Edgar Stach

Smart Structures

Experiments in Linking Digital and Physical Design Strategies

The Smart Structures Lab

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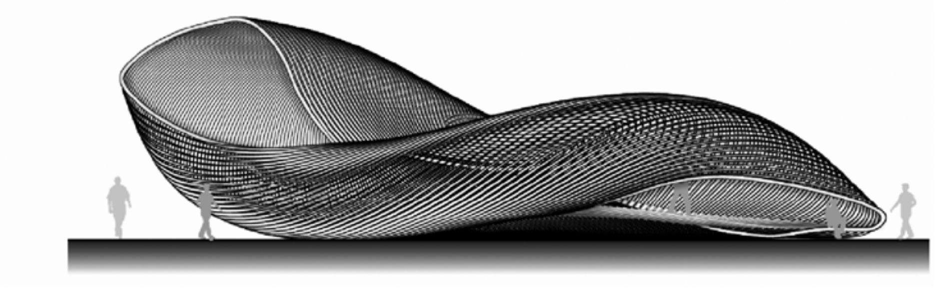
ABSTRACT

During the summer and fall semester of 2006 a new course called *The International Smart Structures Lab* brought together architecture students from the US, the Netherlands and Germany in a collaborative studio setting to focus on new ideas in digital design and synthetic fabrication. The architecture students worked in international teams on design projects taught by faculty from three different institutions.

The idea for the collaborative studio was to transcend political boundaries to achieve a cross pollination of critical pedagogical and style elements. The socio-cultural implications and necessity of such collaborations in an increasingly flat world were a key factor in the creation of the course. New technology in the building industry increasingly calls for architects to blend disciplines. In a studio setting we were able to examine the workflow between digital design and modeling tools, analysis and fabrication tools as well as various analog design and fabrication methods. The collaboration was a very valuable pedagogical experience for all participants because of the design exercise, the digital fabrication component and the shared communication platform.



TEAM7:
SPACELAYER A wormhole to the other side of the world….

1. INTRODUCTION

Digital Design & Manufacturing - Moving Beyond the Virtual

Developments in information and communication technology have an impact throughout the entire life cycle of a building, not only from a process and technical point of view but also from a creative design point of view. The rise of spatial modeling techniques, such as advanced 3D modeling software, cyberspace, virtual reality (VR), besides using intelligent techniques for form creation, enables architects to deal with forms that previously could barely be drawn or built. Internationally, the number of architects who use these innovative approaches and technology is increasing. As a result of these developments, the gap between what the architect envisions and what can be materialized using standard engineering and construction methods is increasing. Therefore, the exploration and adoption of new techniques and methods for design and manufacturing, such as parametric design approaches and digital manufacturing techniques, are necessary.

In the context of international design studios students do research on designing in a digital environment, share their knowledge and experience with each other, build a knowledge base on topics such as virtual and physical prototyping and develop a digital work flow.

The international studio started with design workshops at the partner universities in Delft and Kassel, followed by a workshop on the UT Knoxville campus during the fall semester. During the semester, the collaboration of the international design teams continued via Intranet and digital communication. In addition to exploring cutting edge design ideas, technical innovation and fabrication techniques, the International Smart Structures Lab prepared the architecture students to work in a global environment, and to understand cultural implications in global work practice.

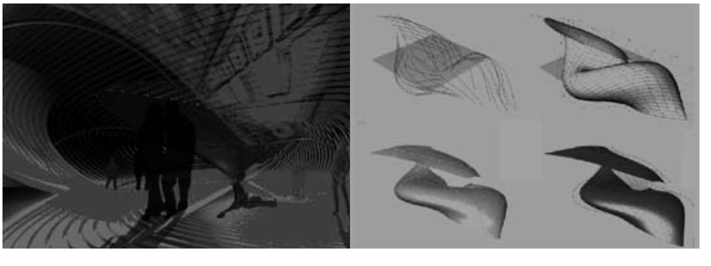
UT Knoxville, the Technical University of Delft and the University of Kassel saw *The International Smart Structures Lab* as a starting point for future collaboration in the areas of teaching, research, and applied technology, enhancing the visibility of their respective institutions. As future goals the team seeks to build a virtual campus showcase or virtual pavilion as a technology carrier.

Hessing showroom 2005 | Utrecht, ONL Oosterhuis and Lénárd
The approach ONL has to non-standard architecture is through mass customization; the means of designing a parametric detail and producing it with unique parameters. A parametric detail is capable of incorporating different specifications. Image from architect's web page.

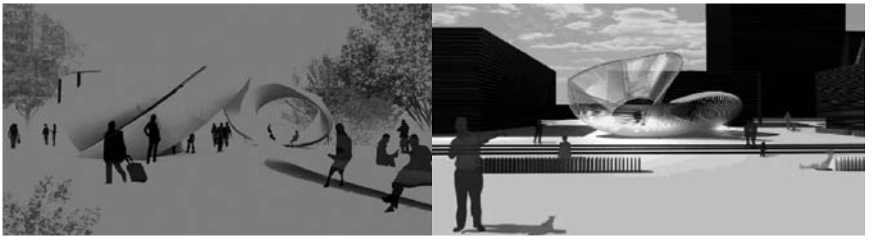
2. The Impact of Digital Design Processes in a Global Teaching Environment

