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AIA

Developing Open Systems and Methods for Collaborative Modeling

Volker Mueller, Bentley Systems, Incorporated

Developing Open Systems and Methods for Collaborative Modeling

- Learn why this problem is not yet solved.
- Learn why researchers are concerning themselves with it.
- Learn how to analyze data sharing needs.
- Learn how to map data.

open systems and methods

- agenda
  - beginnings
  - motivation
  - goals
  - relevance
  - activities
  - next steps
  - participation

beginnings

CAAD futures

4 > 8 JULY 2011

Liège • BELGIUM

Home	Submissions	Programme	Local information	Registration	Contact
About	Submit a paper	Keynote lectures	Venue	Fees	Address & email
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Committees	Submit a workshop	Programme	Travel	Registration form	

Workshop 5

Open Systems and Methods for Collaborative Built Environment Modeling

Schedule	4 July 2011
Format	Half day PM
Chair	Stouffs Rudi, Chaszar Andre - Delf University of Technology
	Tuncer Bige - ETH Zurich
	Coenders Jeroen - ARUP
	Boeykens Stefan - KU Leuven
Location	Sart Tilman Campus
Room	Building B37 - Institut de mathématiques

motivation

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Workshop 5 — **Open Systems and Methods for Collaborative Built Environment Modeling**

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Objectives

Current building and planning practices face the issue that, despite their increasing ability to support the collaborative deployment of project teams' and other stakeholders' distributed intelligence through concurrent as well as asynchronous processes, at early stages of the building process few tools are available to predict and simulate performance in several key aspects of the project, though the early stages are most crucial in terms of decision making. Available tools that can assess, simulate or predict buildings' performances in various respects are currently only employed rather late in the design and planning process, due to their complexity and specificity, resulting in optimizing a given solution (post-rationalization) based on "educated guesses" rather than enabling the planning parties to make better-informed decisions beforehand. Another bottleneck while employing such tools is their incompatibility with the extremely dynamic nature of these early stages. Here, options would have to be evaluated quickly, but since the different software packages are not communicating in real-time with each other, designers and planners are not able to keep momentum while importing, exporting and converting large amounts of model data back and forth iteratively. Important methods and techniques that partially address these issues include parametric-associative modeling, computational intelligence, building information modeling, and file-to-factory techniques. The problem remains that these various techniques and methods only offer partial solutions towards integrated, performance-oriented design and need further developments and non-prescriptive linkages in order to achieve the flexibility and fluidity which are necessary to support true design exploration, especially in the early stages where divergent rather than convergent thinking is prevalent, and standards and other conventions tend to be overly restrictive.

In this workshop we aim to discuss these issues and possible approaches to overcome them, focusing on building design but considering the larger context within which buildings perform and upon which they have an impact. We aim to relate the need for detailed information modeling and exchange for design validation and documentation with modeling approaches that support the dynamic nature of design at the early stages and are able to leverage the strengths of rules and types as well as supporting "expandable rationality," innovation and emergence. We aim to identify concrete R&D steps that can alleviate some of the issues identified above.

Format

The workshop will bring together both invited and other interested researchers, practitioners and developers to brainstorm and discuss on the issues and objectives presented above, with the goal of identifying concrete R&D steps. Participants are invited to submit a position paper or a brief description of research results that can shed light on these issues or suggest possible (partial) solutions. Some will be selected for short presentations. Papers and presentations will form the bases for discussion.

Expected output

We aim to identify concrete R&D steps that can alleviate some of the issues and help to achieve the objectives presented above. It is also the intention to publish the workshop results in a joint publication, possibly a special journal issue.

Objectives

Current building and planning practices face the issue that, despite their increasing ability to support the collaborative deployment of project teams' and other stakeholders' distributed intelligence through concurrent as well as asynchronous processes, at early stages of the building process few tools are available to predict and simulate performance in several key aspects of the project, though the early stages are most crucial in terms of decision making. Available tools that can assess, simulate or predict buildings' performances in various respects are currently only employed rather late in the design and planning process, due to their complexity and specificity, resulting in optimizing a given solution (post-rationalization) based on "educated guesses" rather than enabling the planning parties to make better-informed decisions beforehand. Another bottleneck while employing such tools is their incompatibility with the extremely dynamic nature of these early stages. Here, options would have to be evaluated quickly, but since the different software packages are not communicating in real-time with each other, designers and planners are not able to keep momentum while importing, exporting and converting large amounts of model data back and forth iteratively. Important methods and techniques that partially address these issues include parametric-associative modeling, computational intelligence, building information modeling, and file-to-factory techniques. The problem remains that these various techniques and methods only offer partial solutions towards integrated, performance-oriented design and need further developments and

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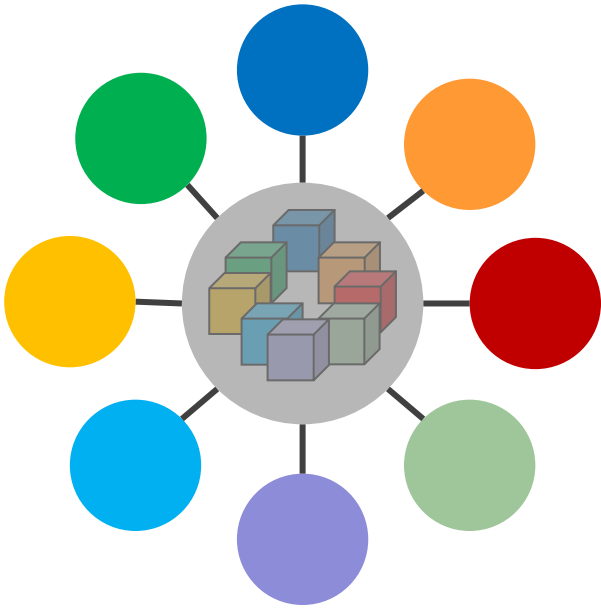
AIA

motivation

- the reality of AEC/O processes
  - collaborative
  - dynamic
  - asynchronous
  - content-rich
  - non-linear
  - multi-disciplinary
  - cross-disciplinary
  - trans-disciplinary



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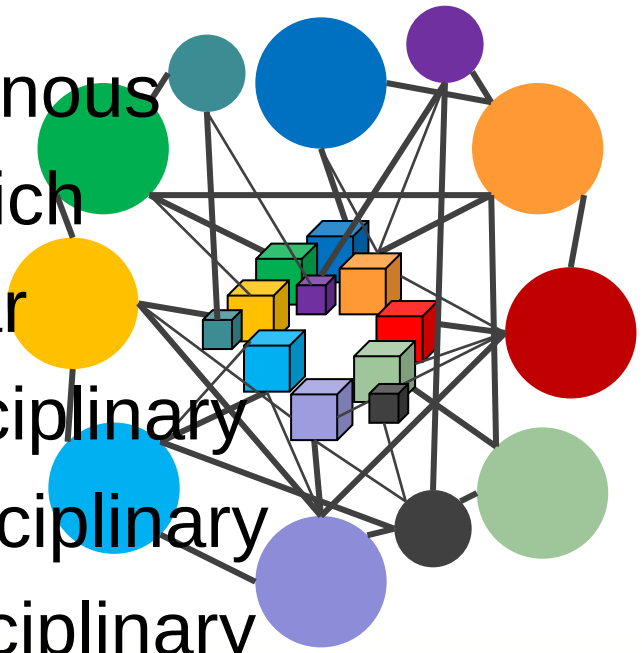
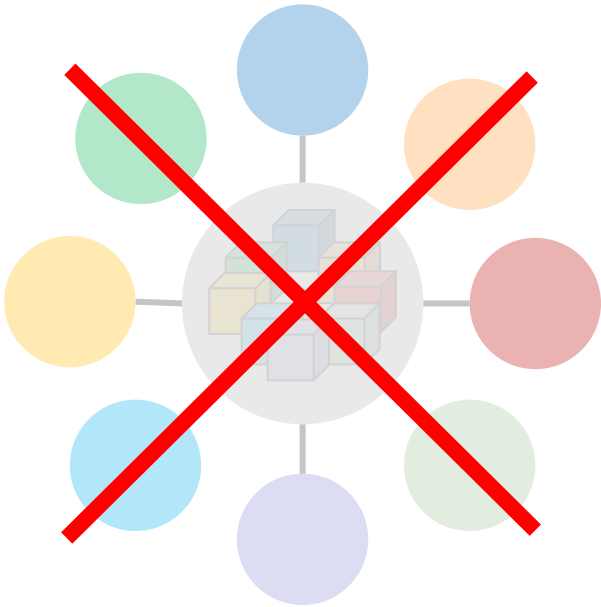
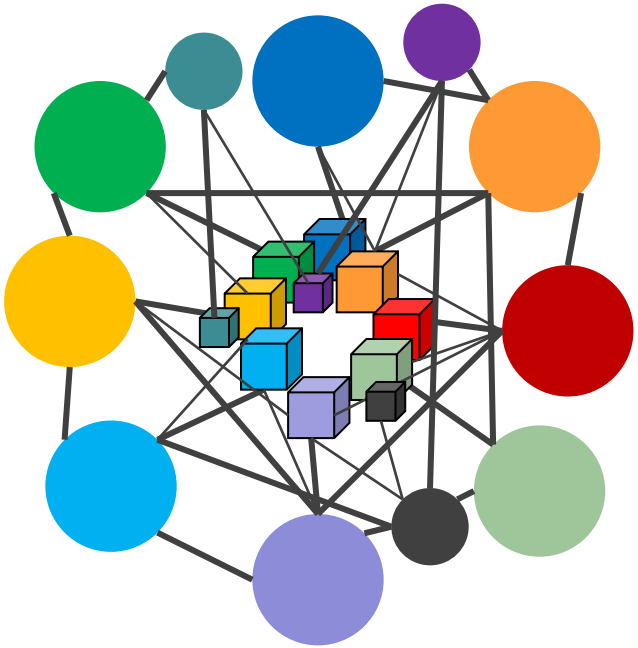
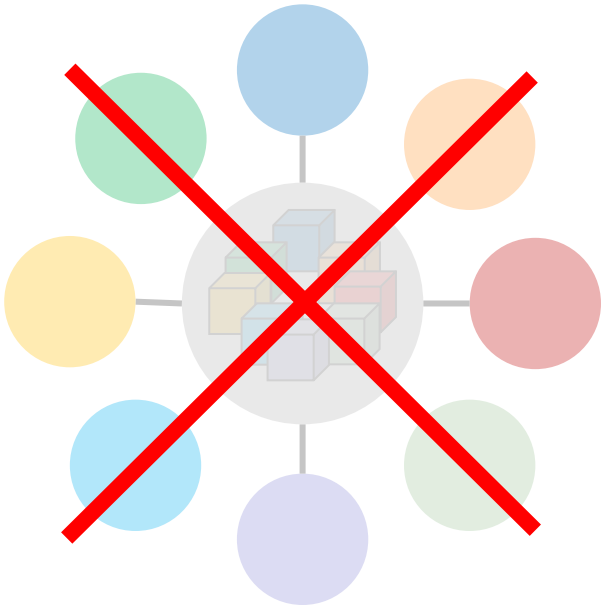




motivation

- the reality of AEC/O processes
  - one word:





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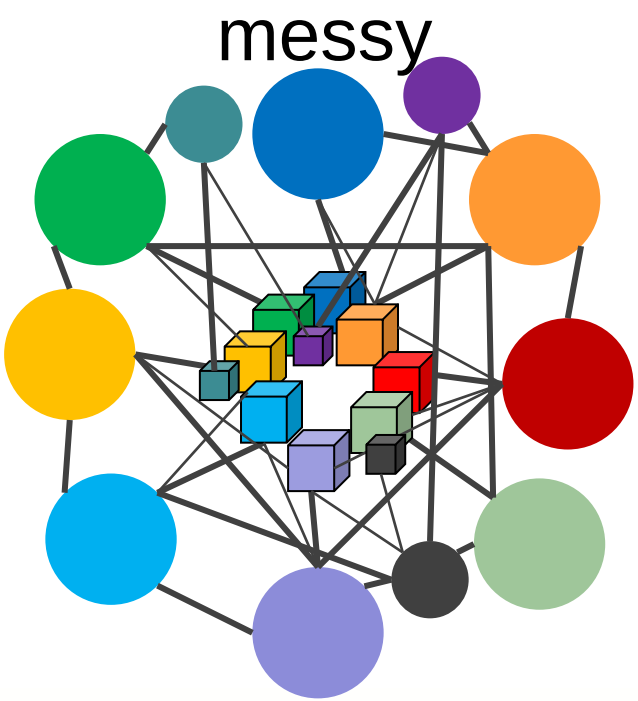
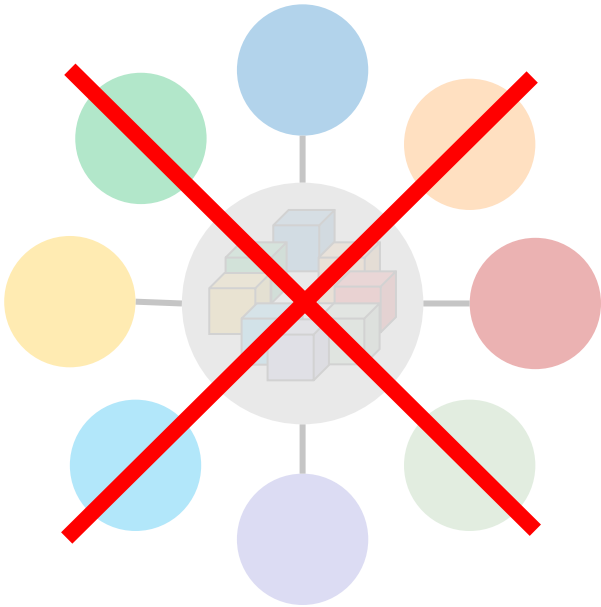




motivation

- desire of intelligent design
  - performance feedback
  - constructability feedback
  - *any* other parameter feedback

motivation

- requirement of freedom & flexibility
  - design data
  - design tools
  - analysis tools
  - *any* other data & tools in project lifecycle

goals

- requirement of freedom & flexibility

  – one word:

  open systems and methods

goals

- requirement of freedom & flexibility

  – ~~one word~~ four words:

  open systems and methods

goals

- requirement of freedom & flexibility
- desire of designing intelligently
  - ~~one word four~~ eight words:

    open systems and methods
    for built environment modeling (BEM)

learning goal #1

why the problem is not solved, yet:

- messy problem

AND

- goal of open and flexible solution

learning goal #2

why researchers are interested in this:

- messy problem

AND

- goal of open and flexible solution

AND

- desire of designing intelligently

relevance

- quality of design
- quality of design to construction process
- quality of construction
- quality of operation

relevance

- ability to react to project specifics
  - required disciplines >>> data
  - required methods >>> tools
    - design
    - analysis
    - representation
- other self-evident reasons
    - meet and discuss after the session
    - (or wait for participation information)

learning goal #3

how to analyze data exchange needs:

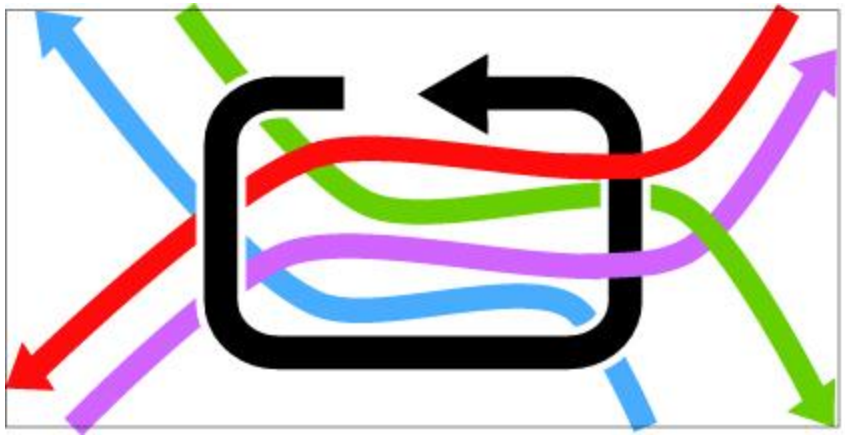
- respond to specific project conditions
  - project goals
  - project partners
    - disciplines >>> data
    - methods >>> tools

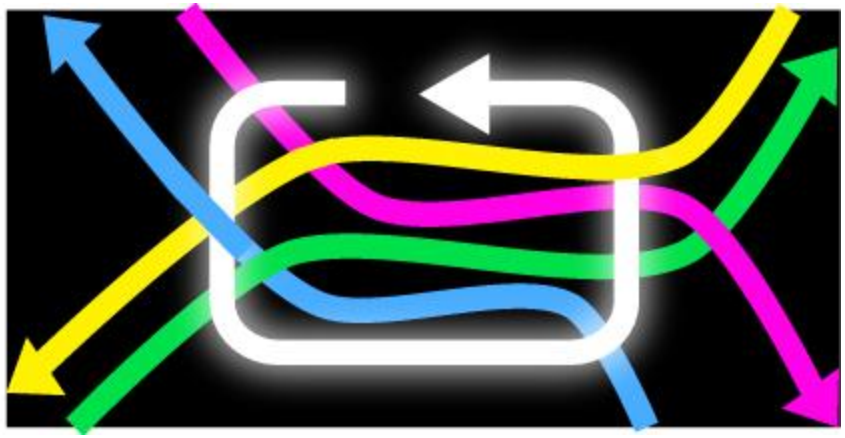
activities

- workshop at CAAD Futures 2011
  on July 4th, 2011

activities

- workshop at CAAD Futures 2011
  on July 4th, 2011
- ongoing discussion on LinkedIn group
  Open Systems & Methods for Collaborative BEM





activities

- discussion topics
  - System implementation
  - MDO[1)] via Open Systems & Methods
  - MDO Interface Issues for Open Systems & Meth
  - Customized Digital Workflows (CDW)
  - Tool nodes
  - Mapping nodes
  - GUI nodes
  - etc.

1) MDO: multi-disciplinary optimization

next steps

- broaden the participation
- continue discussions
  - on LinkedIn
  - in workshops at various conferences
- work towards initial requirements
  - general system architecture
  - specific system components
- start prototype implementations

participation

- workshop chairs (5)
  - Rudi Stouffs, TU Delft
  - Andre Chaszar, TU Delft
  - Tuncer Bige, ETH Zurich
  - Jeroen Coenders, Arup
  - Stefan Boeykens, KU Leuven

publicly accessible information about workshop at:
www.lucid.ulg.ac.be/conferences/caadfutures2011/Workshop5.html

participation

- workshop participants (11)
  - at workshop mostly from academia
  - international
    - Europe (7 participants, 4 countries)
    - Asia (3 participants, 2 countries)
    - Americas (1 participant, 1 country)

participation

- LinkedIn group:
  - Open Systems & Methods for Collaborative BEM
  - 24 Members (10-17-2011)
    - 15 Academic Researchers
    - 7 AEC Professionals
    - 2 Industry Researchers
    - 9 countries
    - 4 continents

learning goal #4

how to map data:

learning goal #4

~~how to map data:~~
(impossible in remaining time)

learning goal #4

~~how to map data:~~
(impossible in remaining time)

how to participate:

learning goal #4

~~how to map data:~~
(impossible in remaining time)

how to participate:

- LinkedIn group:
  - Open Systems & Methods for Collaborative BEM

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Division of Capital Asset Management
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SKANSKA

DESIGN MODEL VS. CONSTRUCTION MODEL

- Zahra Assar
- Luciana Burdi
- Laura Herbert
- Ethel Macleod
- Erik Sanford

- Identify the differences between a design phase and construction phase BIM.

