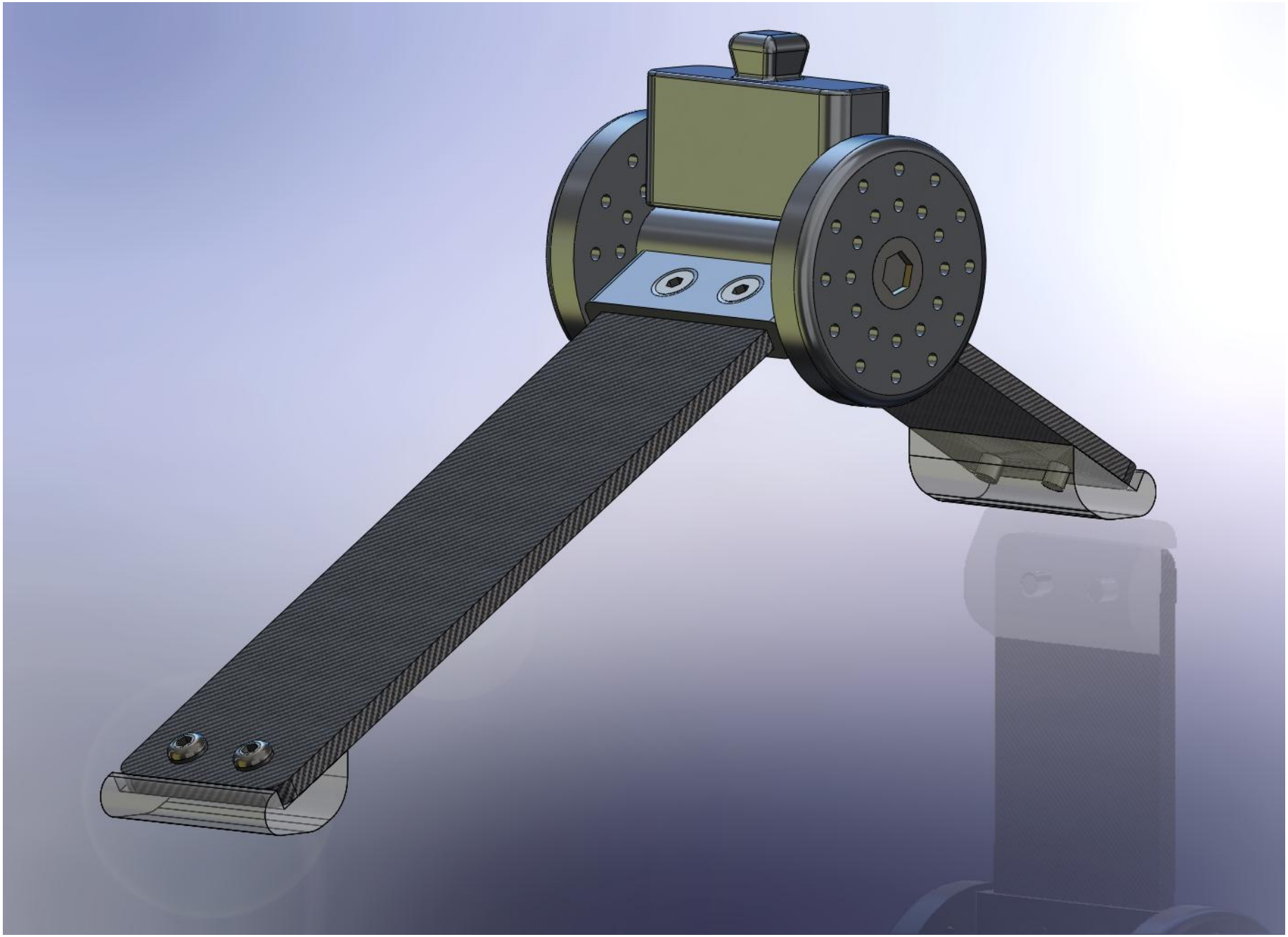