Academia is rapidly developing the capabilities to move beyond the virtual. Comprehension of CAD, CNC and rapid prototyping are as crucial to architectural training today as was knowledge of manual tectonics for the architects of yesterday. Digital technologies are complementary, especially related to processes of creative design. Students in the international studio explored and used a wide range of digital and analog design and fabricating tools. The application of digital design and fabrication methods provided the opportunity for extensive data exchange or even real time CAD modeling between students. By using a central database students could work simultaneously on the same CAD model. Digital fabrication methods were used throughout the design process with the benefit that every student had the exact three dimensional physical models in his hands. The data for Laser cutting, CNC milling and 3D printing could be developed in different locations and shared among the team members. This capability opened up a very different academic experience for the students. Knowledge or technologies not available on their home campuses no longer limited design development or outcome. The potential for this approach to share resources and knowledge globally in order to develop and execute architectural projects was evident.

The human, collaborative and pedagogical challenges of the collaborative studio were not so much on the technical side (the 'hard skills') but much more on the human side (the 'soft skills'). Working across different time zones, synchronizing communication between the students and finding time slots for larger group discussions became challenges. It turned out that face to face time was very important in the first workshops to build the teams and jumpstart the projects. Still, cultural differences were an issue in terms of language skills, taking responsibility and team play.
The authors learned that for a successful outcome and to avoid frustration in a collaborative studio students need to have the same skill level in using digital tools. Communication between faculty and among students is absolutely crucial and needs to be structured and reinforced. It was pedagogically challenging to advise students from other campuses via the internet and Skype.



TEAM7: SPACELAYER
Morphology process: After digitizing the physical model with a 3D scanner creating curves through the existing polylines and then loft tem together, optimizing the surface geometry by pulling the control verticies on smooth curves.



TEAM INFO LOOP - TEAM SPACELAYER
- synergy between introvert monofunctional and extrovert multifunctional parts, forcing interaction between visitors.

In general the experiences the author made were immensely valuable in terms of the flat-world teaching model and the general push for globalization in teaching and research. The opportunity to enter an international academic classroom and to connect effectively with faculty and students though communication media opens a completely new vision on how and who we teach. Envision an e-classroom where students from around the world meet, learn and work together.
Virtual campus extension though e-learning will change the academic world, and institutions that open up their campuses for students around the world will be at the forefront of globalized education. Collaboration not only provides education to students who would otherwise have no access to the preferred institution but also serves to cross-fertilize culturally and politically.

There is much work still to be done to bridge the gap between the constructs of knowledge and analysis and the fluent, associative process of human design cognition. How can digital technology conclude the correct concepts in its own system from diverse architect-generated input? To find the right user interface will remain the chief concern.

3. Course Content: Design, Computation and Production of Free-Form Buildings
Digital design and fabrication are changing architecture in fundamental ways. In the last decade the increasing use of computer-aided design and manufacturing has enabled the construction of free form buildings, changing and challenging the building industry of the 21st century. This trend raises some fundamental questions. How can emerging industrial processes reshape building design and construction? How do new construction systems work? What digital design methods, materials, and building details are emerging? What are the implications for design and industry? What new paradigms can contemporary fabrication offer architecture?

Smart Structures Lab
The design project for the Smart Structures Lab was a portable prefab pavilion that is representative of the three participating universities. The pavilion is the technology carrier for the

university and becomes the showcase for innovation and connection to other disciplines on campus/externals. It acts as an advertisement instrument for all three campuses. The only strict design requirement is that when disassembled, the pavilion should fit in one overseas container. The final goal is to build this pavilion as a traveling exhibit.

Such a project requires an integrated 3D approach with CAD, FEM (Finite Element Method), CAMP (Modeling and Prototyping) and CAB (Computer-Aided Building). The collaboration in this studio was structured around three one-week workshops in Delft, Kassel and Knoxville. Each individual workshop had a definite goal. The students learned the design techniques (Delft University of Technology) and the structural design of non Cartesian architecture (University of Kassel). Student teams developed a design project based on the experience and knowledge gained during travel and workshops in Europe and continued the design development as an interactive virtual studio during the semester. As the final project at the end of the semester the students from all three universities fabricated drawings, models and mock ups using the digital fabrication facilities in Knoxville.

The design process that emerged was based on numerous digital and traditional design media used interchangeably throughout the design process, judging in an exploratory manner what medium would be beneficial to explore the particular design issue at hand. The design tools used in the studio fall into five different categories:

Digital analytical tools: 3D scanner, FE software

Digital modeling tools: Maya, Rhino, FormZ, Autocad

Digital fabrication Tools: Laser Cutter, 3 axes CNC milling machine, rapid prototyping

Digital representation tools: digital film, web design, desktop publishing software

Analog fabrication tools: Vacuum molding, welding, casting, fiber/matrix molding

Communication tools: Skype, blackboard website

The design teams did not use the different design tools in a linear fashion from analog to digital; rather they alternated fluidly between methods throughout the design and fabrication process.

The International Smart Structures Lab addressed the following key issues:

- The complex relationship between force, form and material in 3D Forms: form-finding, structural morphology and optimization.
- The streamlining of interactive processes between design, engineering, analysis and manufacturing.
- The development of new materials and production for interactive building skins.
- The engineering and prototyping of production, and the completion of construction processes.
- The influence of production methods on design and engineering components.
- The social, economic and management consequences of changing production skills.
- Quality control in production and construction processes.
- Reflections on building technology.
- The design, development and prototyping of building components.
- Design methodology for component design and product development.
- How digital manufacturing methods inform the creation of architecture.