- Explain methods for managing BIM expectations throughout the project.

- Understand the process of BIM development from design through construction.

- Identify the potential impact of differences between the design and construction models.

SPRINGFIELD DATA CENTER PROJECT

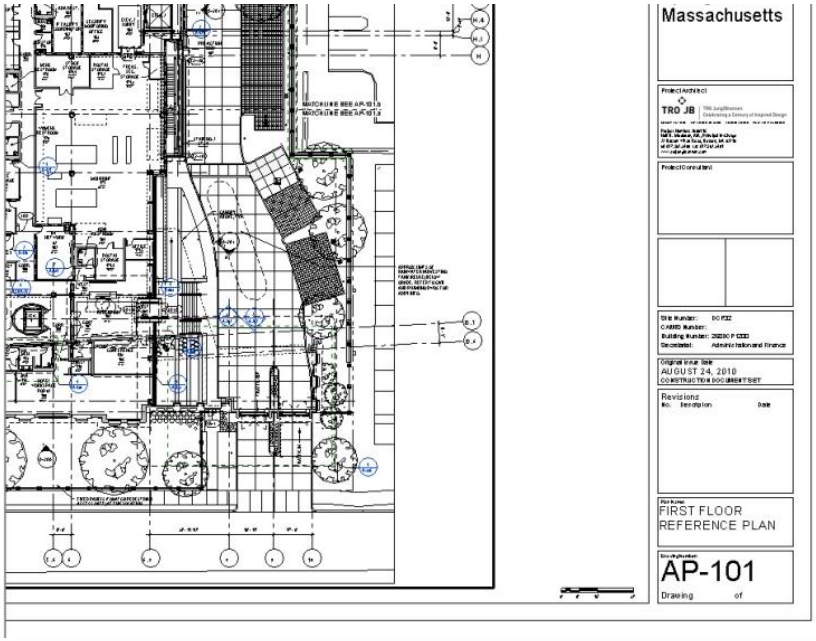
- Tier III N+1 Data Center
  - Active backup facility
  - Redundant systems
  - Secure facility
- 145,000 sqft
- $110 M Project Cost

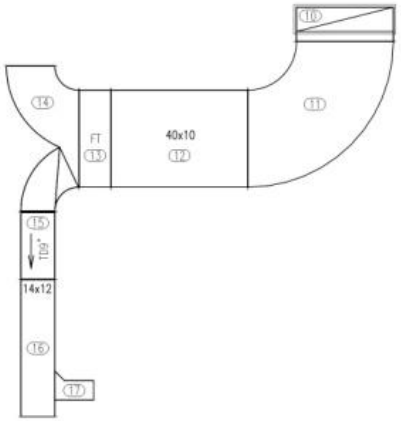
SPRINGFIELD DATA CENTER PROJECT

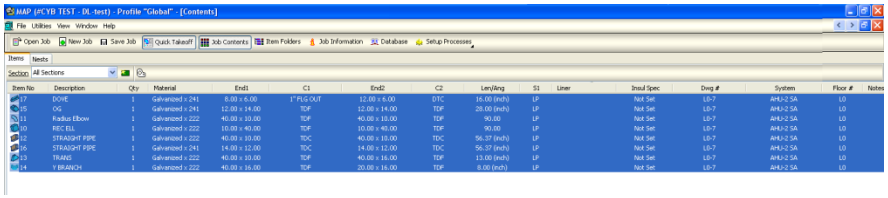
- Groundbreaking on July 22, 2010
- Anticipated Completion in December 2012
- LEED Gold Anticipated

INHERENT DIFFERENCES - USES

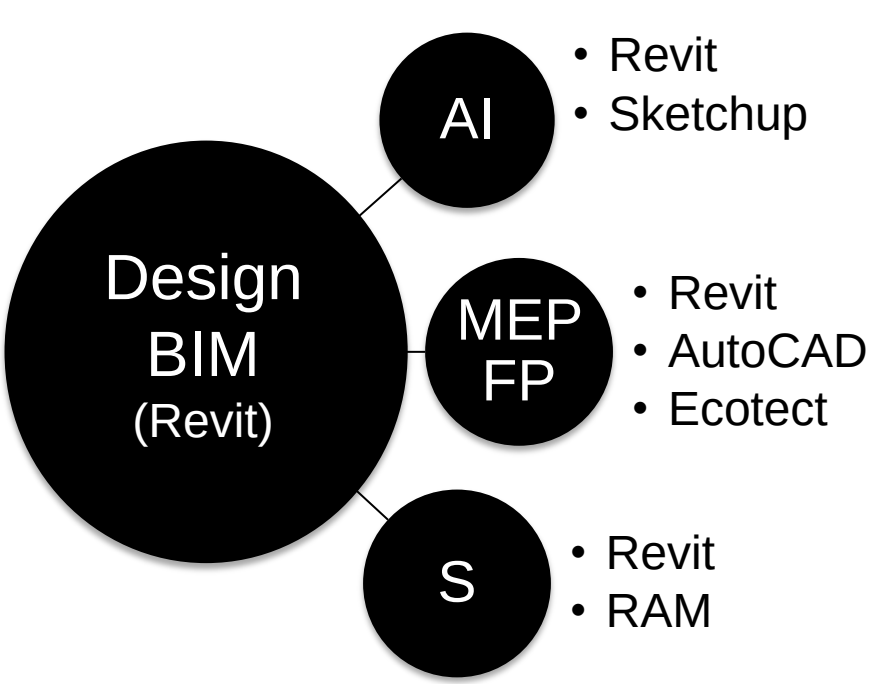
- Design
  - Documentation
  - Visualization
  - Analysis
- Construction
  - Fabrication /Shop Drawings
  - Coordination
  - Scheduling

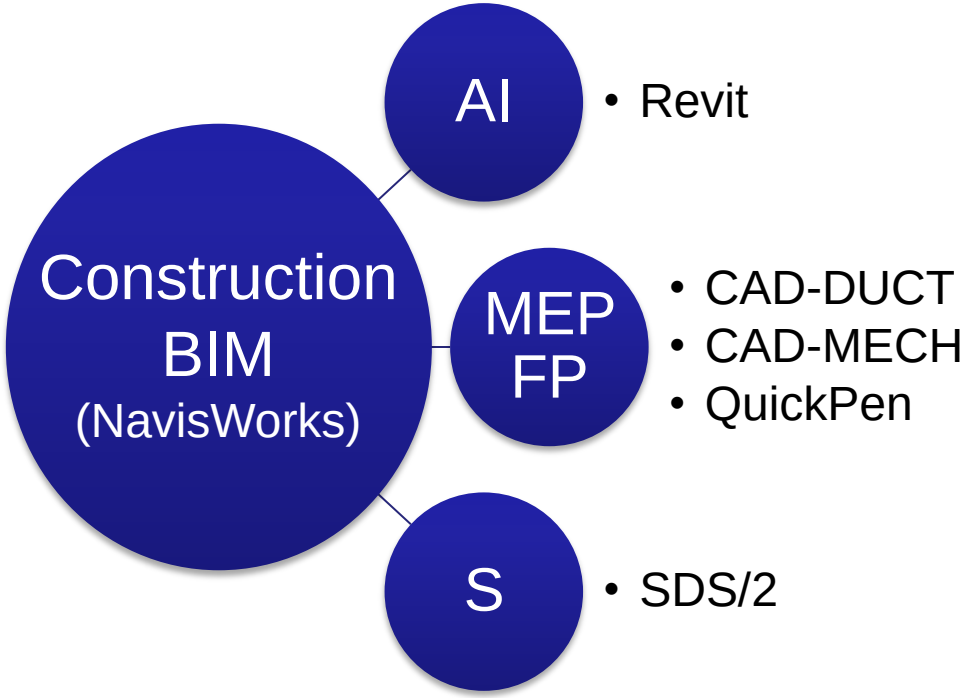






INHERENT DIFFERENCES – SOFTWARE USED





MANAGING EXPECTATIONS

- BIM Execution Plan
  - Identify BIM Goals and Uses

Priority (1-3)	Goal Description	Potential BIM Uses
1- Most Important	Value added objectives	
1	Address field conflicts	Spacial Coordination - 3D Construction Coordination
3	FYI - Asses the value of using the BIM model for cost estimating	Quantities Take-offs
2	Address logistic conflicts	To some degree - 4D modeling
2	Look-ahead schedule for coordination with subcontractors	4D modeling - when needed
3	Track progress during construction	4D modeling - if needed
1	Identify concerns with construction sequences	4D modeling
1	Facilitate the Commissioning Phase	Model and Tag Major Equipment
2	Facilitate the construction phase coordination/shop drawing review	Live Coordination Meetings (With Model)
1	3D Record Model for coordination with sub-contrators	Record Model (Navisworks)
1	3D model to be used for Phase 2	Record Model (Revit)
2	Provide or explore the option to produce an FM model	FM Model (?)
2	3D Record of the site utilities	Site utilities Model (major civil)
1	Pre-fabrication/On time deliveries	Subcontractors 3D Model
2	Details on the existing building and its relation with the new addition	Existing Conditions Building Model
1	Helping users to understand the project, thus accelate decision making	Develop Graphics for design presentations
2	Improve safety on site	Safety Plan in BIM
1	Address conflicts in design	Spacial Coordination - 3D Design Coordination
1	Evaluate the lighting in the office space of the new addition	Lighting BIM analysis

MANAGING EXPECTATIONS

- Model Element Worksheet
  - Assign Model Author
  - Establish LOD per phase
  - Describe workflow

PHASE		SCHEMATIC DESIGN			DESIGN DEVELOPMENT			CONTRACT DOCUMENTS			CONSTRUCTION		
File Format													
Application & Version													
MODEL ELEMENT BREAKDOWN (CSI Uniformat)		LOD	Party	Notes	LOD	Party	Notes	LOD	Party	Notes	LOD	Party	Notes
	Roof Construction	1	A/S	Modeled placeholder by both	2	A/S	Duplicated, EOS by A, construction by S, A to manage levels, S to add TOS level in their model and monitor difference. A+S to monitor slabs.	3	A/S	Duplicated, EOS by A, construction by S, A to manage levels, S to add TOS level in their model and monitor difference. A+S to monitor slabs.	3	CM	CM - Changes made after consolidation set
	Canopy Construction	0	S		1	S	Greater attention to detail in this are as design develops	3	S		3	SUB	Steel Fabricator
	Dunnage and Grating	0	S		1	S	Modeled generically?	3	S		3	SUB	Steel Fabricator
	Misc. Metals											SUB/CM	Misc Metals Sub to extent of contract
	Gusset Plates	0	S		1	S	Placeholder form for clash detection, details	1	S	Placeholder form for clash detection, details	3	SUB	Steel Fabricator
	Bracing	1	S		2	S		3	S		3	SUB	Steel Fabricator
	House keeping pads	1	E		2	E	S references A/E for generic locations and provides 2D detail			S references A/E for generic locations and provides 2D detail	3	SUB	Individual subs to model their required pads
B20 Exterior Enclosure													
	Exterior Walls	1	A		2	A		3	A		3	CM	CM - Changes made after consolidation set
	Exterior Windows/Curtain wall	1	A		2	A		3	A		3	CM	CM - Changes made after consolidation set
	Exterior Doors	1	A		2	A		3	A		3	CM	CM - Changes made after consolidation set
	Veneer on Foundation Walls	1	A	Modeled as entire wall, duplicated w/struct	2	A	Modeled as wall on structural foundation	2	A	Modeled as wall on architectural placeholder foundation wall	2	CM	CM - Changes made after consolidation set
	Veneer on Existing Walls	1	A		2	A		3	A	Modeled as separate wall	3	CM	CM - Changes made after consolidation set
	Exterior Louver system	1	A	Built as Curtain wall	2	A		3	A	Built as solid wall	3	CM/SUB	CM - Changes made after consolidation set, SUB - Operating Louvers

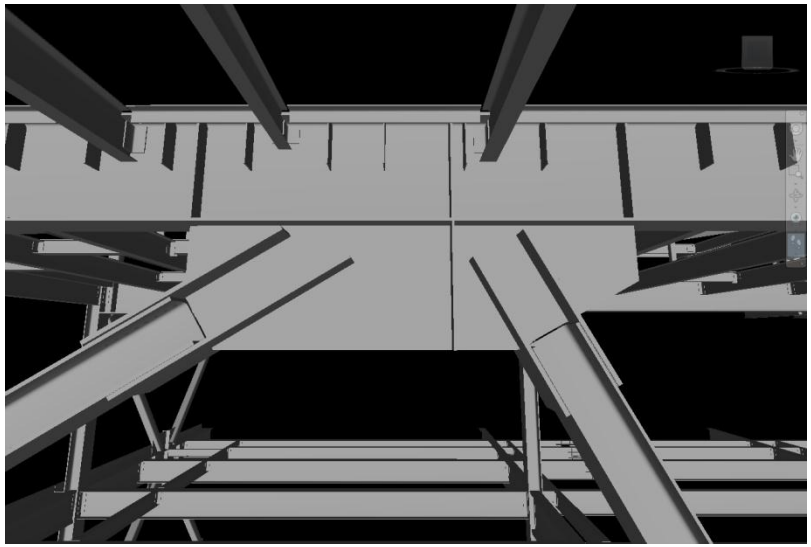
BIM LEVEL OF DEVELOPMENT

LOD ↑ = MODEL USES ↑

- Refer to AIA E202 for Guide
- Use Model Element Worksheet to Determine Uses
- LOD is NOT consistent across model
  - Walls = LOD 300
  - Wall Base = LOD 0 (not modeled)
- **Warning: Elements may appear more accurate than designed**

BIM DEVELOPMENT

Steel Framing – Design Model

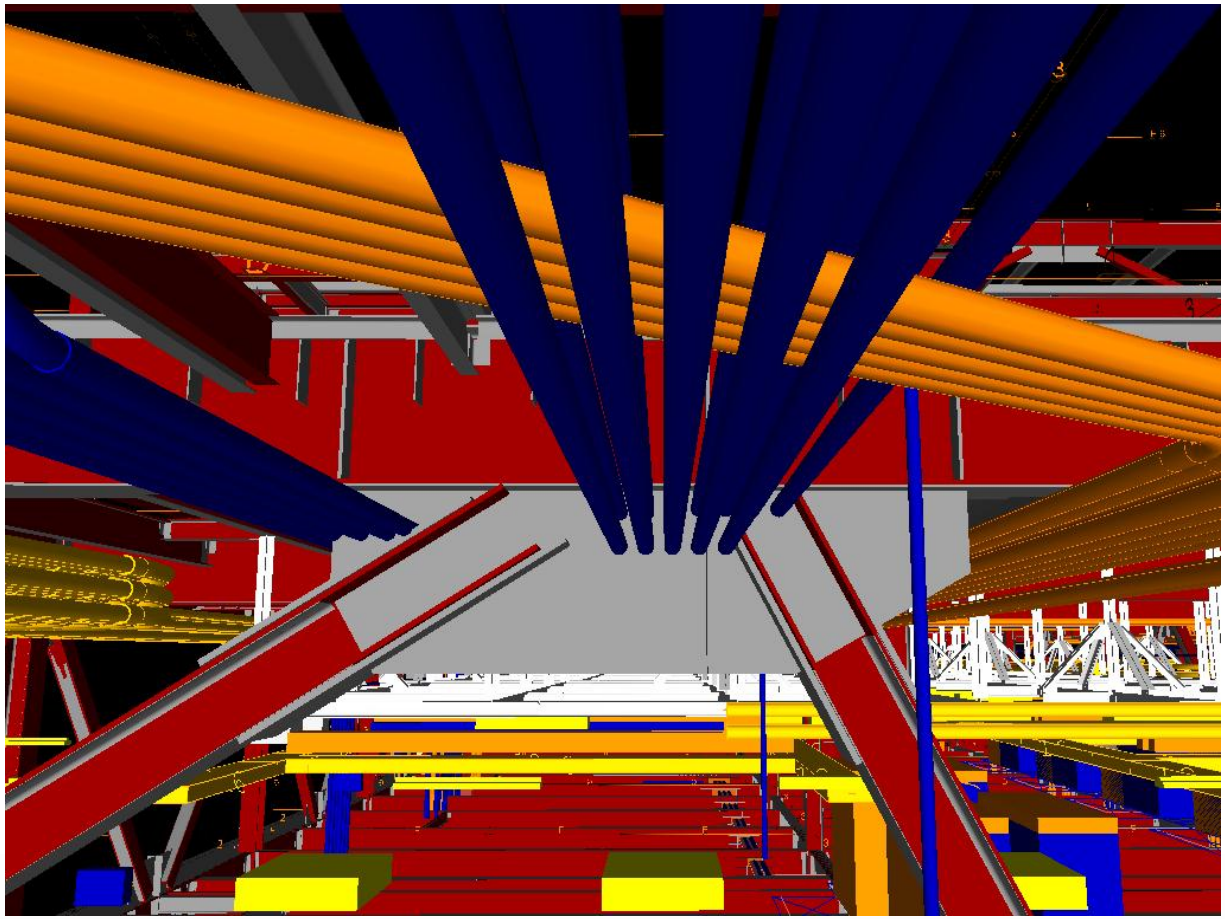


Steel Framing – Fabrication Model

- Higher LOD in Construction Model
  - Fabrication models from subcontractors
- Current software and practice limitations prevent higher LOD in design model

POTENTIAL IMPACT

- Model Exclusions
  - Design model LOD limitations excludes content
  - Some components are 2D (details) only