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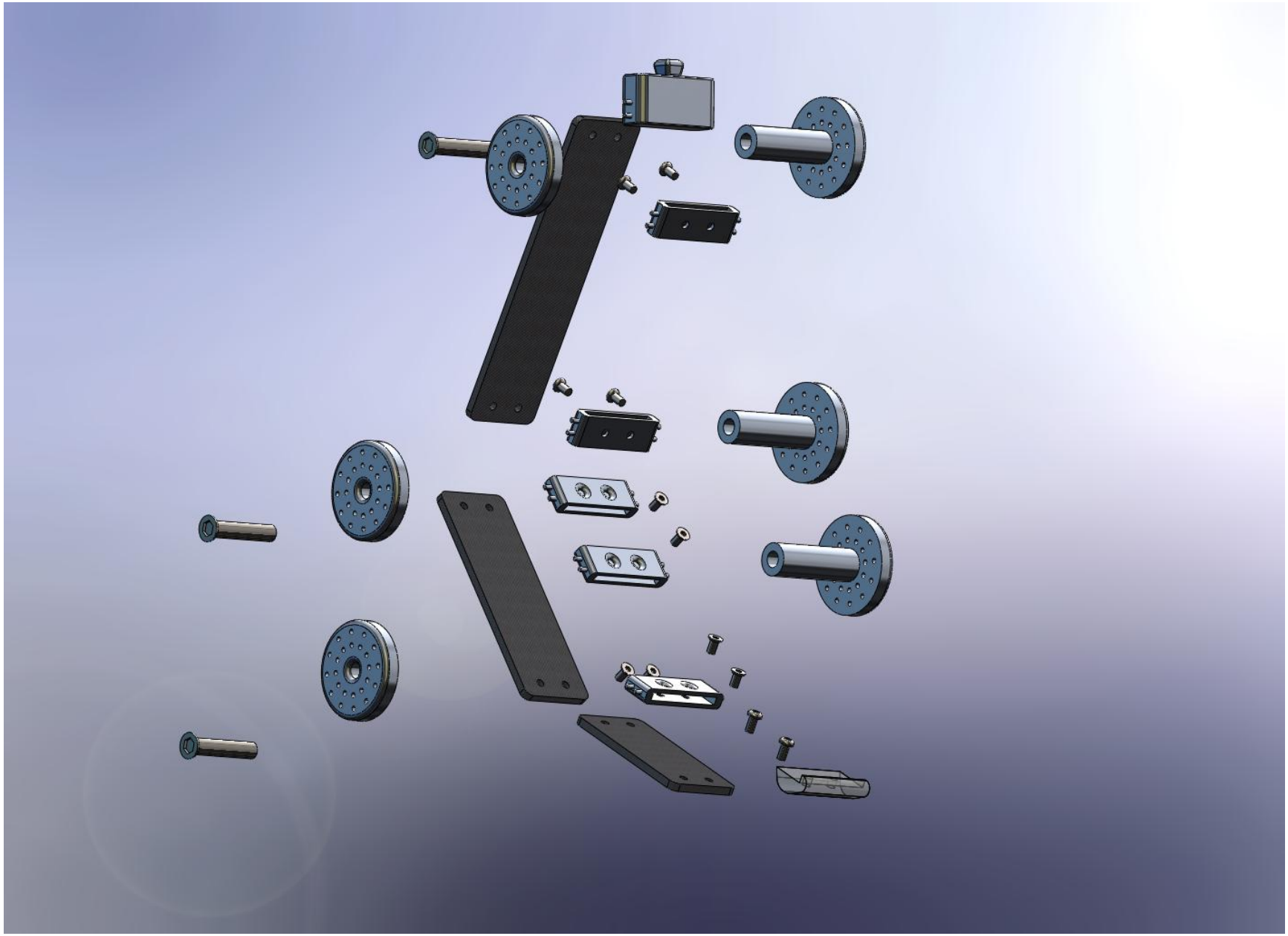