- The effect of architectural systems inspired by nature and the translation and production using computer-controlled machines.

Course goals:
The students learned the design techniques and the structural design of non-Cartesian architecture. Student teams developed a design project based on the experience and knowledge gained during travel and workshops in Europe. As an interactive virtual studio the design teams developed the design project during the semester.

- As the final project at the end of the semester the students from all three universities fabricated drawings, models and mock ups using the digital fabrication facilities in Knoxville.
- The American students were exposed to an emerging architectural paradigm developed in the US and Europe. They learned how to design structures and fabricate an architectural project using new digital techniques.
- Students made use of new communication networks to work virtually together on their group projects. 1. Web space for Smart-Structures.org (e.g. for publishing) 2. Internal communication via mailing list, yahoo group platform 3. Communication via video chat.

4. Student projects:

First Price

International Smart Structures Lab: USA - Netherlands – Germany TEAM 8: MOBILE WORKSHOP

Astrid Nolte | Katharina Überschär | Thomas Allen

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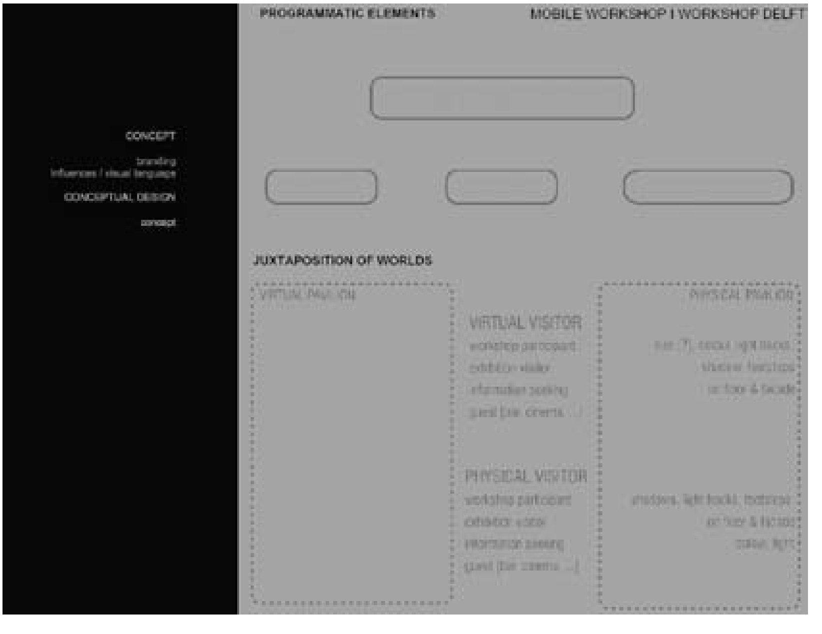