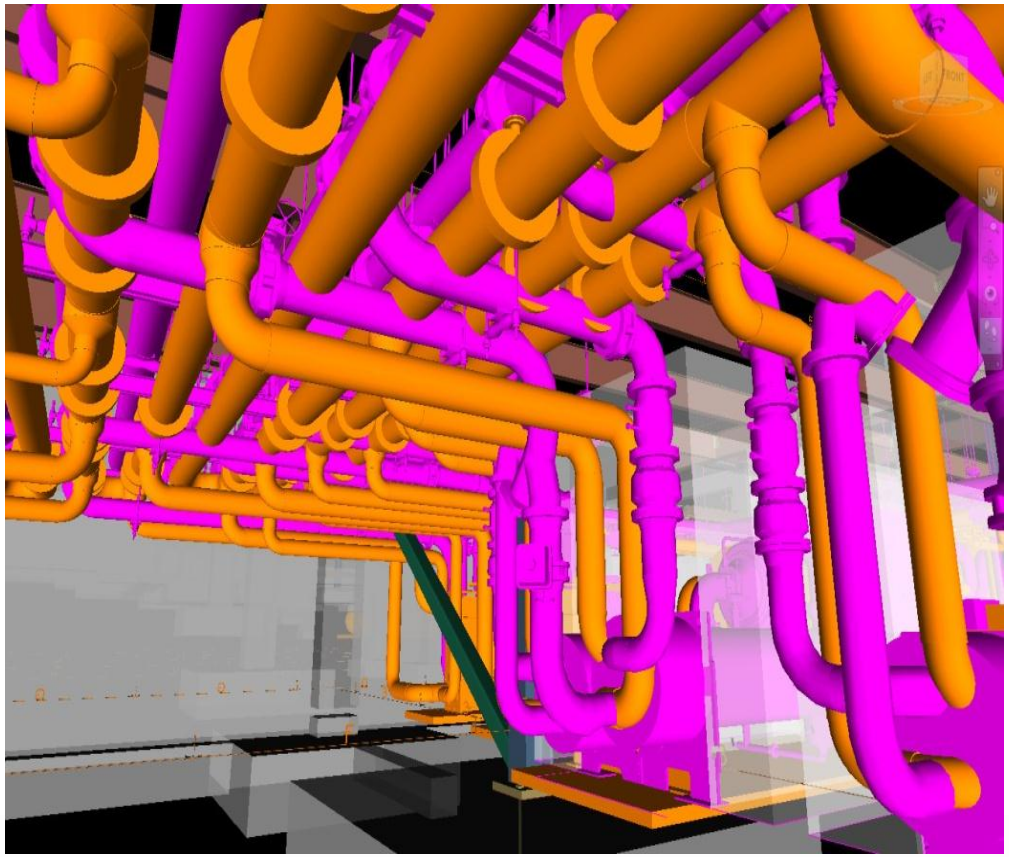


Color Key:

- Design Framing
- Construction Framing
- Design Conduit
- Construction Conduit

POTENTIAL IMPACT

- Modeling Differences
  - Design software is not accurate for fabrication



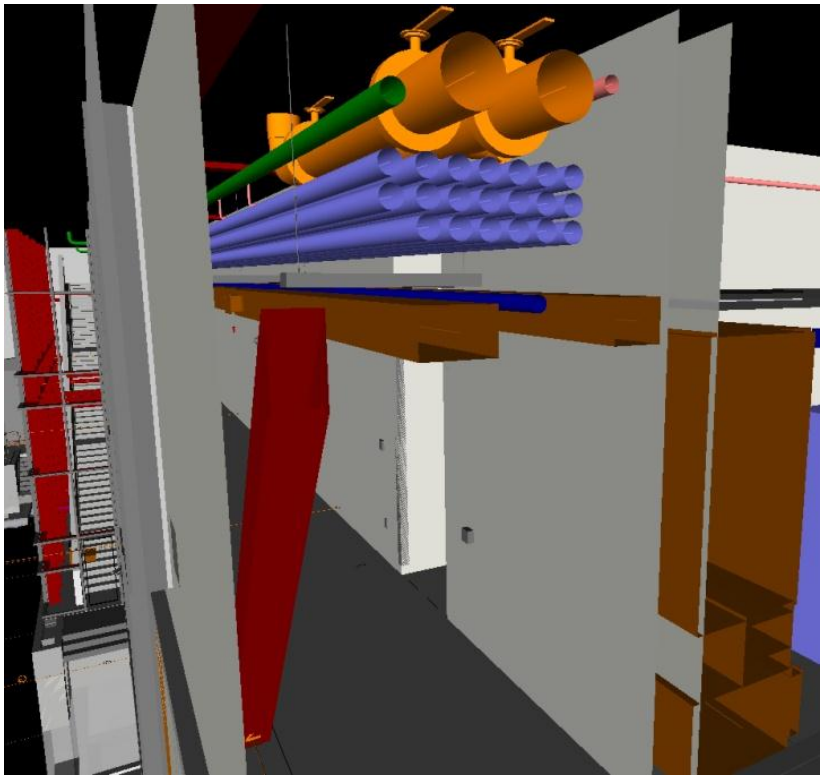
Color Key:

Design Piping

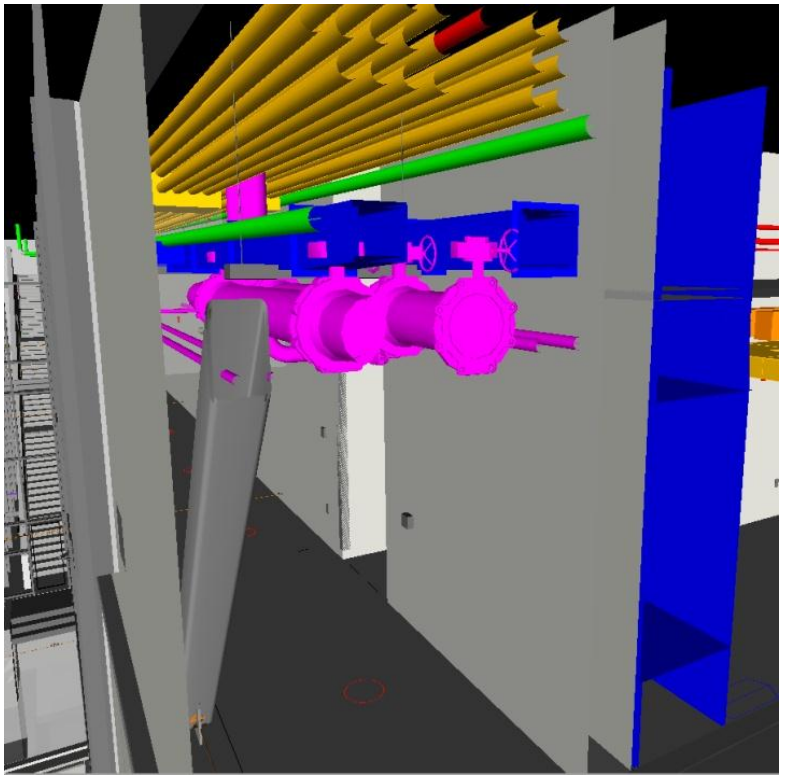
Construction Piping

POTENTIAL IMPACT

- Constructability modifications
- Accessibility modifications



Design MEP/FP



Construction MEP/FP

LESSONS LEARNED

- Early involvement of the construction team
  - Improved understanding of design model content and limitations
  - Design assist possibilities
  - Right people / Right time modeling processes

- BIM Execution Plan use
  - Owner and contractor involvement needed
  - Tool for open communication
  - Defines Objectives
  - Manages Expectations

Division of Capital Asset Management

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SKANSKA

DESIGN MODEL VS. CONSTRUCTION MODEL

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- Ethel_Macleod@gensler.com
- Erik.Sanford@skanska.com


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makes a difference™
AIA

“Cost-effective strategy to panelize a double curved surface”

LORENZO MARASSO
Designer – Gensler Los Angeles

Ordine degli Architetti di Torino - Turin, Italy
MArch – Yale University – New Haven – CT – USA
BArch – Politecnico di Torino – Italy

Prior experience:
Greg Lynn FORM - Venice, California
Office for Metropolitan Architecture – Rotterdam, The Netherlands;
Asymptote Architecture - New York;
Eisenman Architects - New York;

GENSLER LOS ANGELES – Sport Studio

Cost-effective strategy to panelize a double curved surface

Lorenzo Marasso – Gensler Los Angeles

GENSLER LOS ANGELES – Sport Studio

FARMERS FIELD NFL STADIUM
DOWNTOWN LOS ANGELES

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SHENBEI PERFORMING ARTS CENTER
DISTRICT OF SHENYANG - CHINA

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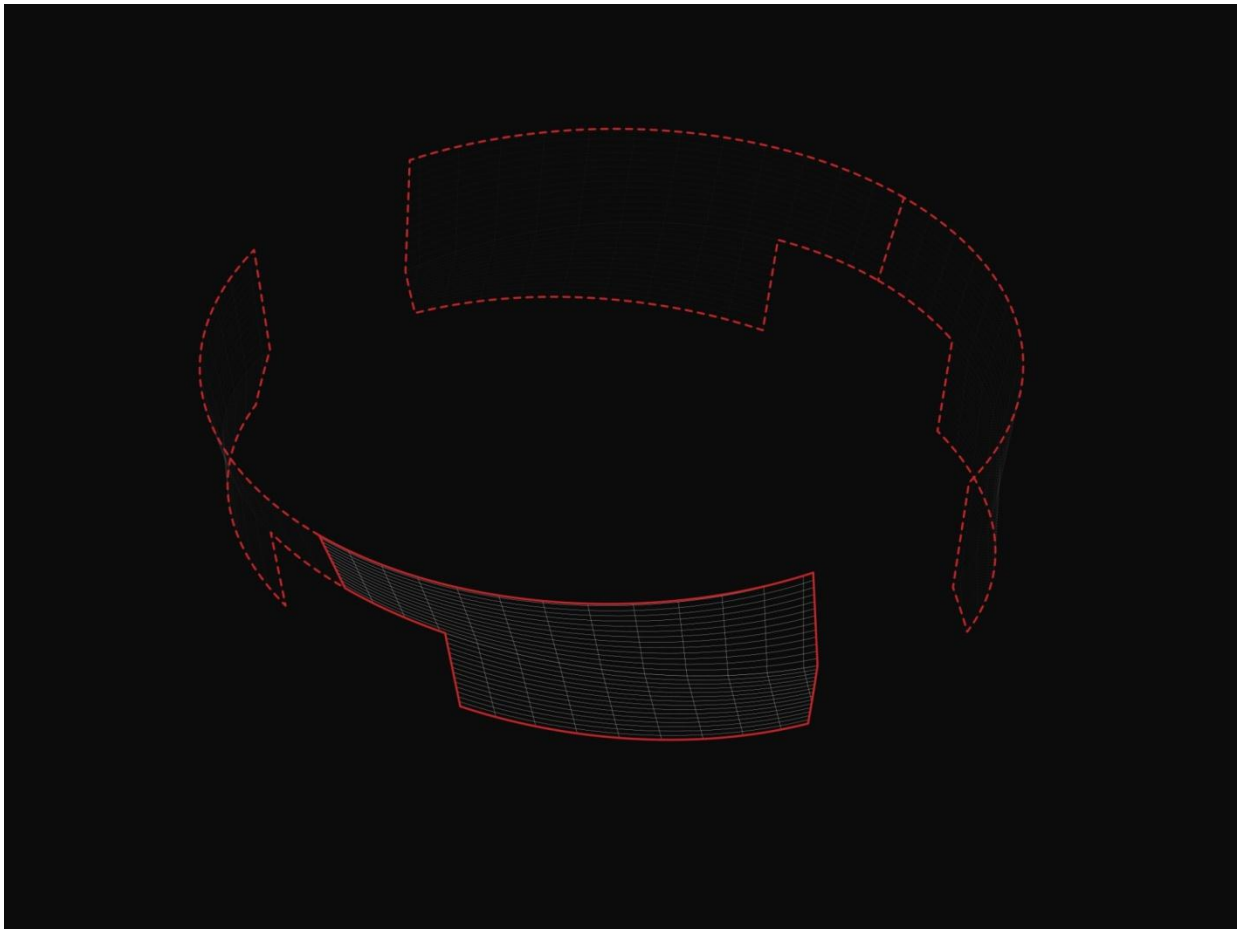

SHENBEI PERFORMING ARTS CENTER
DISTRICT OF SHENYANG - CHINA

Cost-effective strategy to panelize a double curved surface
Lorenzo Marasso – Gensler Los Angeles

TODAY'S LEARNING OBJECTIVES

Learning Objective #1:

To design and implement a cost-effective paneling solution using generative and computational tools.

TODAY'S LEARNING OBJECTIVES

Learning Objective #1:

To design and implement a cost-effective paneling solution using generative and computational tools.

Learning Objective #2:

How computational software can make your life easier in understanding these geometrical properties of your design and allow you to find an effective solution for them.

TODAY'S LEARNING OBJECTIVES

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To design and implement a cost-effective paneling solution using generative and computational tools.

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How computational software can make your life easier in understanding these geometrical properties of your design and allow you to find an effective solution for them.

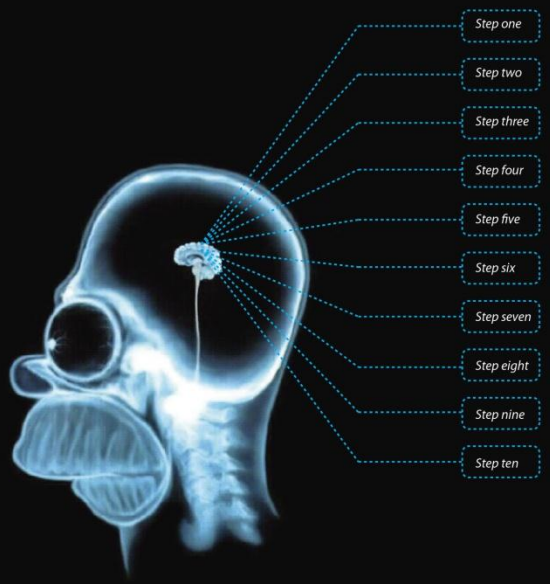
Learning Objective #3:

Computational Tools don't solve problems "per se" but offers almost endless possibilities so it's up to the user to customize the tool in order to get the desired result.

LOGIC vs EXECUTION

LOGIC

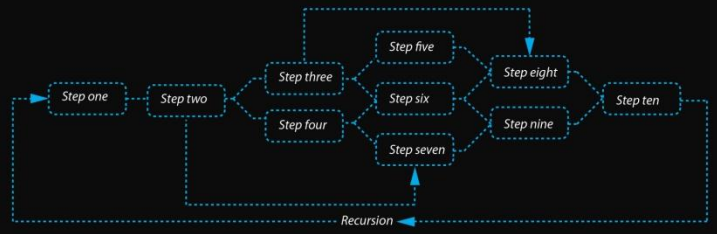
- - *Specific methods are introduced in order to obtain a hyper-controlled surface / panelization system. This allows for a value-engineered skin system that uses only one size of panel*



VS

EXECUTION

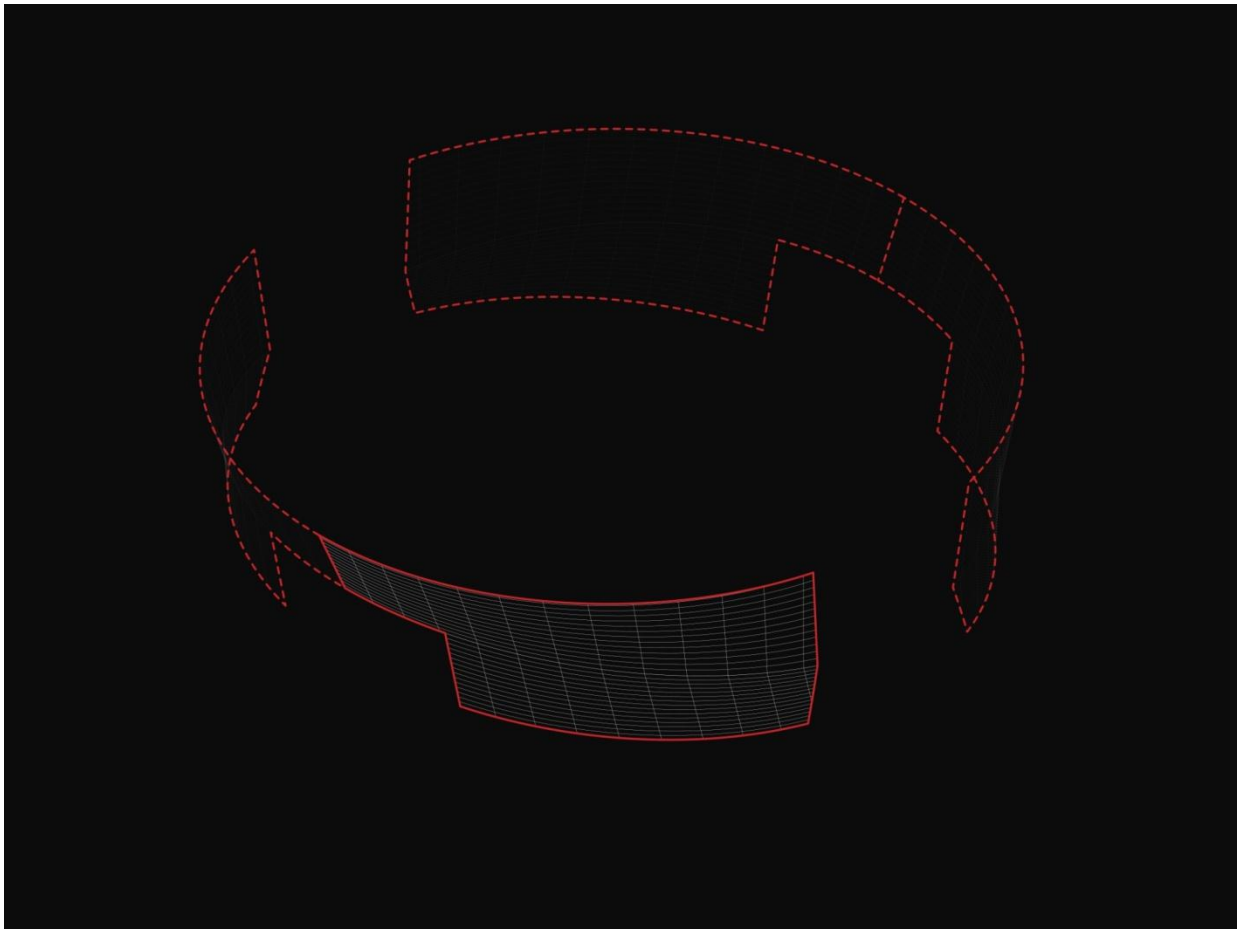
- - *The logic is then recorded into a recursive loop function that has the ability to generate the panels en-mass, as well as keep them oriented to the specifications.*