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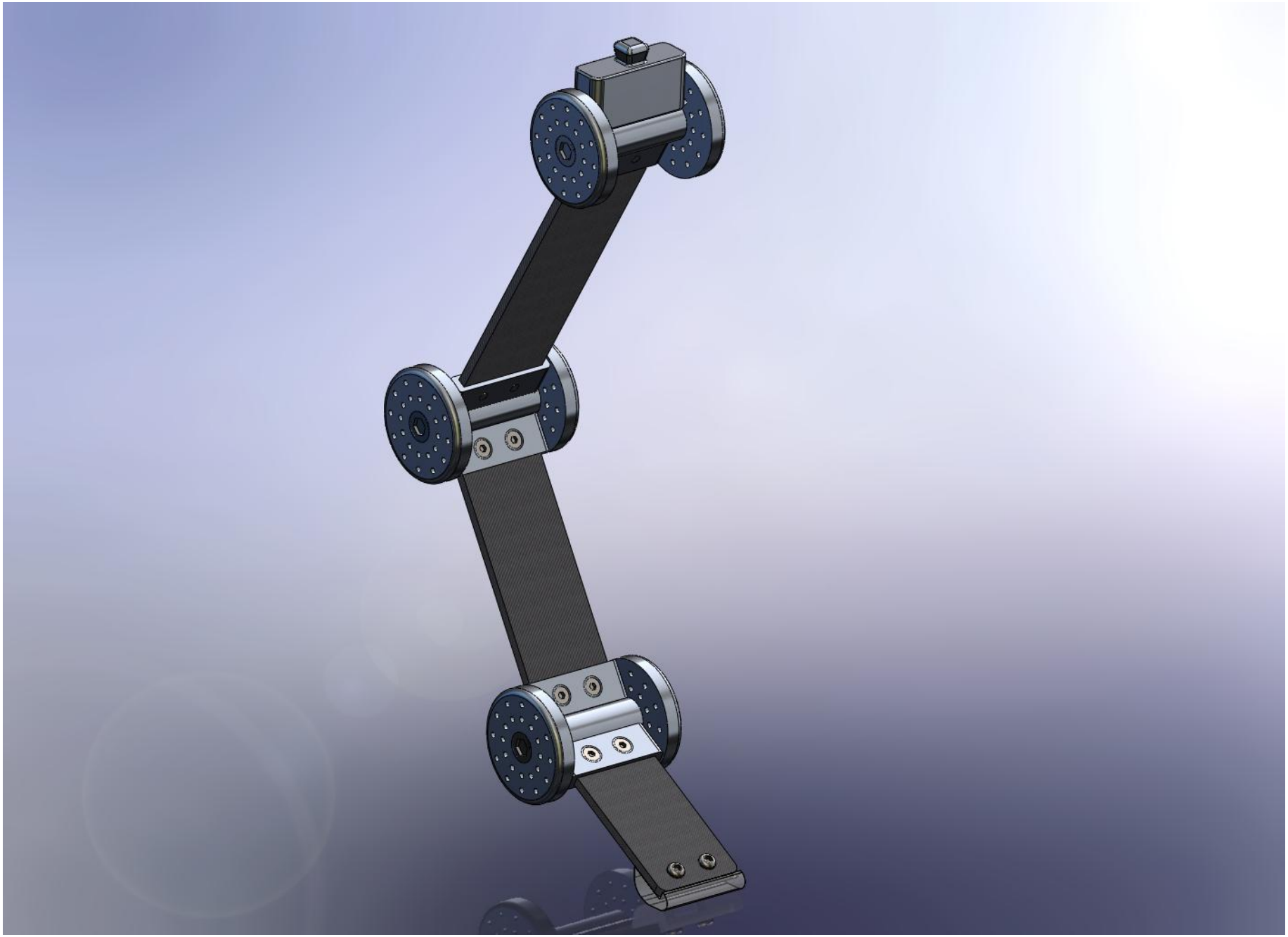


Engineering drawings of LegoLeg courtesy of Giovanni Talei Franzesi, Jacquelyn Kunkel, and Matthew Rodriguez. Used with permission.

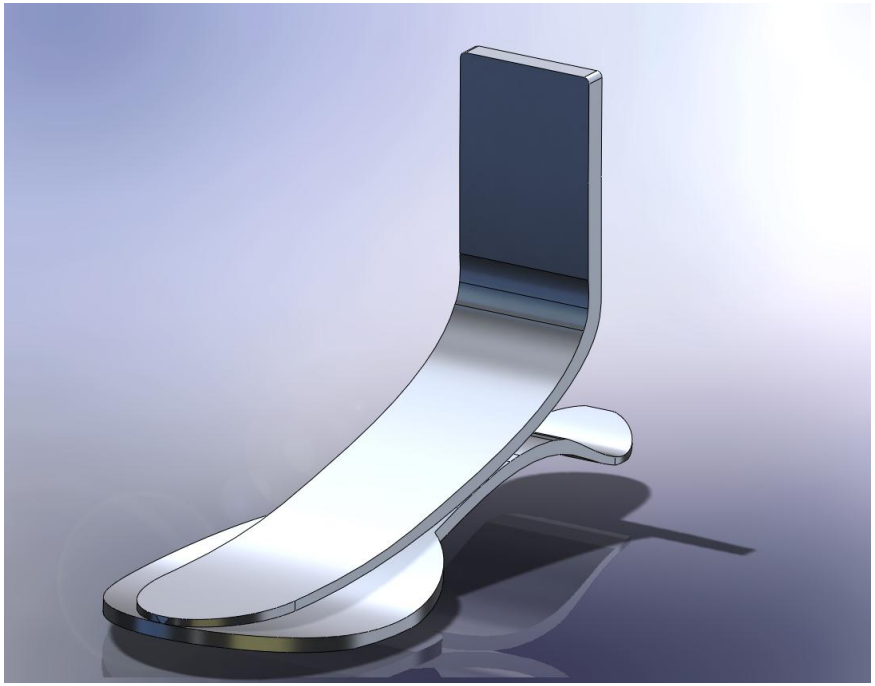
To India and Beyond!