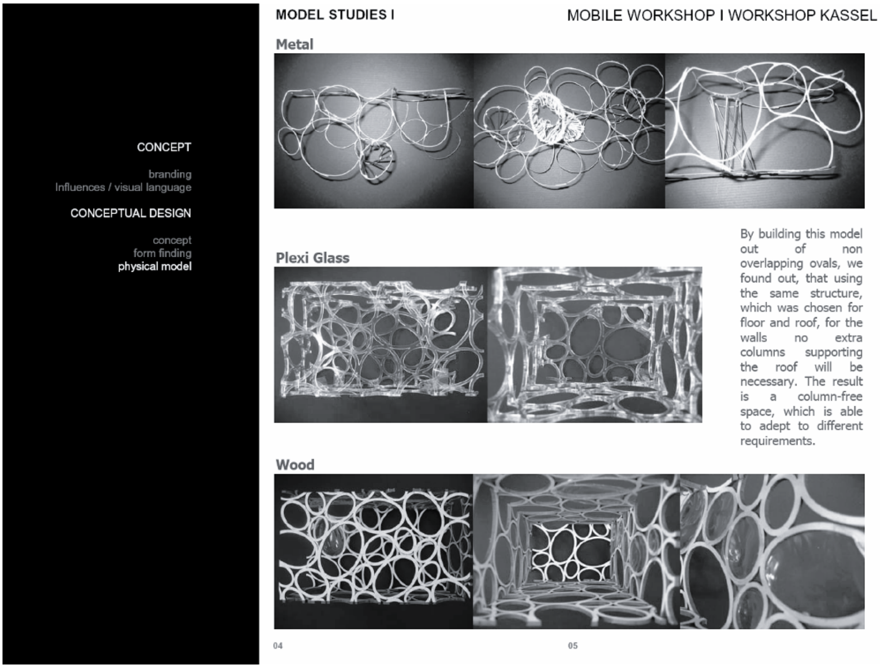

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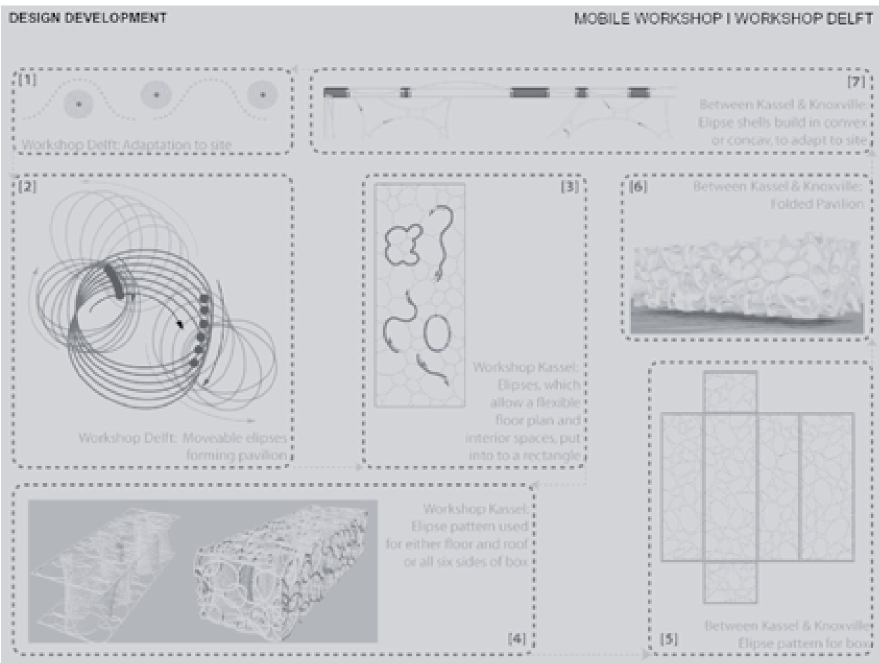

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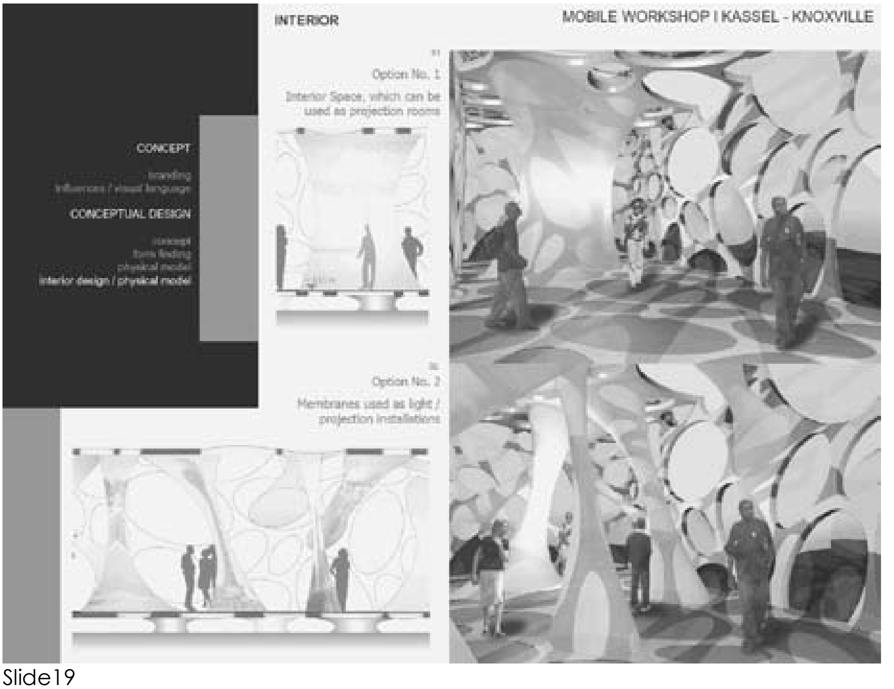

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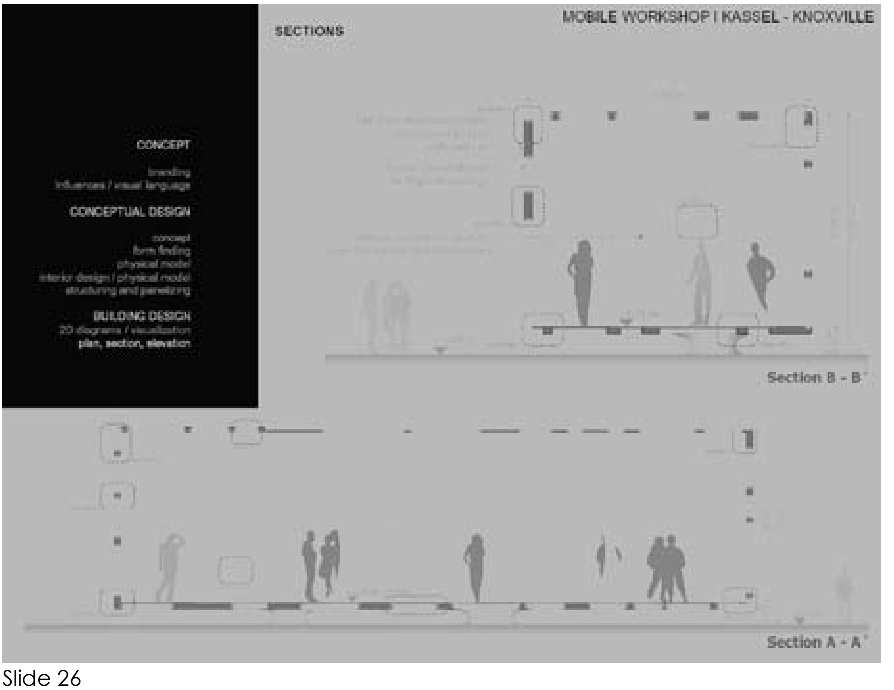