Cost-effective strategy to panelize a double curved surface

Lorenzo Marasso – Gensler Los Angeles

THE PROJECT'S SURFACES ARE DOUBLE CURVED

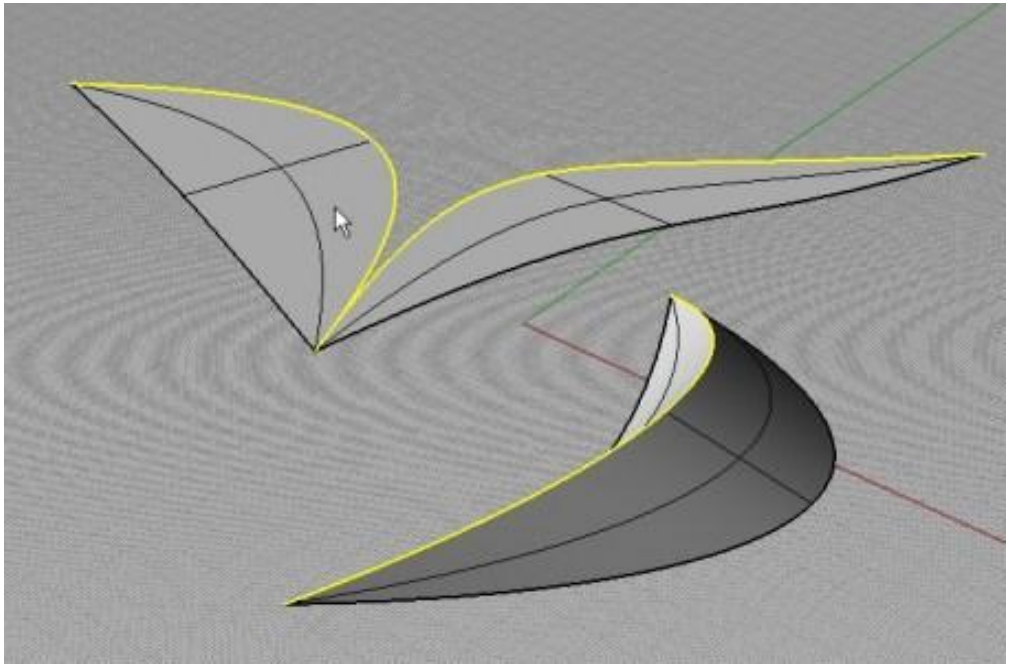


SHENBEI PERFORMING ARTS CENTER
DISTRICT OF SHENYANG - CHINA

Cost-effective strategy to panelize a double curved surface
Lorenzo Marasso – Gensler Los Angeles

UNDERSTANDING CURVATURE – SINGLE CURVATURE

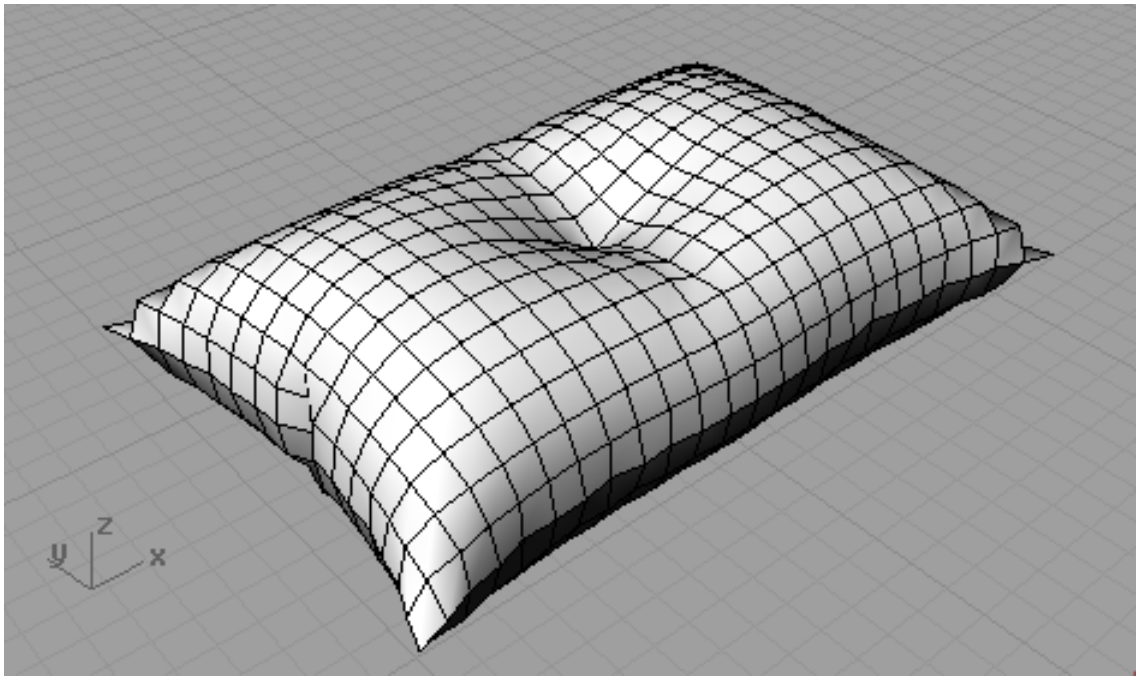
1. The main problem is **geometrical**. *Single Curved Surfaces* can be flattened without stretching them and subdivide them in the 2D space and then transfer those information without data loss back to the 3D space.



Example of "unrolling" a surface

UNDERSTANDING CURVATURE – DOUBLE CURVATURE

2. The second main problem is that a *double curved-surface* can be subdivided into unique components but they will all result in different sizes which requires a high deal of customization and high costs.



Example of "double-curved" components

UNDERSTANDING CURVATURE – DOUBLE CURVATURE

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Zaha Hadid
Train Station
Innsbruck,
Austria

UNDERSTANDING CURVATURE – DOUBLE CURVATURE

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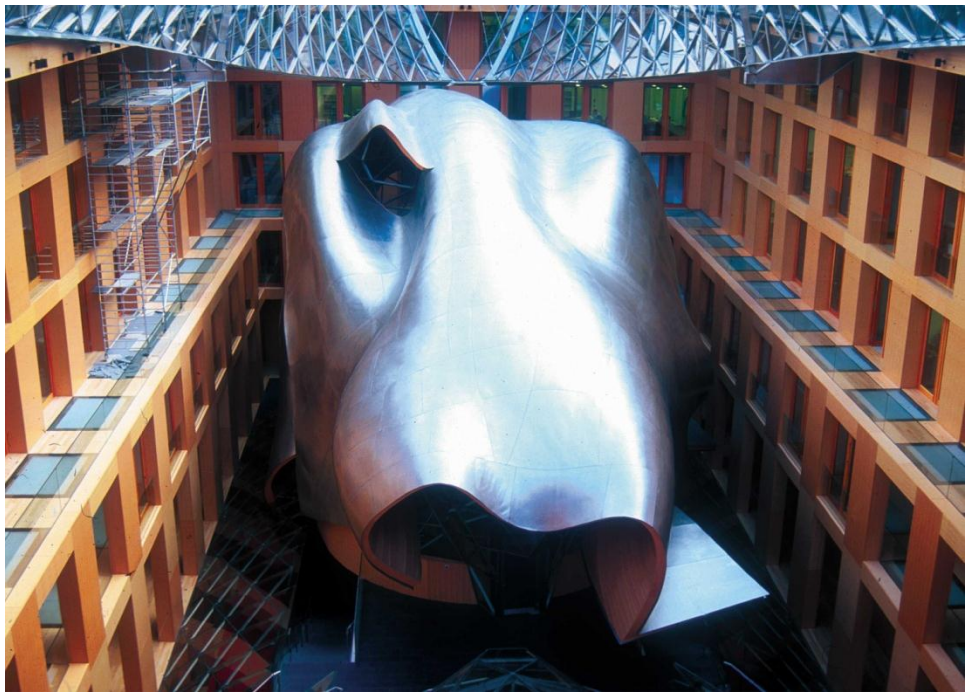


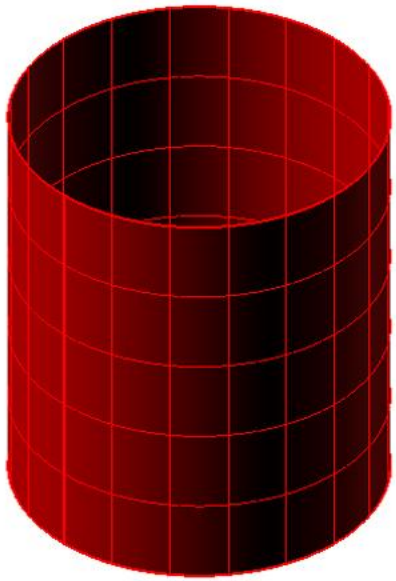
Gehry Partners
Deutsche Bank
Berlin,
Germany

SOLUTION: DESIGNING SINGLE CURVED SURFACES

3. Ideally we should be designing surfaces that can be "developed" or "unrolled" as they will conform to panels of the same size without stretching or tearing of the material.

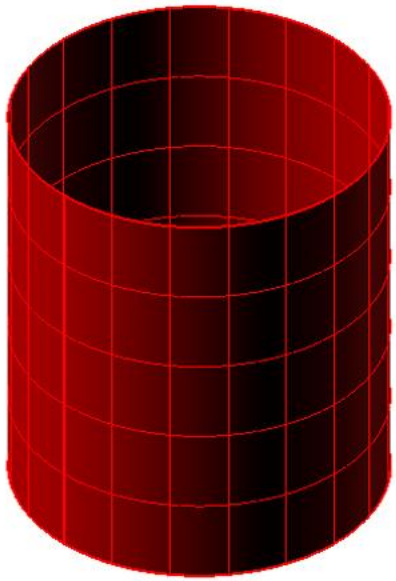
Gehry Partners
Disney Hall
Downtown
Los Angeles

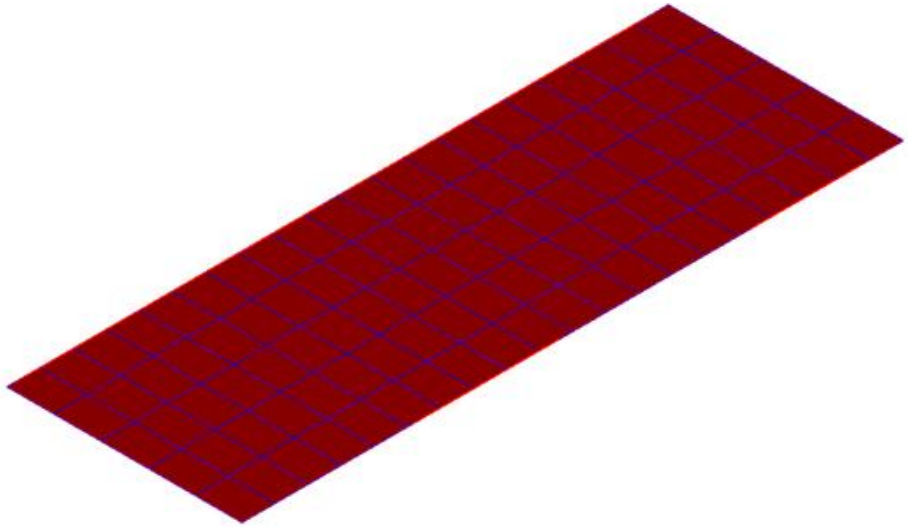
TRANSLATION FROM SURFACE TO COMPONENT



RULED and DEVELOPABLE SURFACE:
CYLINDER

TRANSLATION FROM SURFACE TO COMPONENT

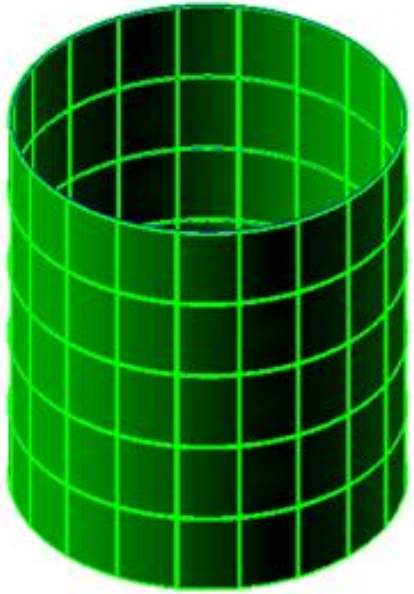




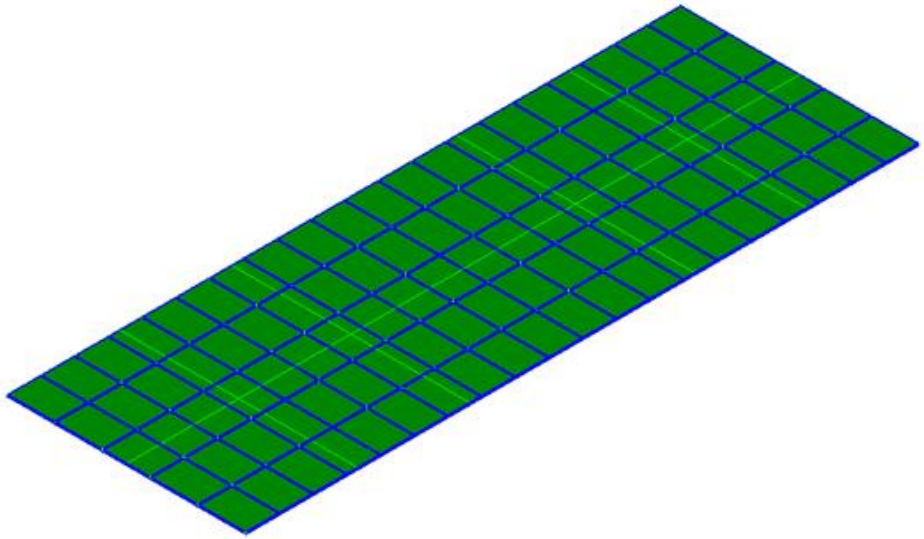
RULED and DEVELOPABLE SURFACE: CYLINDER

A cylinder can be unrolled and subdivded and all subdivisions result of the same size.

TRANSLATION FROM SURFACE TO COMPONENT

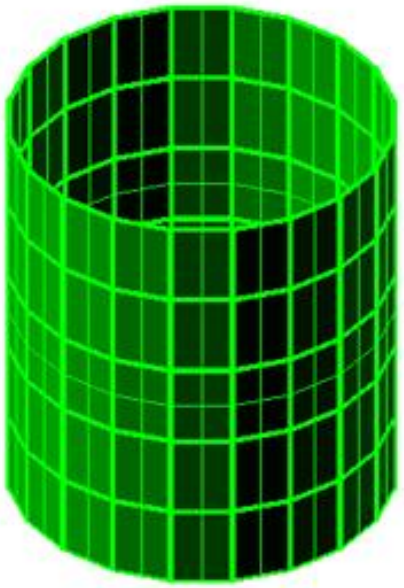


RULED and DEVELOPABLE SURFACE: CYLINDER

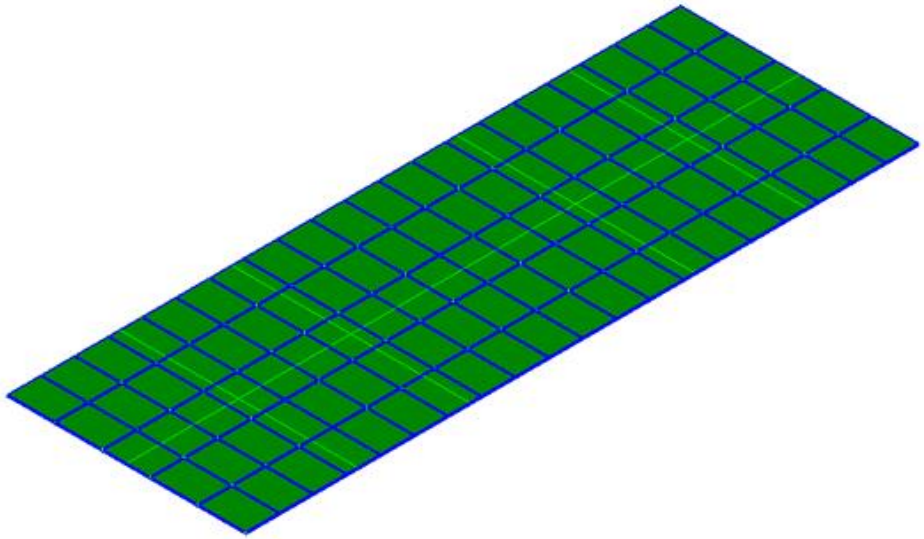


Panels can be rolled in one direction

TRANSLATION FROM SURFACE TO COMPONENT

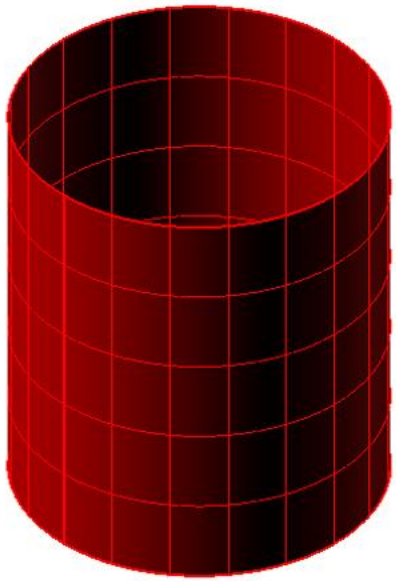


RULED and DEVELOPABLE SURFACE: CYLINDER



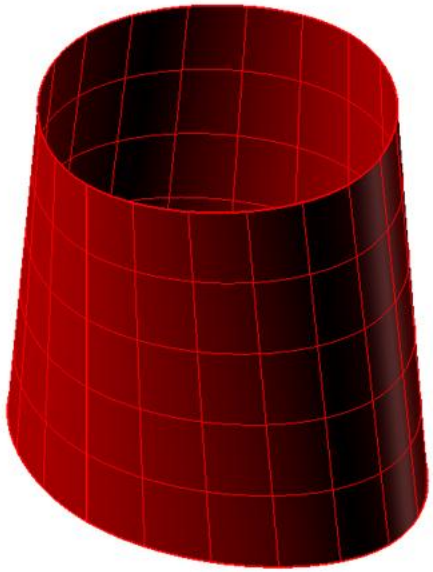
Panels can remain flat giving a “segmented” look to the surface

TRANSLATION FROM SURFACE TO COMPONENT



DEVELOPABLE SURFACE (also known as "single-curved surface") :