- IDEAS competition
- MIT Public Service Center Fellowships
- A few fellowships via. Class

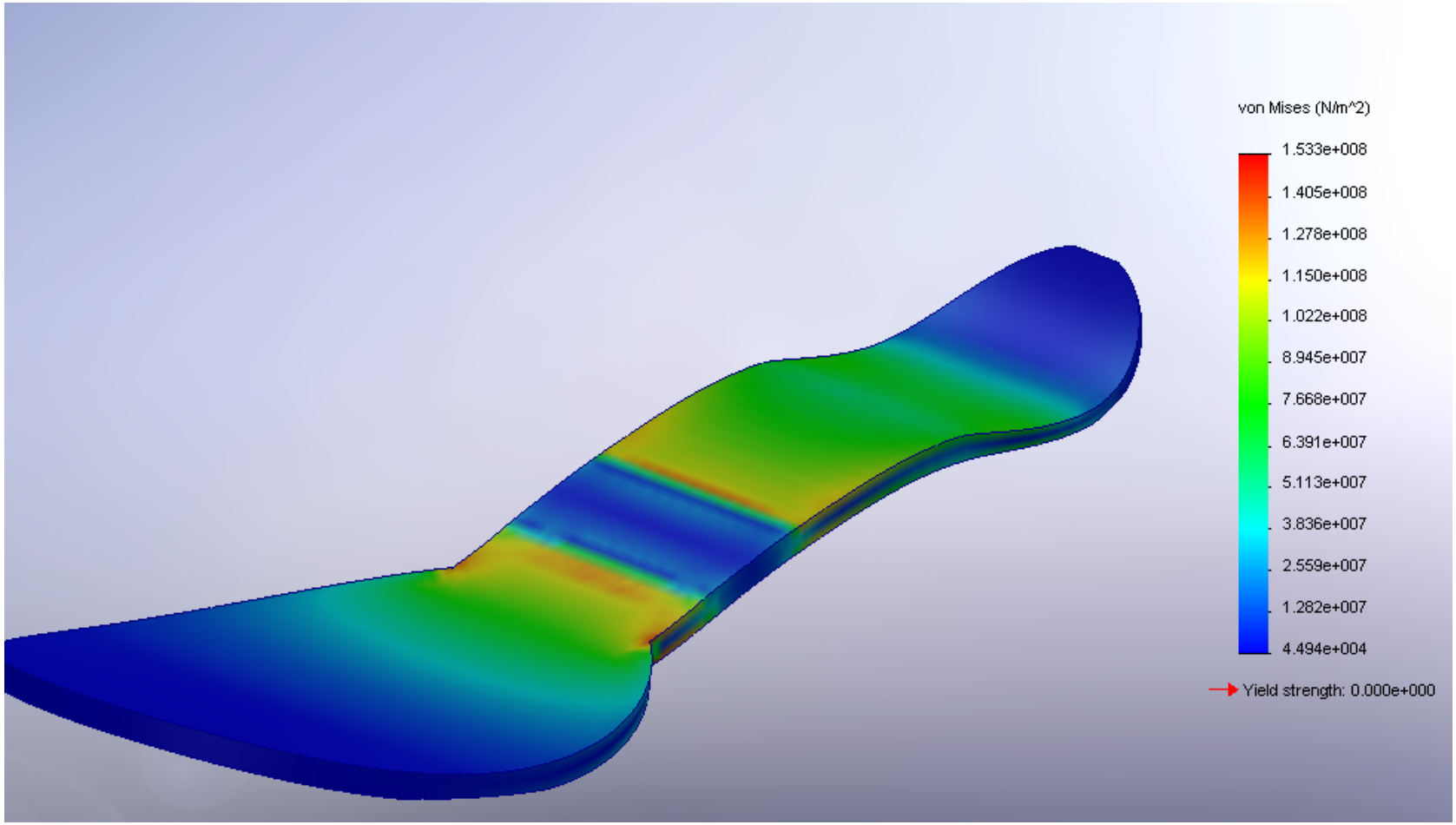
- Refine prototypes
- Learn about O&P in developing world

Solidworks® (optional)

Solidworks®



COSMOSXpress



Homework!

- Read Winter's paper and answer the questions.
- Solidworks® (optional)
  - Follow the tutorial (model and analyze)

EC.722 Special Topics at Edgerton Center:Developing World Prosthetics
Spring 2010