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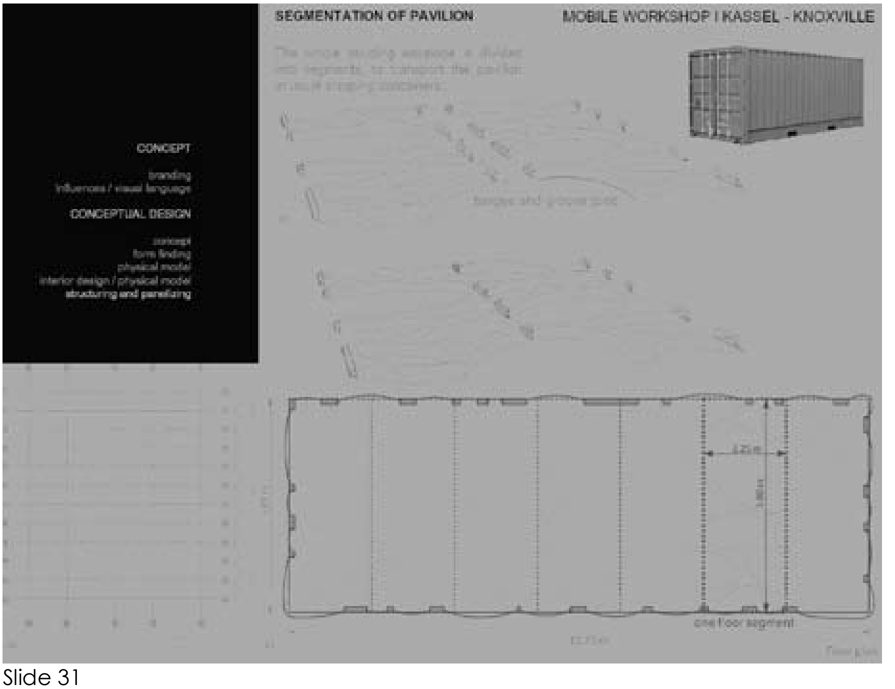

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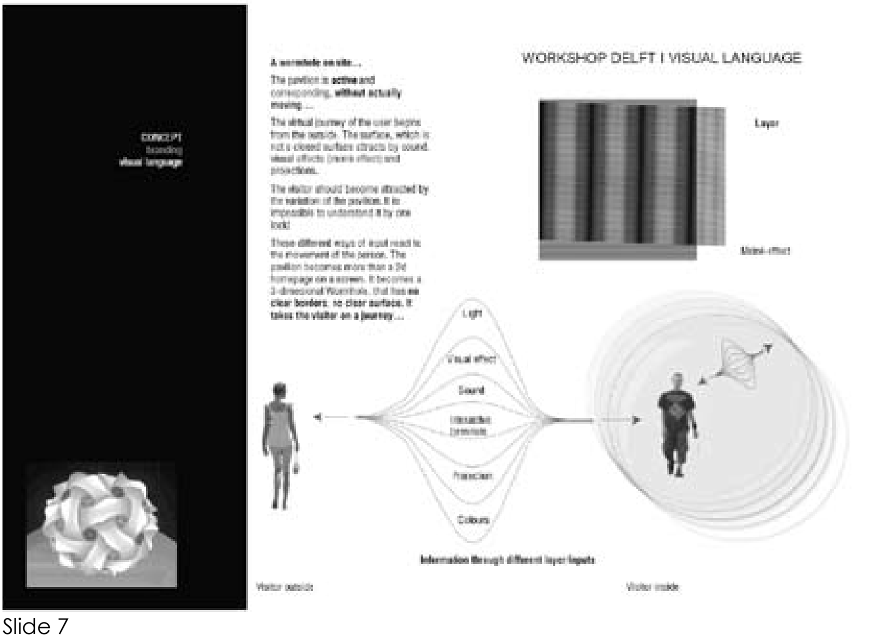
Second Price

International Smart Structures Lab: USA - Netherlands - Germany TEAM7: SPACELAYER
David Seeland I Jana Beermann I Geoffrey Overmyer