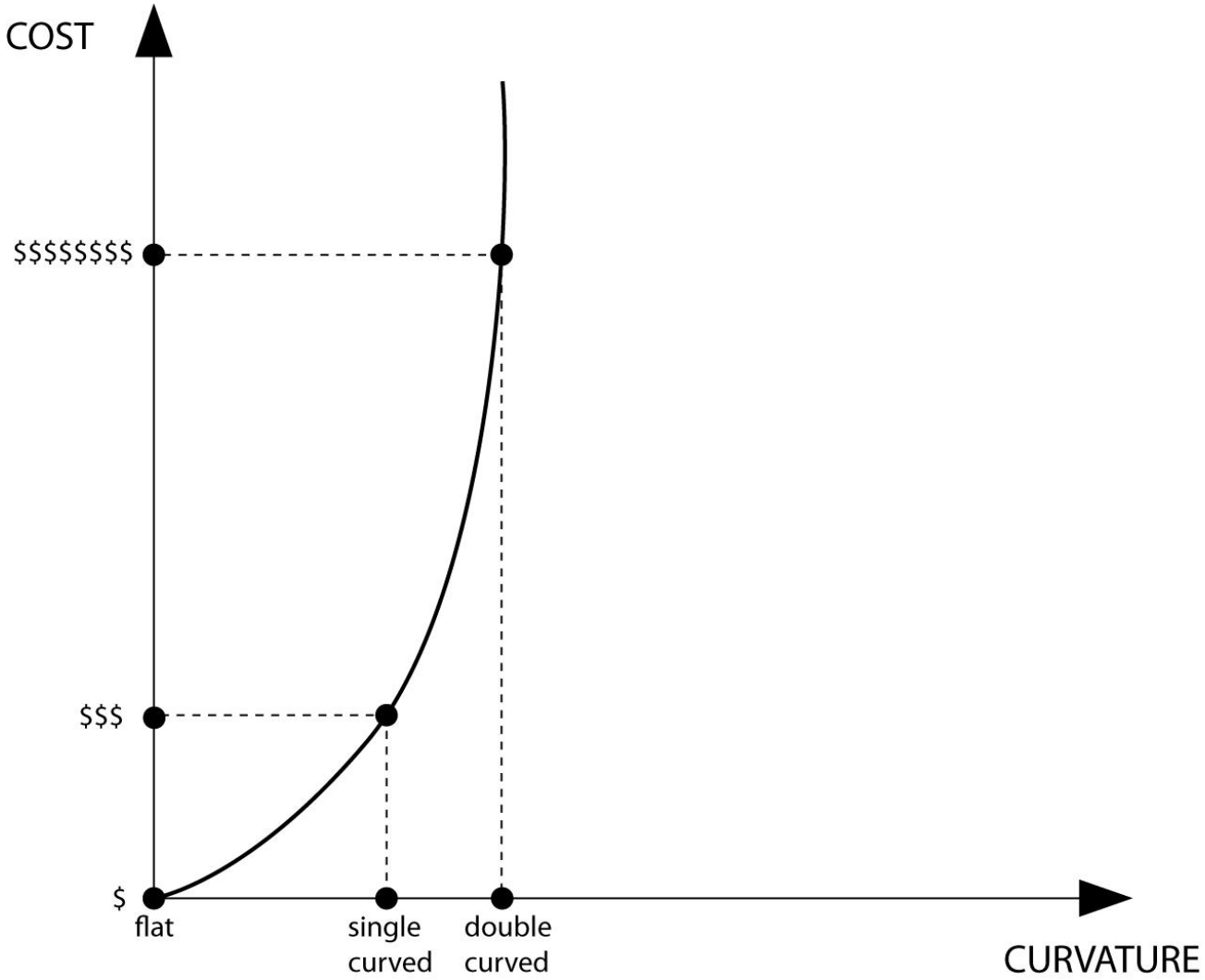
All Panels are <u>identical</u>



RULED LOFT (also known as a double-curved surface) :

All panels are <u>unique</u>

THE COST OF FLAT vs SINGLE-CURVED vs DOUBLE-CURVED



Cost-effective strategy to panelize a double curved surface

Lorenzo Marasso – Gensler Los Angeles

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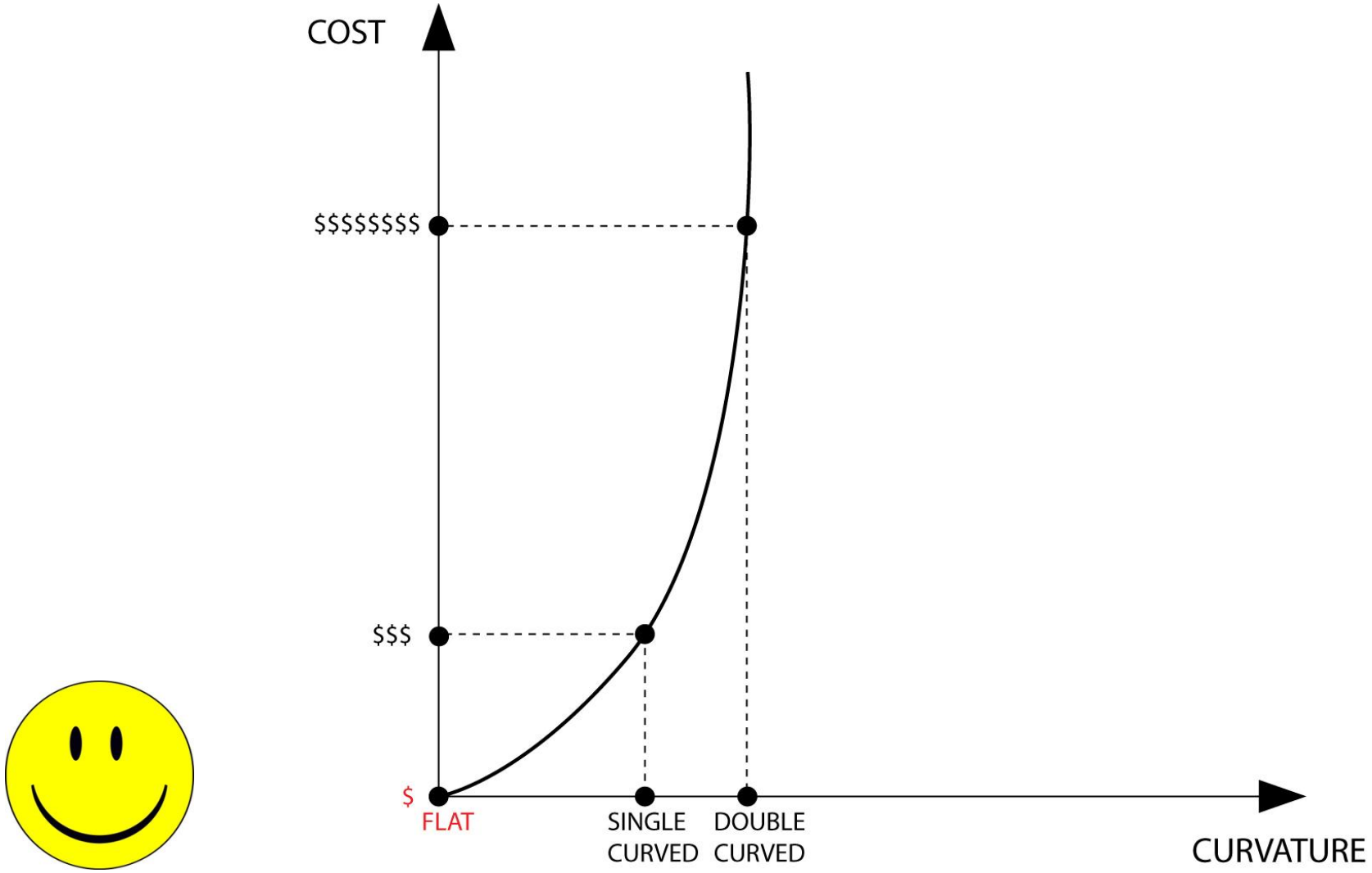

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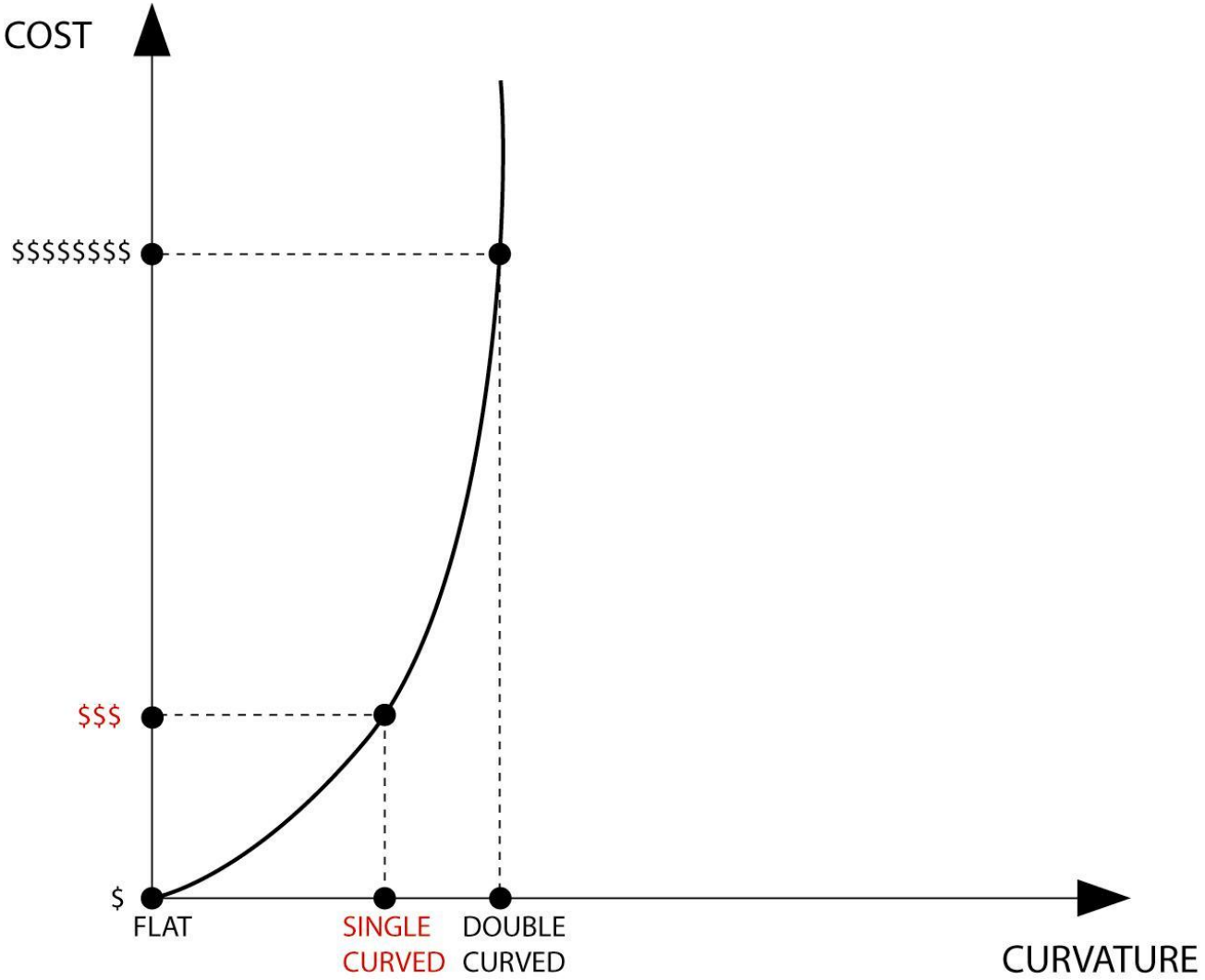

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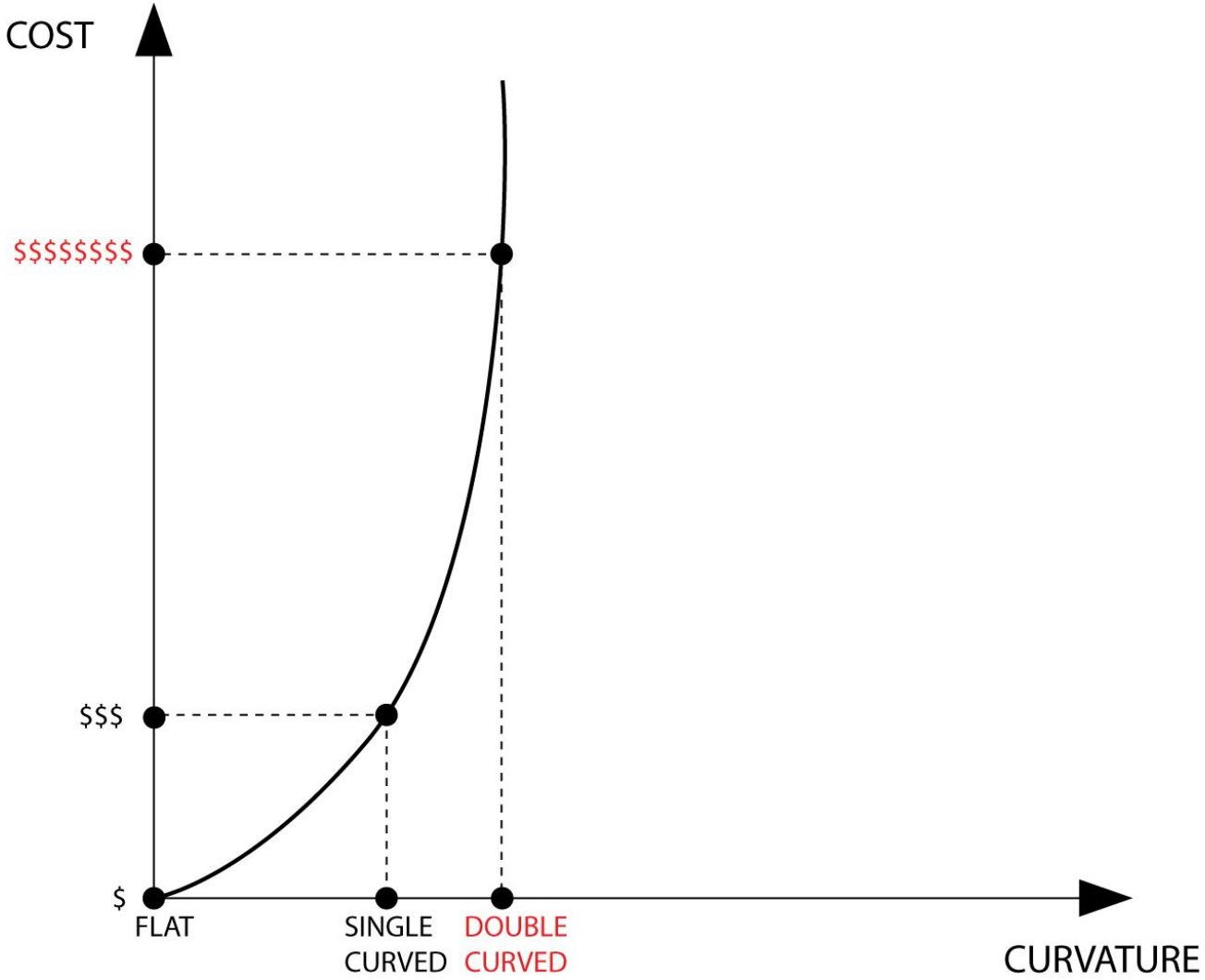

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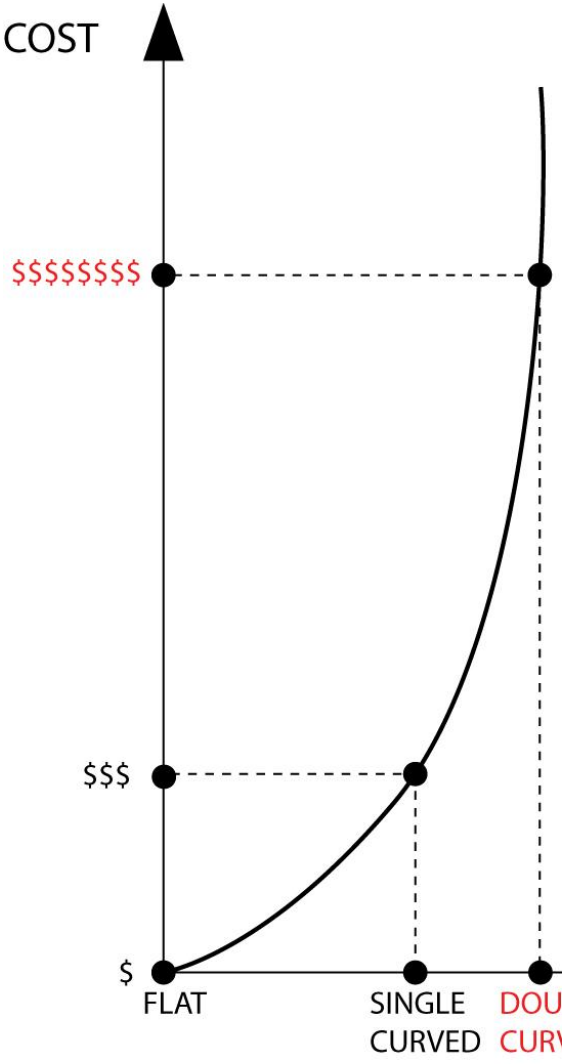
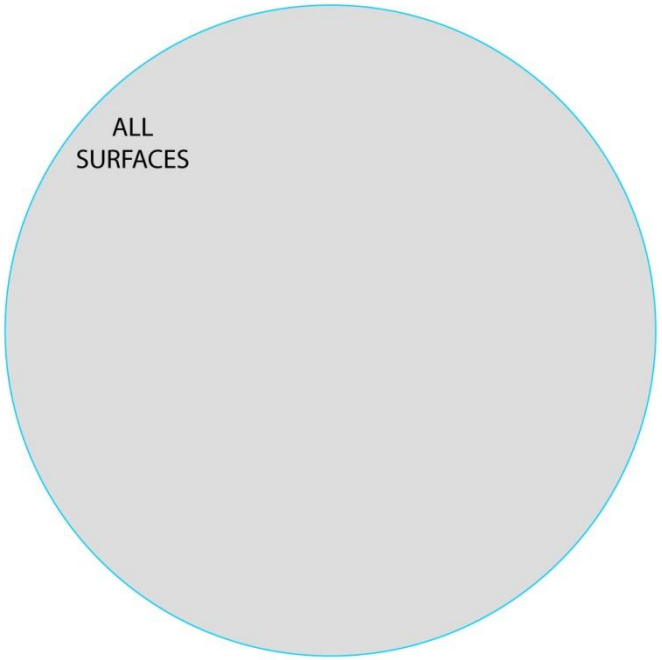


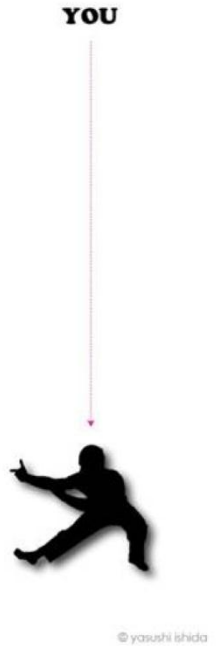
Cost-effective strategy to panelize a double curved surface

Lorenzo Marasso – Gensler Los Angeles

CATEGORIES OF CURVED SURFACES

There are different categories of surfaces.





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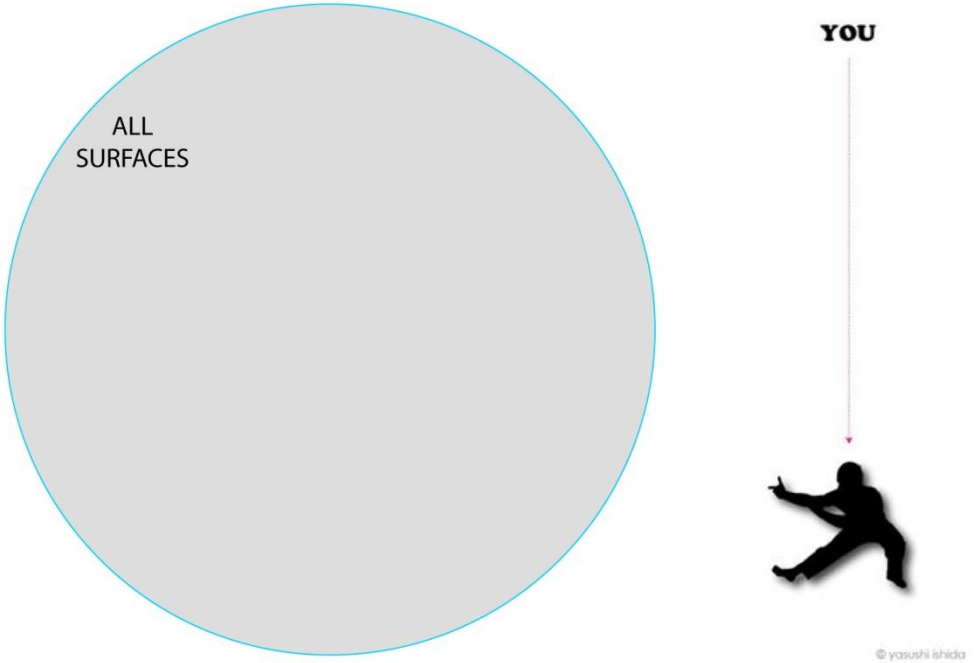
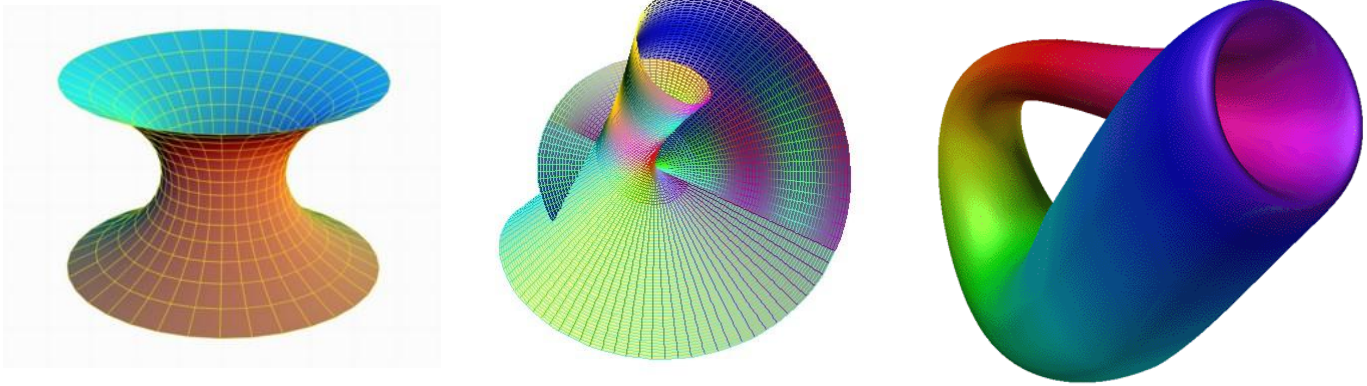


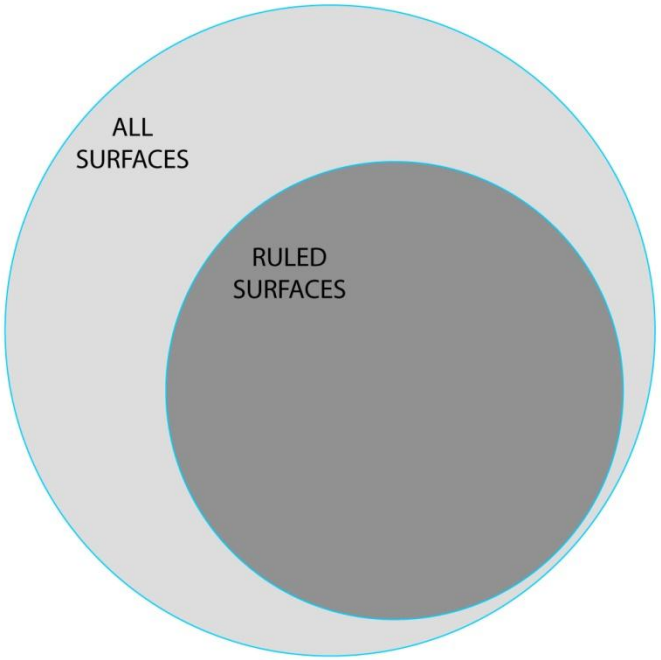
ALL SURFACES:

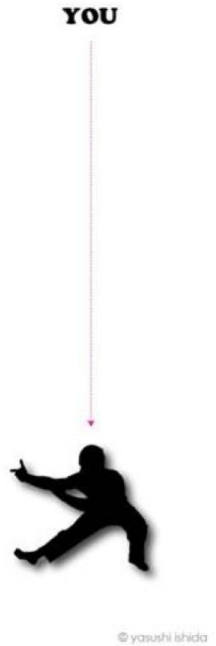
Surfaces with various configurations and different constructs



CATEGORIES OF CURVED SURFACES

The ones that interest us today are so called *RULED SURFACES*



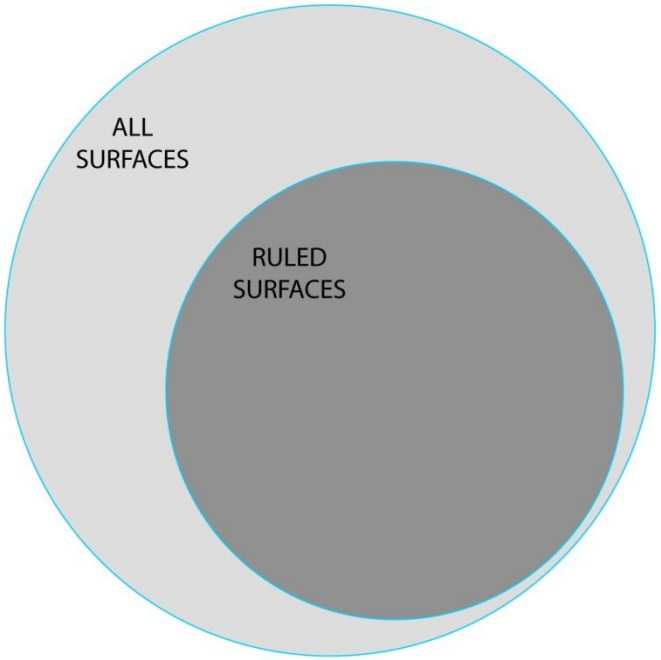


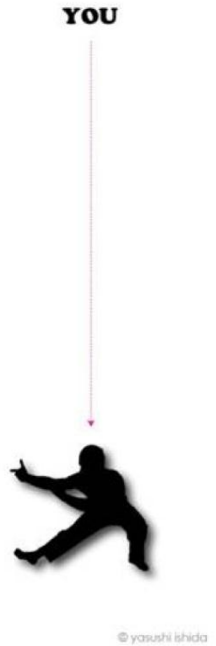
CATEGORIES OF CURVED SURFACES

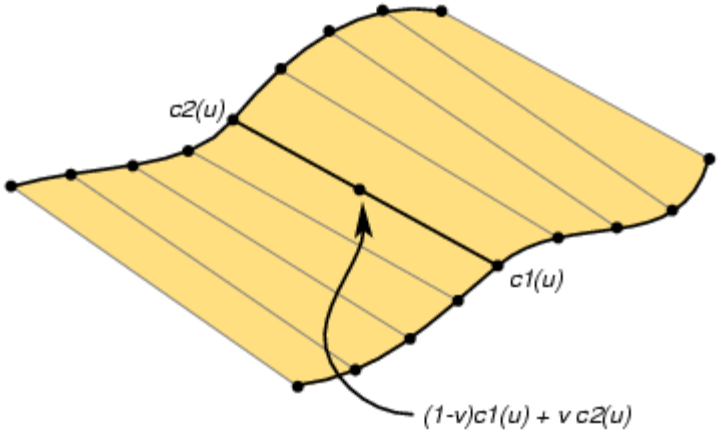
The ones that interest us today are so called *RULED SURFACES*

RULED SURFACES:

Surfaces obtained by sweeping a *straight line* in space

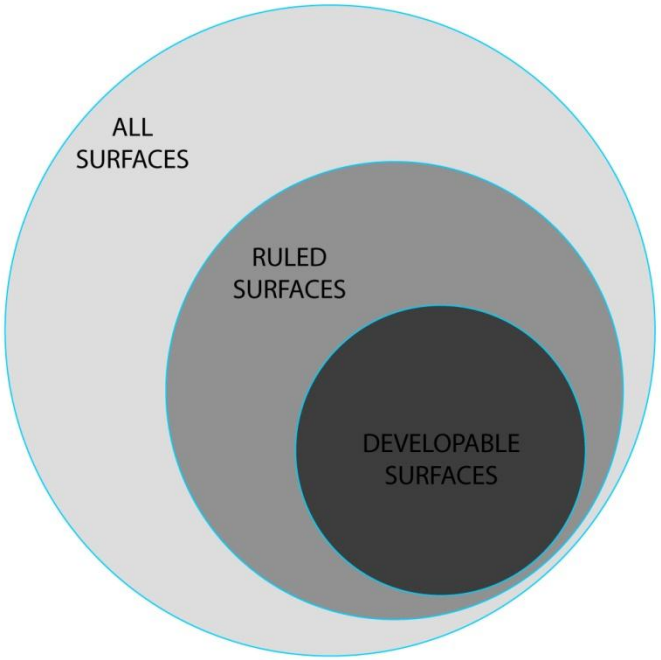


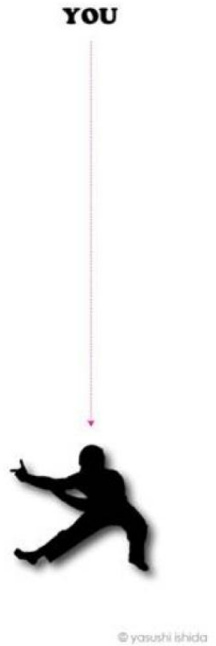




CATEGORIES OF CURVED SURFACES

A sub-category of *RULED SURFACES* are the *DEVELOPABLE SURFACES*



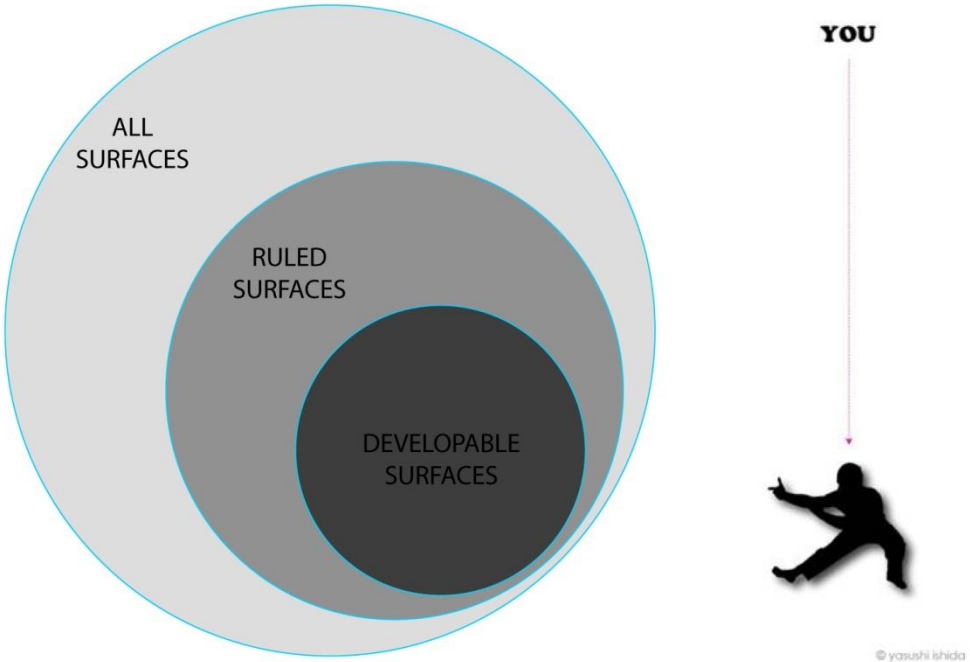


CATEGORIES OF CURVED SURFACES

A sub-category of *RULED SURFACES* are the *DEVELOPABLE SURFACES*

DEVELOPABLE SURFACES:

They are ruled surfaces except on every line there is a tangent plane with the same tangency in every point



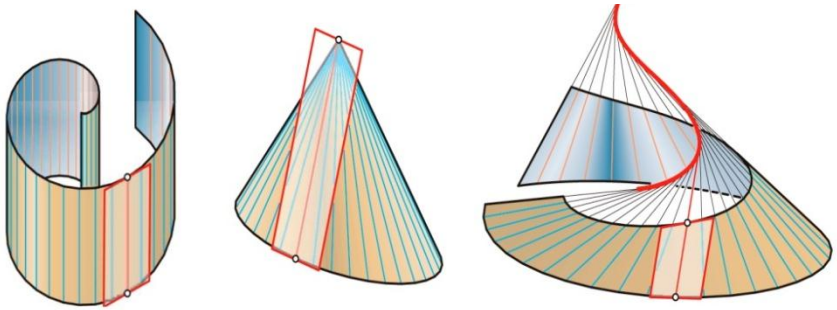
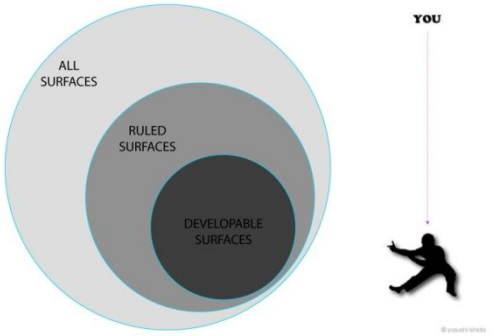


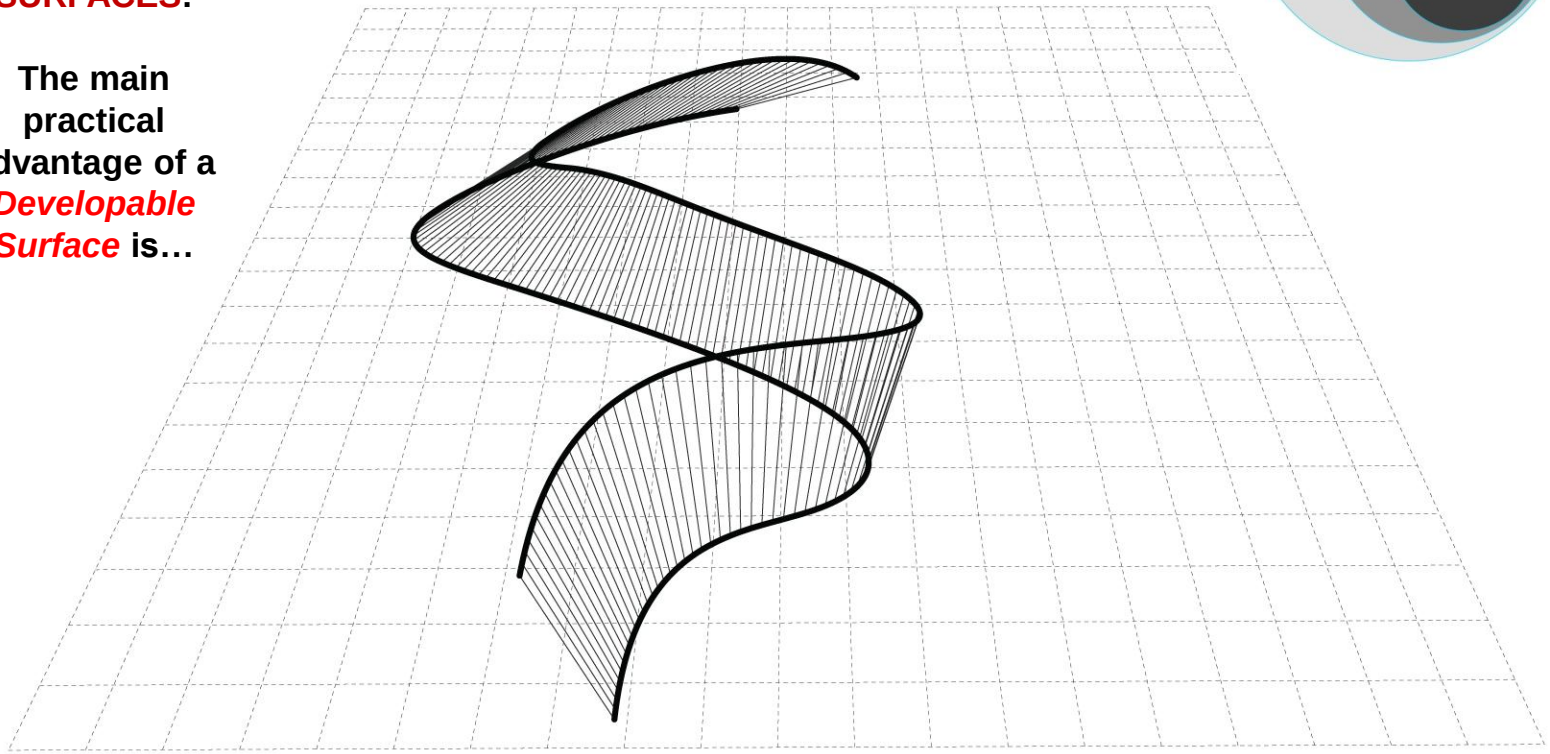
Figure 1: Three basic types of developable surfaces. (From left to right) General cylinder, general cone, tangent surface. Figure credits: (Pottmann et al., 2007).