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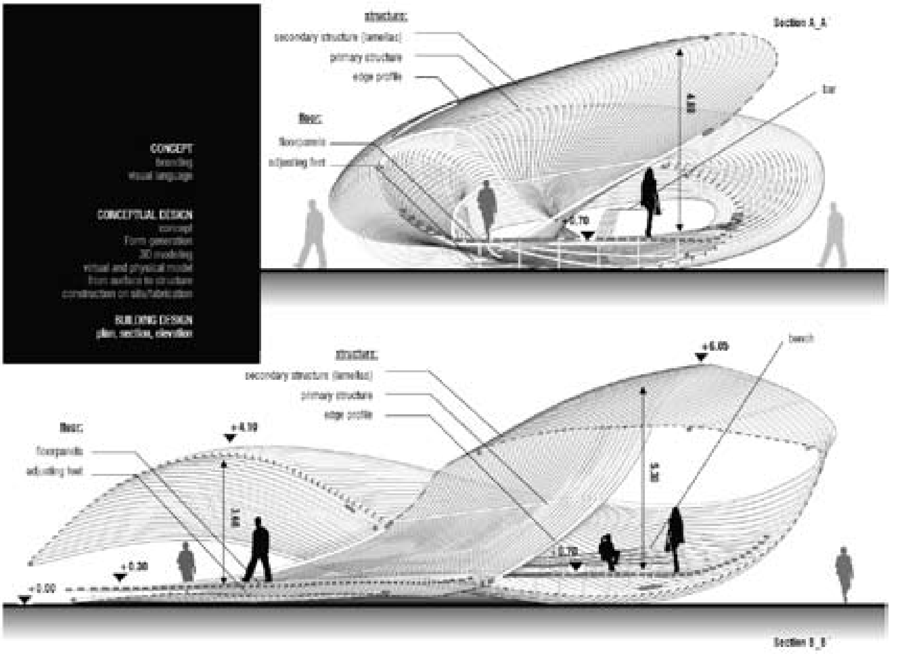

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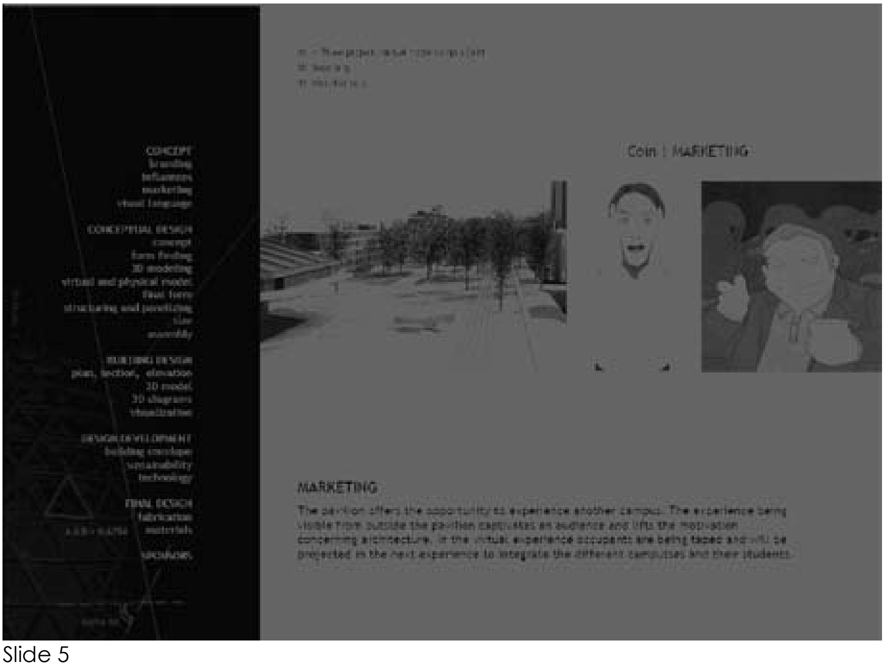
Third Price

International Smart Structures Lab: USA - Netherlands - Germany TEAM4: COIN

Augustus Pastore_Knoxville | Joost Hillen_Delft | Andreas Wolfram_Kassel



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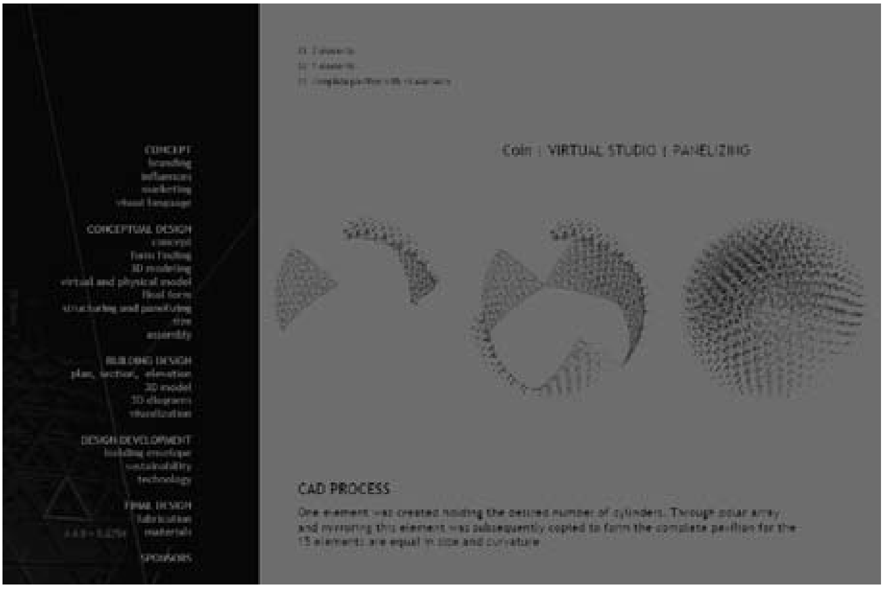
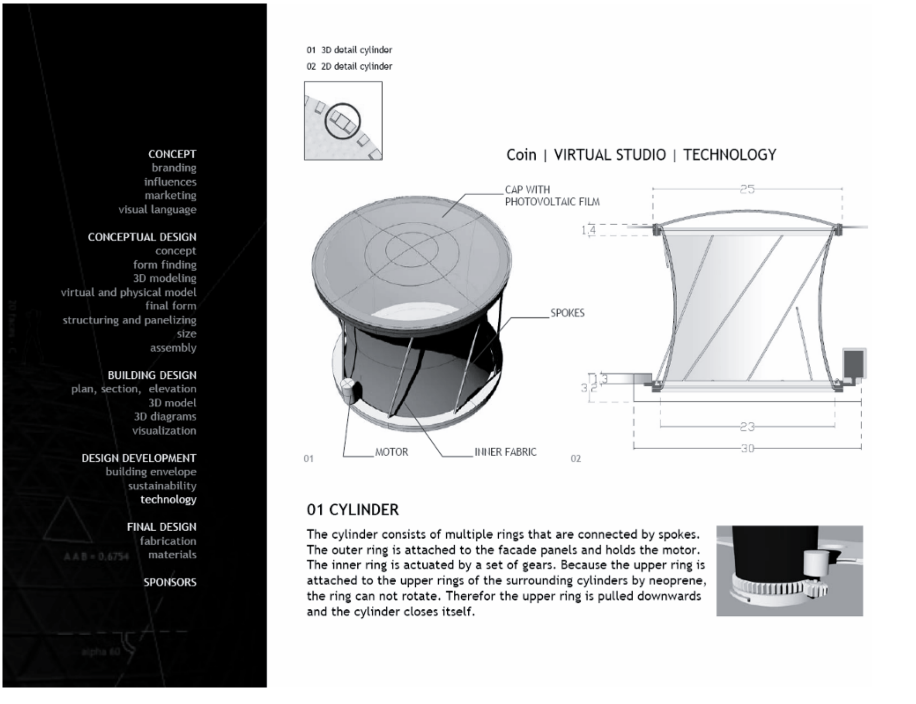