CATEGORIES OF CURVED SURFACES

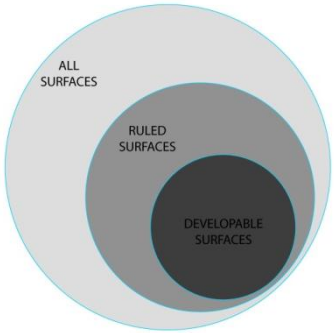


DEVELOPABLE SURFACES:

The main practical advantage of a *Developable Surface* is…

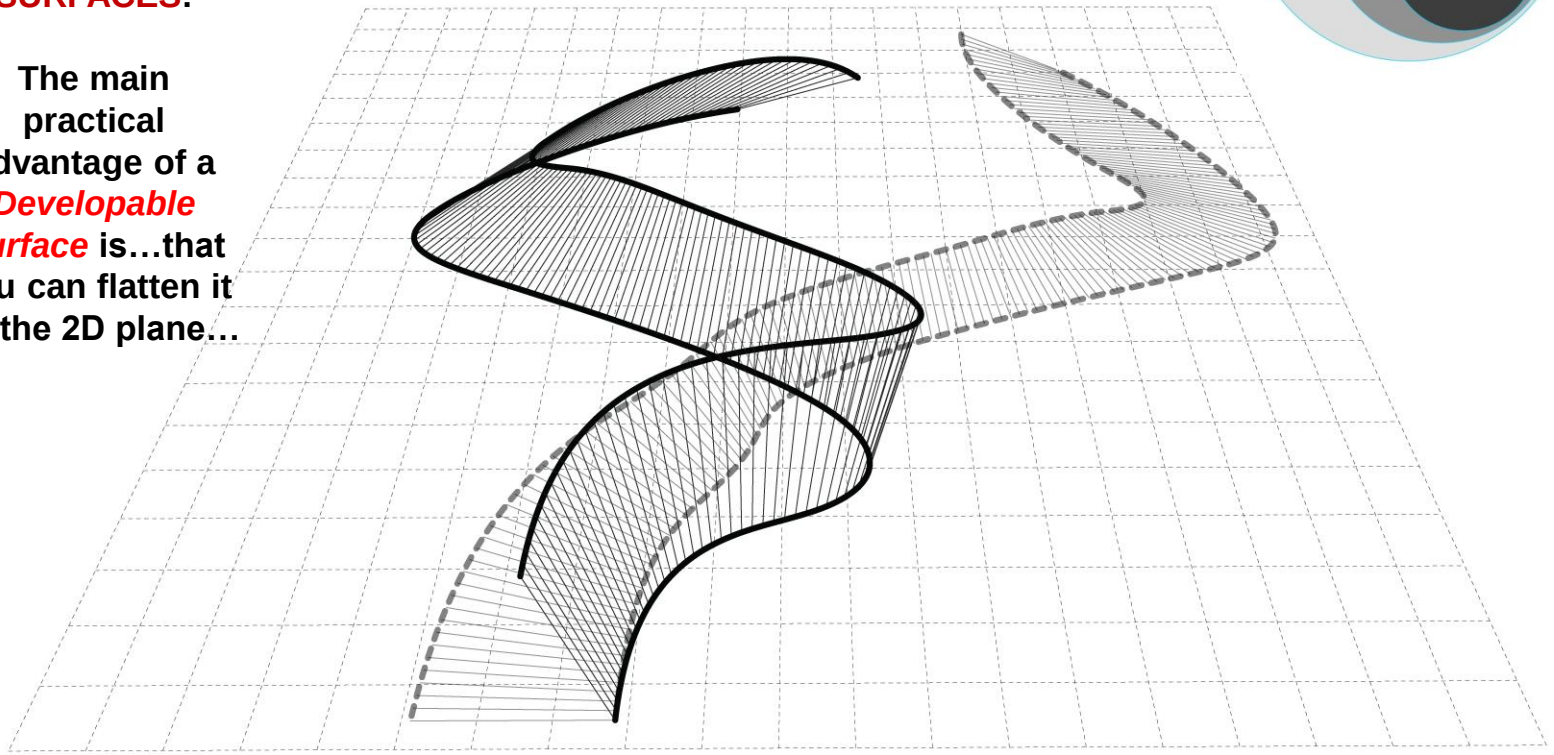


CATEGORIES OF CURVED SURFACES

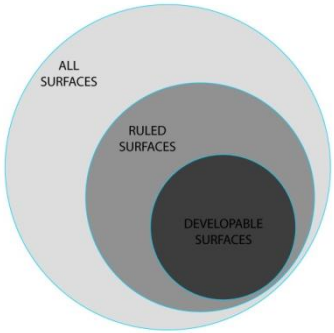


DEVELOPABLE SURFACES:

The main practical advantage of a *Developable Surface* is…that you can flatten it on the 2D plane…

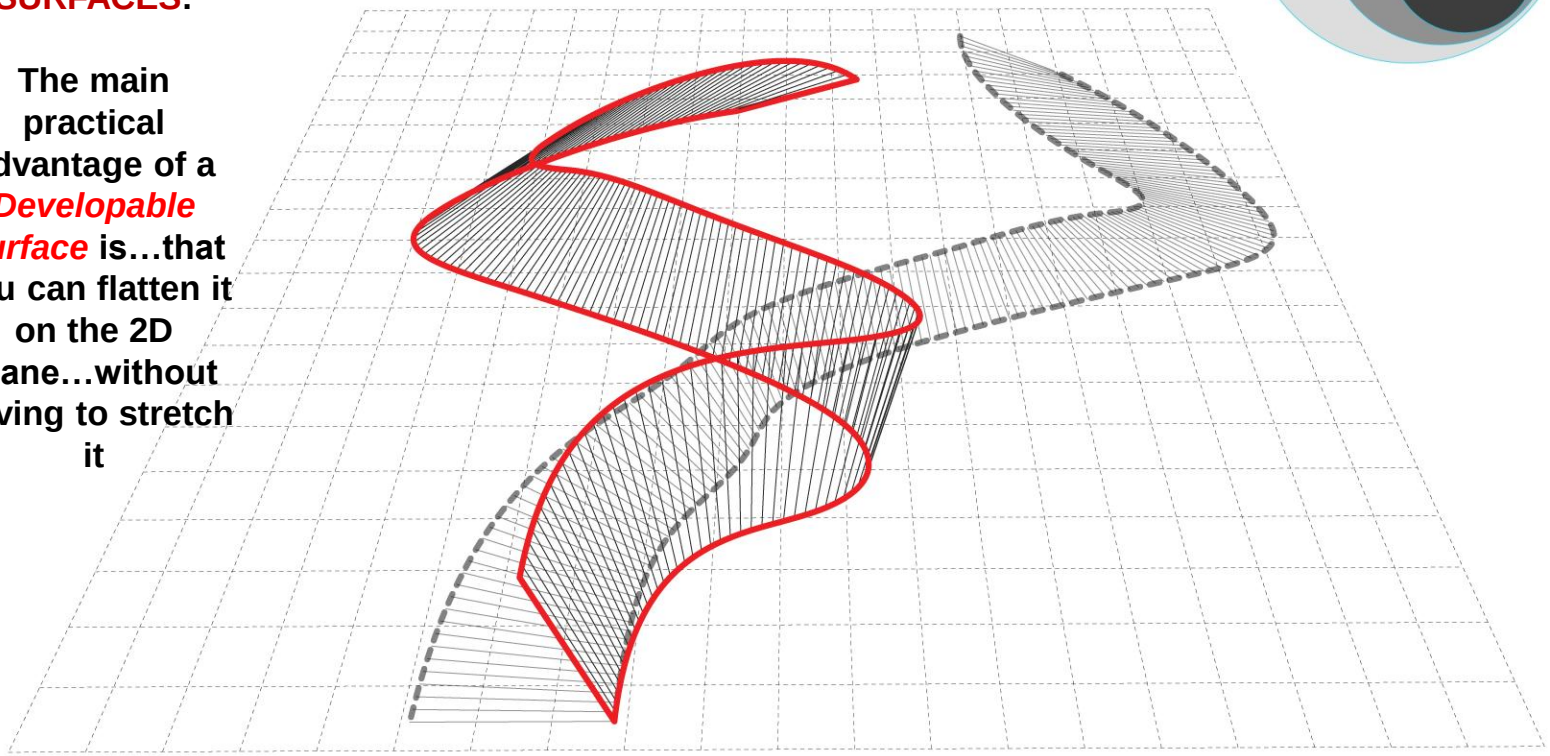


CATEGORIES OF CURVED SURFACES

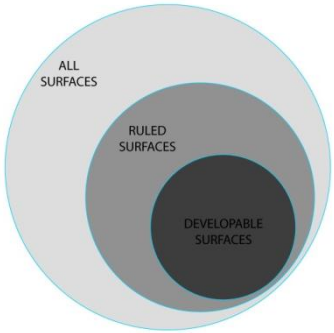


DEVELOPABLE SURFACES:

The main practical advantage of a *Developable Surface* is…that you can flatten it on the 2D plane…without having to stretch it

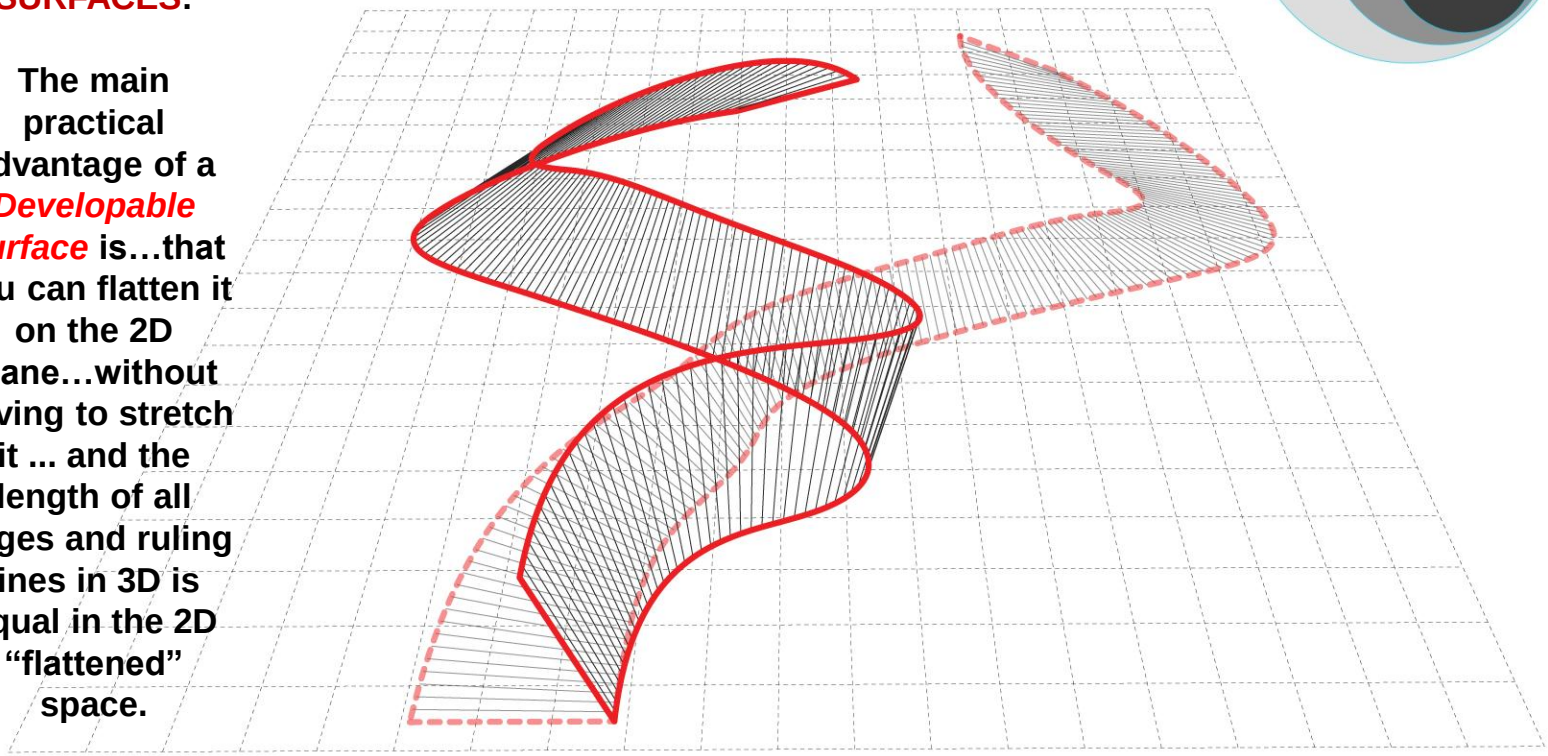


CATEGORIES OF CURVED SURFACES

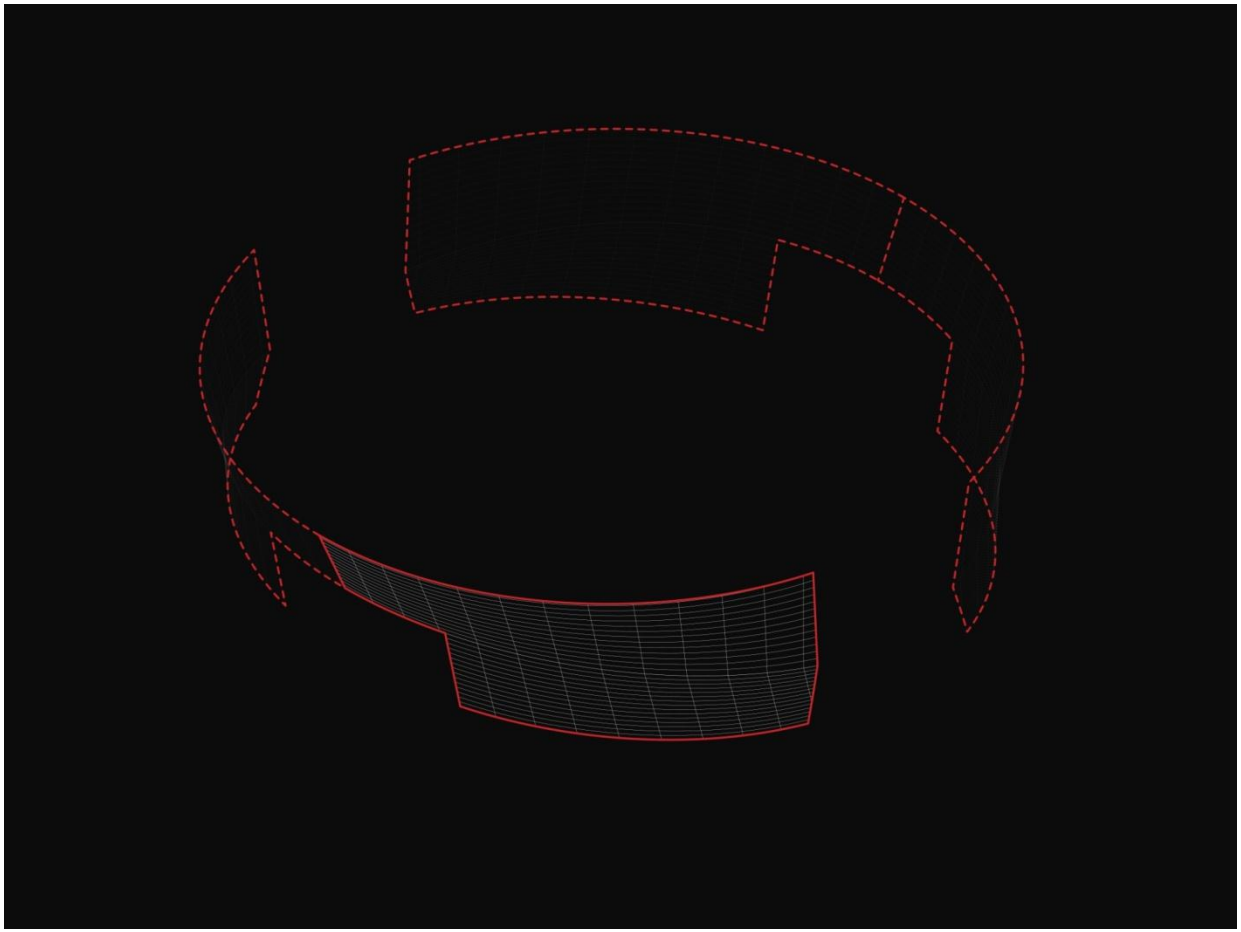


DEVELOPABLE SURFACES:

The main practical advantage of a *Developable Surface* is…that you can flatten it on the 2D plane…without having to stretch it ... and the length of all edges and ruling lines in 3D is equal in the 2D "flattened" space.



THE PROJECT'S SURFACES ARE RULED BUT NOT DEVELOPABLE



SHENBEI PERFORMING ARTS CENTER
DISTRICT OF SHENYANG - CHINA

Cost-effective strategy to panelize a double curved surface
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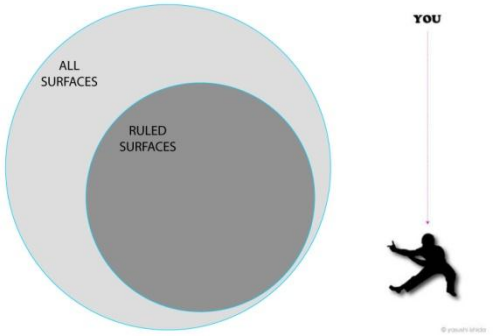
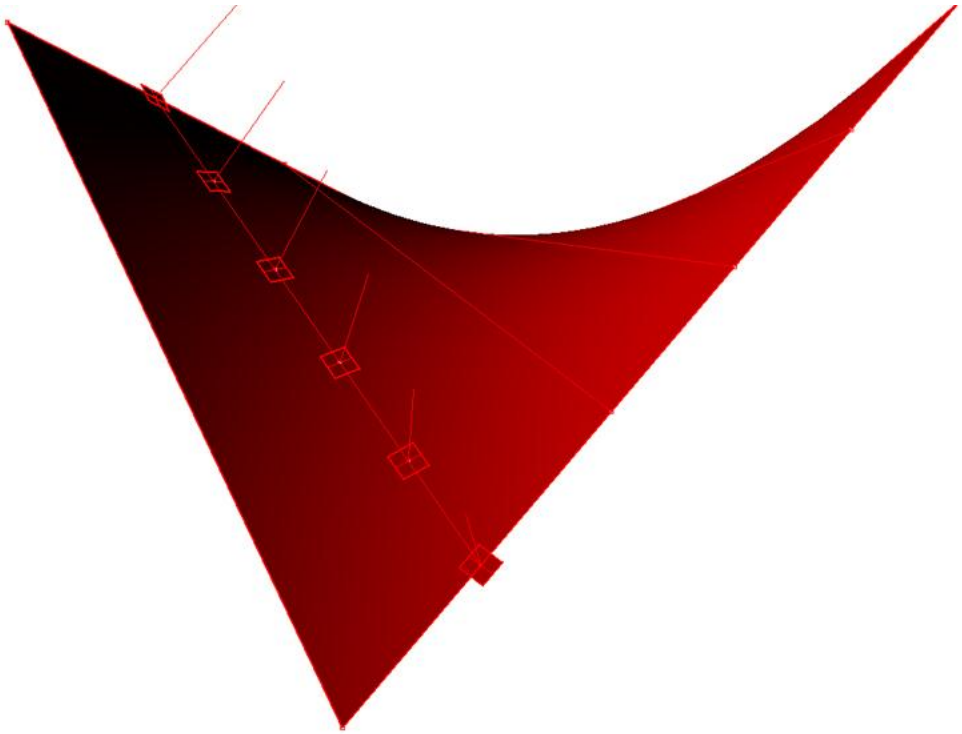
PARAMETERS TO EVALUATE CURVED SURFACES