01 INTERIOR EXPERIENCES
CONCEPT
branding
influences
marketing
visual language
CONCEPTUAL DESIGN
concept
form finding
3D modeling
virtual and physical model
final form
structuring and panelizing
size
assembly
BUILDING DESIGN
plan, section, elevation
3D model
3D diagrams
visualization
DESIGN DEVELOPMENT
building envelope
sustainability
technology
FINAL DESIGN
fabrication
materials
SPONSORS

Slide 48


CONCEPT
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concept
form finding
3D modeling
virtual and physical model
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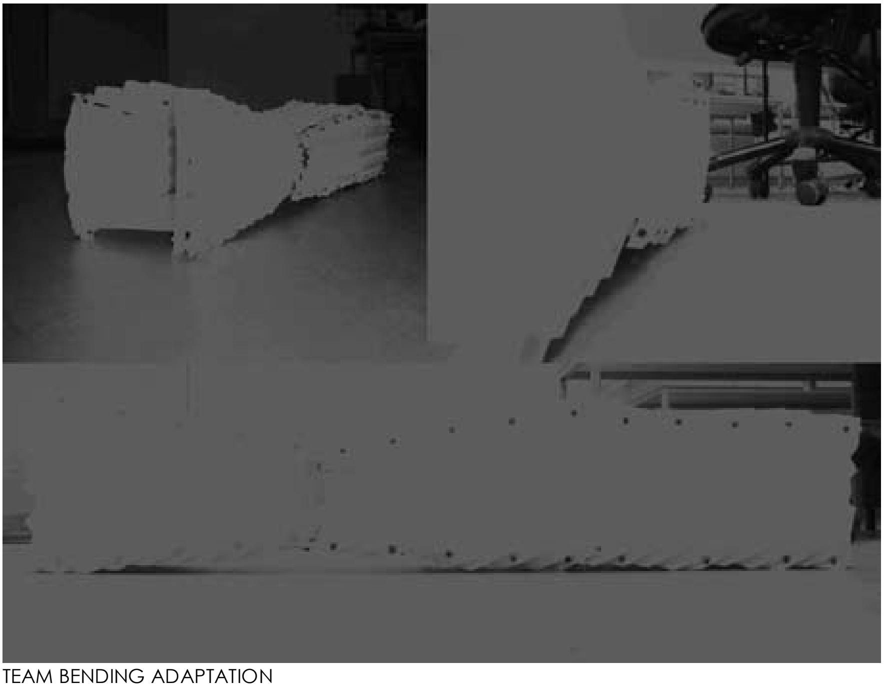
size
assembly
BUILDING DESIGN
plan, section, elevation
3D model
3D diagrams
visualization
DESIGN DEVELOPMENT
building envelope
sustainability
technology
FINAL DESIGN
fabrication
materials
SPONSORS
01 3D detail cylinder
02 2D detail cylinder
Coin | VIRTUAL STUDIO | TECHNOLOGY
CAP WITH PHOTOVOLTAIC FILM
SPOKES
MOTOR
INNER FABRIC
01
02
25
1.4
3.2
23
30
01 CYLINDER
The cylinder consists of multiple rings that are connected by spokes. The outer ring is attached to the facade panels and holds the motor. The inner ring is actuated by a set of gears. Because the upper ring is attached to the upper rings of the surrounding cylinders by neoprene, the ring can not rotate. Therefor the upper ring is pulled downwards and the cylinder closes itself.

Team 6 Andrew Holcomb, UT | Johannes Kuhnen, Kassel | LizzyEisenhauer, UT



TEAM BENDING ADAPTATION
Maarten Moerman, Delft | Thomas Wortmann, Kassel, | Craig Reschke, UT

APPENDIX

5. Assignment (condensed)

STUDENT DESIGN COMPETITION: SMALL EXHIBIT DWELLINGS
- SMART STRUCTURES PAVILION

Imagine: a national platform for your ideas – constructed and put to the test at full, working scale. Innovative design strategies are needed for the project on all levels: dwelling, energy performance + systems, material assemblies, logistics, marketing – and for the integration of aesthetic, environmental, engineering and social practices.

The SmartS Pavilion will serve as the technology carrier for the three collaborating universities as well as their showcase. The SmartS Pavilion becomes an advertisement tool for all three campuses and can be used as a virtual classroom/chat room. The pavilion is mobile and can travel for advertising in China, Europe etc. The pavilion is the virtual extension of the physical campuses via IT. The student design competition Smart Structures is looking for a proposal for a mobile pavilion. The pavilions will represent all three campuses and will serve as a virtual campus expansion.

SmartS Pavilion

The pavilion will serve as the technology carrier for the three collaborating universities and will be their showcase:

- SmartS Pavilion becomes an advertisement tool for all three campuses and can be used as a virtual classroom/chat room.
- The pavilion is mobile and can travel for advertising in China, Europe etc.
- The pavilion is the virtual extension of the physical campuses via IT.
- The pavilion is a powerful tool for fundraising.

The SmartS Pavilion will be portable and will use different design strategies:

- Container, box in the box
- collapsible
- deployable
- Inflatable (parts or the total structure – caterpillar)

The SmartS Pavilion will use new technologies:

- PV Cells as power supply
- Communication technology
- New Materials
- Smart Materials – smart wrap
- Adaptable – temperature, sunlight, place and program

Dimension: Not less than 100 m^2.
Location: Urban settings in different temperature zones.
Program: Multi purpose spaces: Exhibit, Computer Pool etc., to be determined by team.
Technical infrastructure: Pavilion can operate independently and provides its own power supply.

Workshop 1 Delft, Netherlands. Digital Design Techniques

During the seven-day workshop in Delft all students will team up to conceptualize their design projects. They will be introduced to parametric design using the 3D modeling softwares Rhino and Maya. The teams will first create parametric design ideas. Each day a small design task has to be solved. Every second day will be a pin up.

Goal: Initialization of international student teams and start of the Smart Structures competition. The design ideas should address the following bullets:

- The pavilion must be shaped like a symbol / icon
- What is the marketing idea, branding
- Develop a visual language to present the three universities in a pavilion
- Overall concept
- branding [branding, form, concept]
- 3D modeling / form finding / design
- Virtual and physical models

Workshop 2, Kassel, Germany. Structural Design Techniques

Goal: The student teams will learn how to structure complex geometries using new construction methods and calculation software (Finite Element software ANSYS and RSTAB.)

The design ideas should address the following bullets:

- From surfaces to structures:
- Structuring, penalizing, optimization with RStab or ANSYS
- Structuring as Part of Design
- Concepts must be found

During Fall Semester

During the semester the student teams will continue working on their designs in a virtual working environment developing the project in four phases:

Each student team breaks down into sub teams working on special tasks.

1: design (architecture)

2: fundraising (consulting by business school, development officer)

3: computing (consulting by engineering)

4: materials and components (consulting by engineering)

Workshop 3, Knoxville, USA, Fabrication Techniques

At the end of the semester student groups from Kassel and Delft meet at The University of Tennessee, Knoxville to finalize their design projects. The students use the digital fabrication facilities at the University of Tennessee.

6. Cooperating Universities

9 faculty members from 4 departments at 3 different Universities were involved in The International Smart Structures Lab. Faculty members include:

The University of Tennessee Knoxville, USA I College of Architecture and Design
Associate Professor Dipl.-Ing. Edgar Stach, stach@utk.edu
Knoxville students: Thomas Allen, Jarrett Benson, Mary Eisenhauer, Andrew Holcomb, Jamison Hupp, Luke Kim, Geoffrey Overmyer, Augustus Pastore, Craig Reschke

University of Kassel, Germany I Department of Architecture, Chair of Structural Design
Professor Manfred Grohmann, bgrohmann@asl.uni-kassel.de
Dipl.-Ing. Oliver Tessmann, Dr.-Ing. Gregor Zimmermann
Kassel students: Jana Beermann, Katharina Überschär, JohannesKuhnen, David Seeland, Patrick Taylor, Astrid, Nolte, Matteo Soru, Marina Gullo, Andreas Wolfram, Thomas Wortmann

University of Kassel - Kunsthochschule, Germany
Chair of Digitalpool
Dr. Des. Markus Schein

University of Delft, Netherlands I Department of Architecture
Professor Bige Tuncer, e.b.tuncer@tudelft.nl
Professor Andrew Borgart, Paul de Ruiter, Bart van Bueren
TU Delft students: Sanne Plomp, Maarten Moerman, Joost Hillen, Wessel Dragt, Sander Mulders

Acknowledgements

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- The University of Tennessee QEP Award 2006 - Ready for the world initiative
- The College of Architecture and Design, UT Knoxville
- TU Delft, Chair of Informatics
- The University of Kassel

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