- Tangent Planes

- Angle between Normals



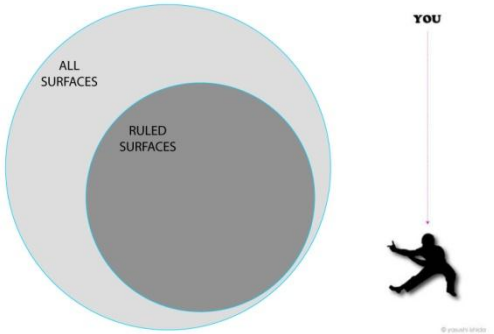


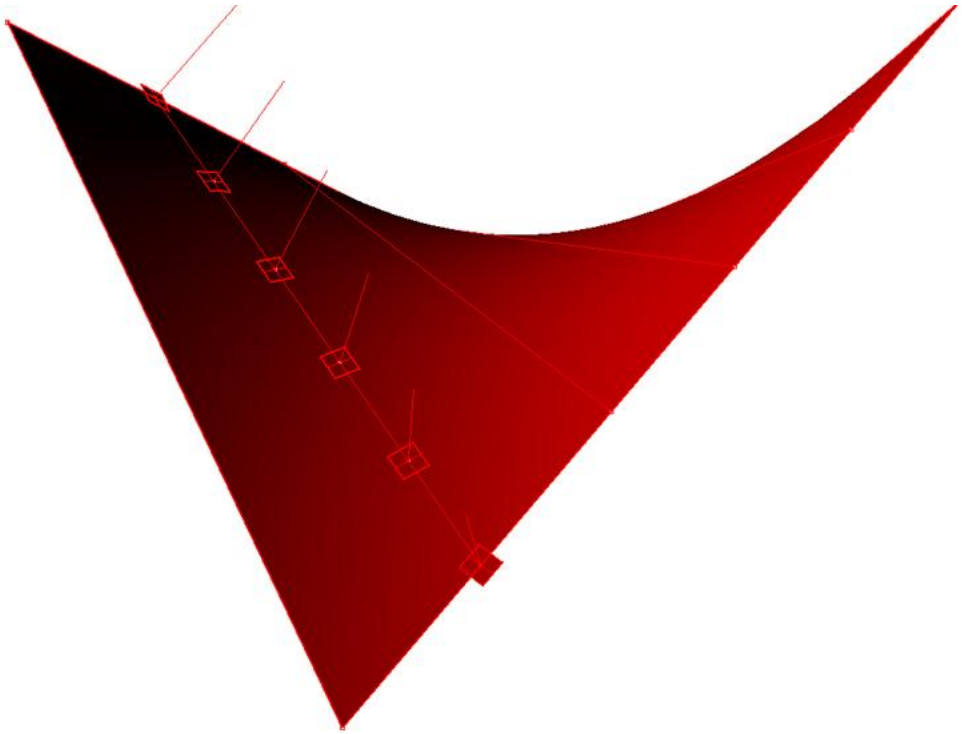
RULED SURFACE:
HYPERBOLOID

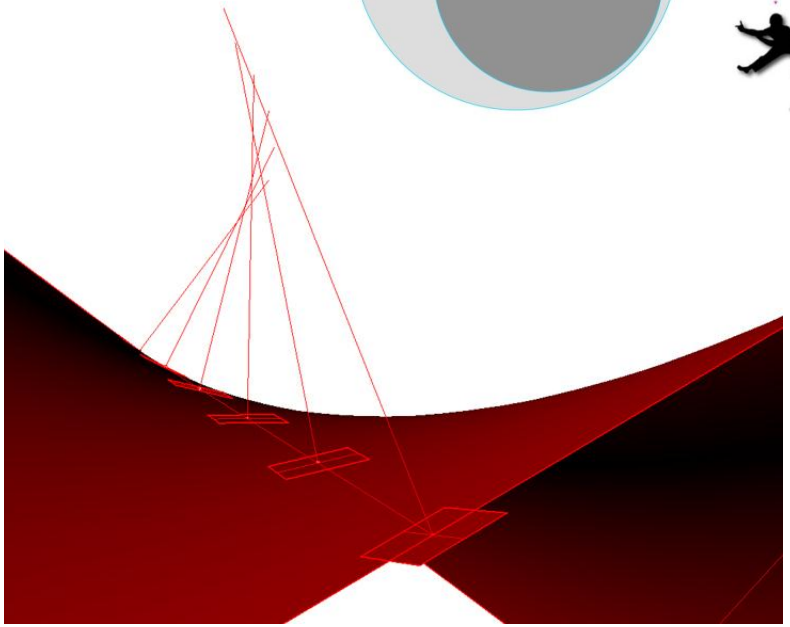
PARAMETERS TO EVALUATE CURVED SURFACES

- Tangent Planes

- Angle between Normals



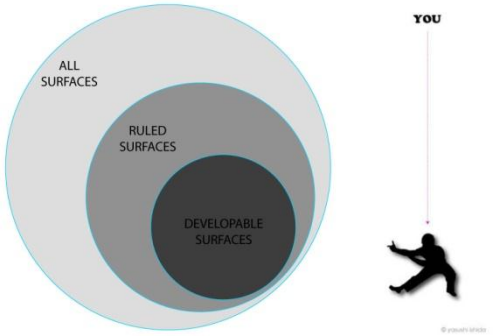


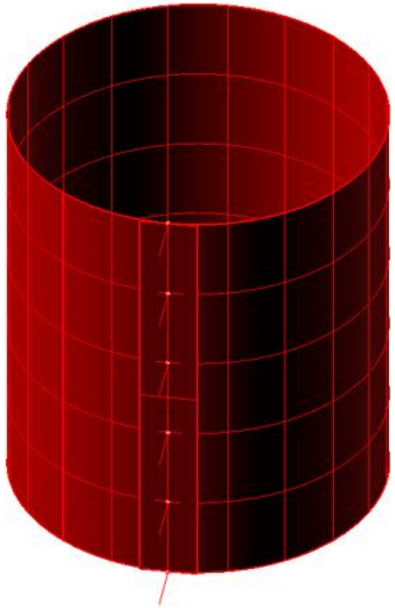


RULED SURFACE:
HYPERBOLOID

Tangent Plane **is "tangent" in every point at all times except the normals are not parallel to each other**

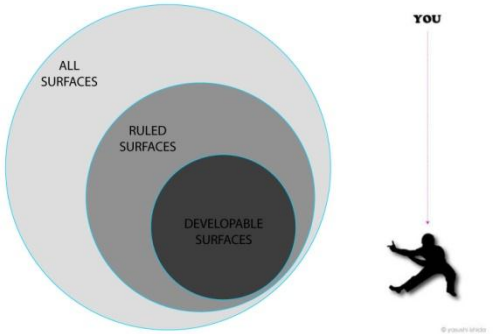
PARAMETERS TO EVALUATE CURVED SURFACES
- Tangent Planes
- Angle between Normals

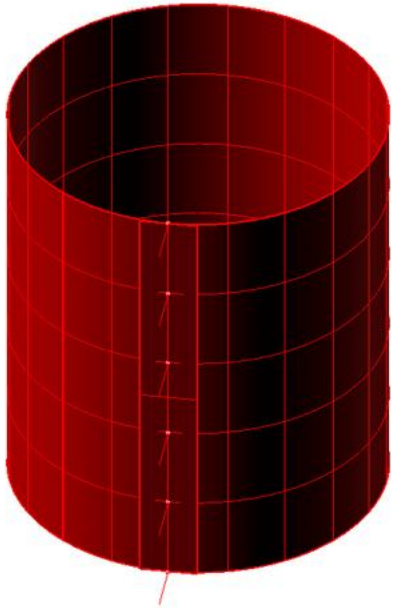




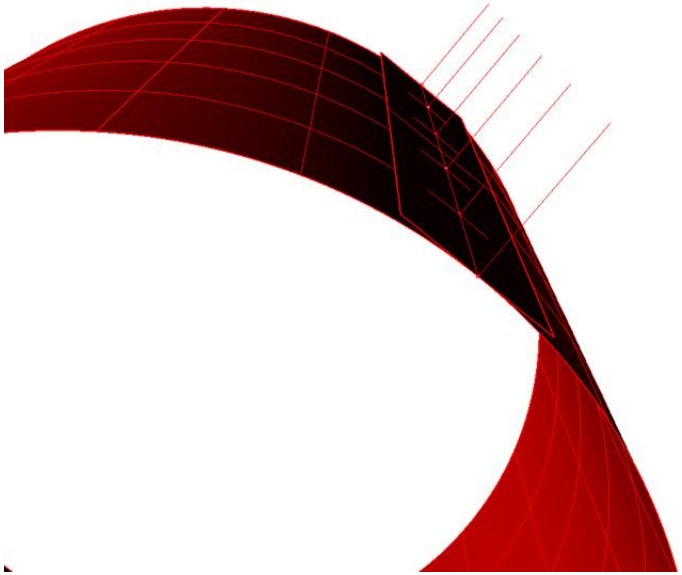
RULED and DEVELOPABLE SURFACE:
CYLINDER

PARAMETERS TO EVALUATE CURVED SURFACES
- Tangent Planes
- Angle between Normals



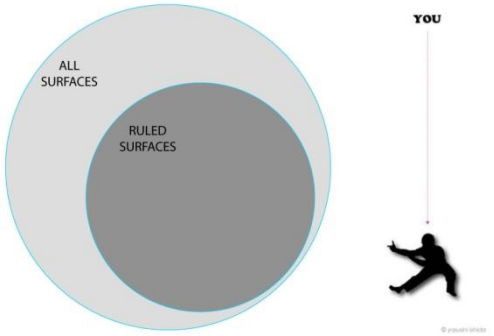


RULED and DEVELOPABLE SURFACE: CYLINDER



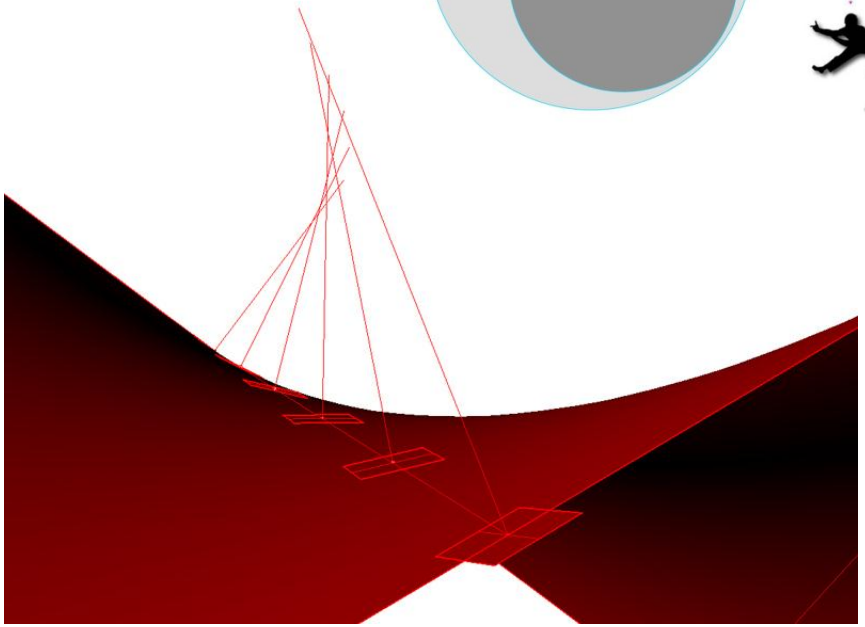
Tangent Plane **is "tangent" in every point at all times except the normals are not parallel to each other**

PARAMETERS TO EVALUATE CURVED SURFACES
- Tangent Planes
- Angle between Normals



If the surface's tangent planes have the same tangency value the surface IS developable

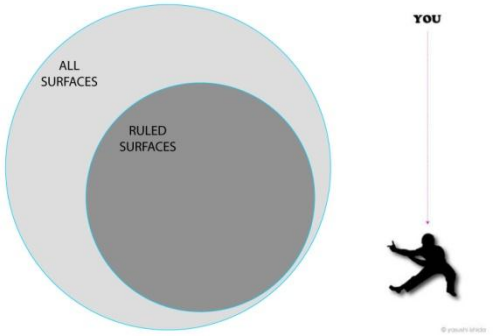
If the surface angle between the normals is equal to zero the surface IS developable



RULED SURFACE:
HYPERBOLOID

Tangent Plane **is "tangent" in every point at all times except the normals are not parallel to each other**

PARAMETERS TO EVALUATE CURVED SURFACES
- Tangent Planes
- Angle between Normals

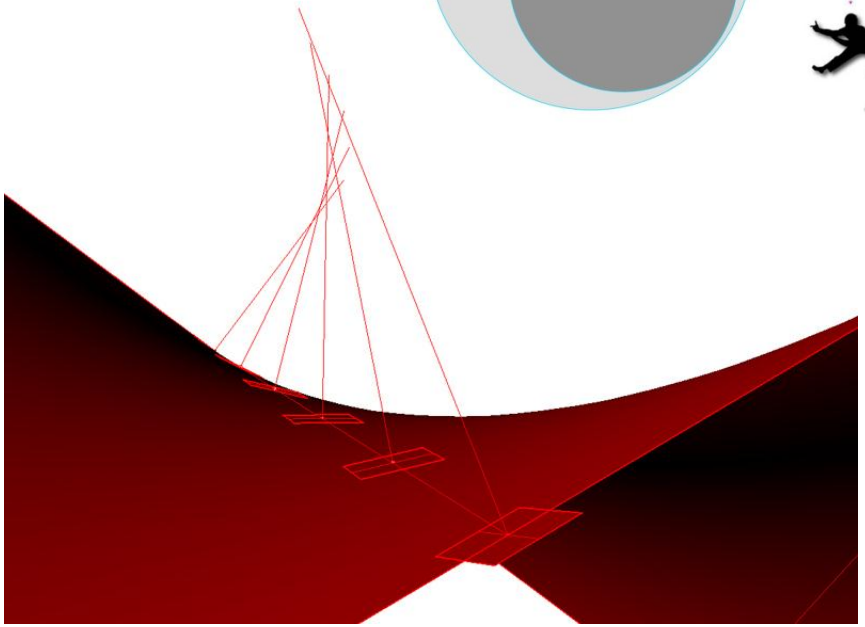


If the surface's tangent planes have the same tangency value the surface IS developable

If the surface angle between the normals is equal to zero the surface IS developable

If the surface's tangent planes numeric value is close from one another then the surface is very close in being developable

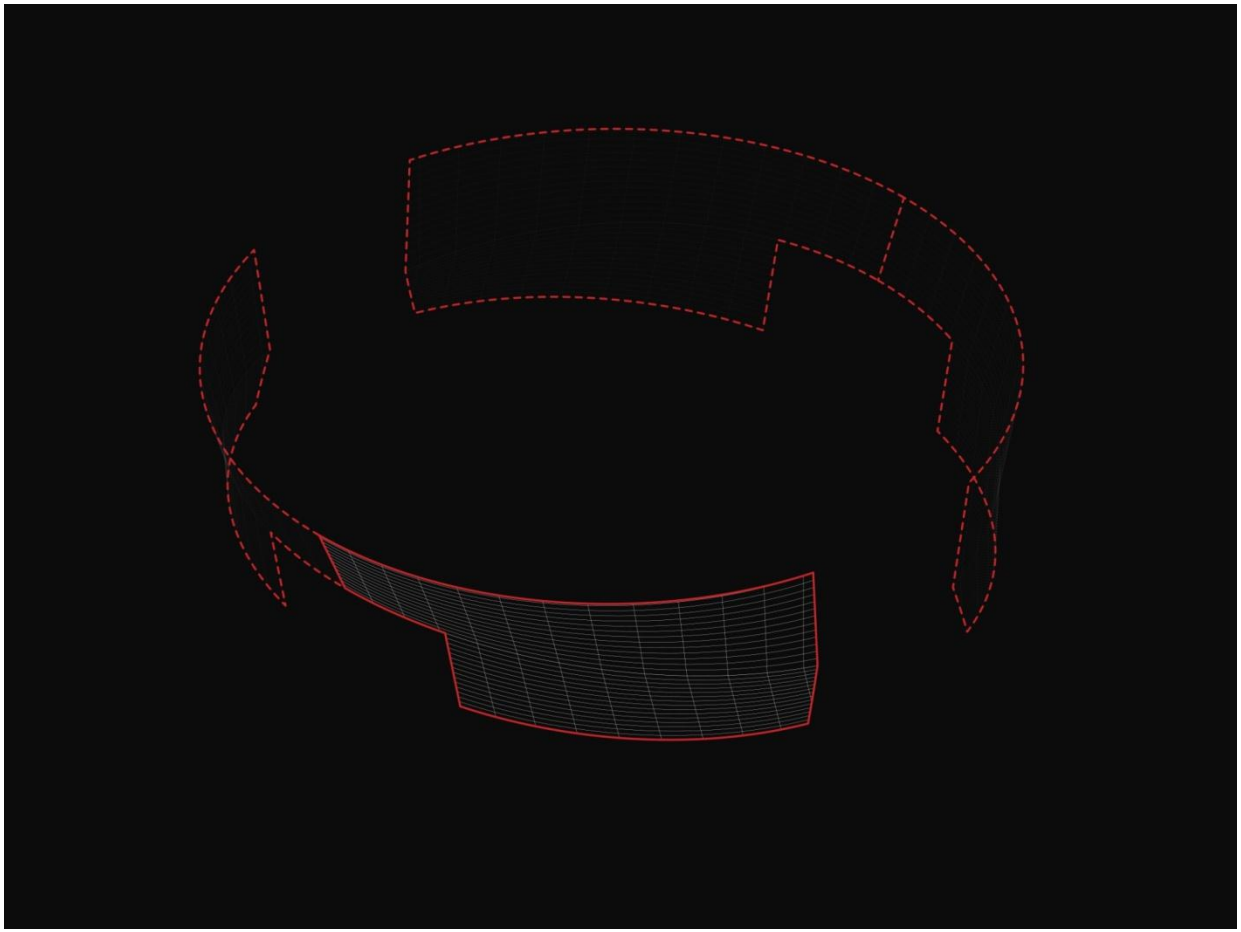
If the surface angle between the normals closer to zero then the surface is very close in being developable



RULED SURFACE:
HYPERBOLOID

Tangent Plane **is "tangent" in every point at all times except the normals are not parallel to each other**

THE PROJECT'S SURFACES ARE ALMOST DEVELOPABLE



SHENBEI PERFORMING ARTS CENTER
DISTRICT OF SHENYANG - CHINA

Cost-effective strategy to panelize a double curved surface
Lorenzo Marasso – Gensler Los Angeles

THE SKIN GEOMETRY

SHENBEI PERFORMING ARTS CENTER
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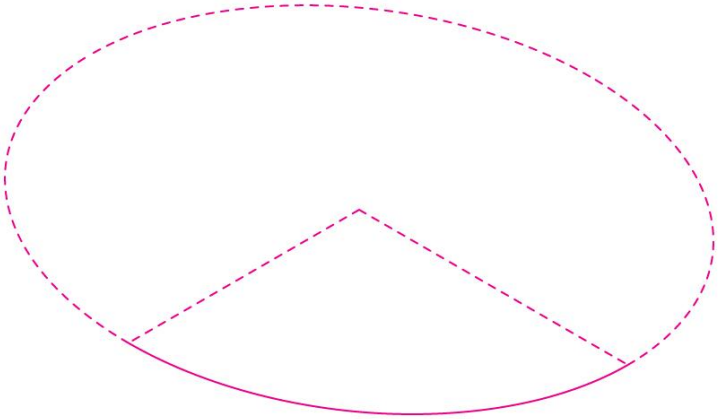
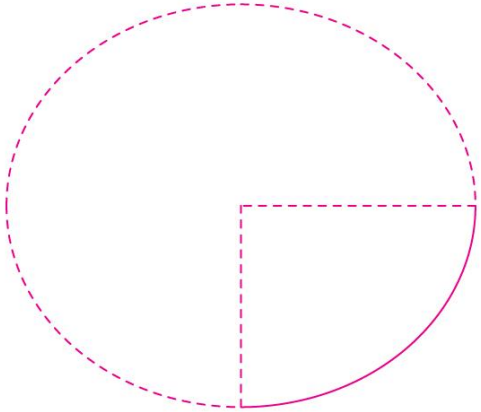
THE SKIN GEOMETRY

ELEVATION



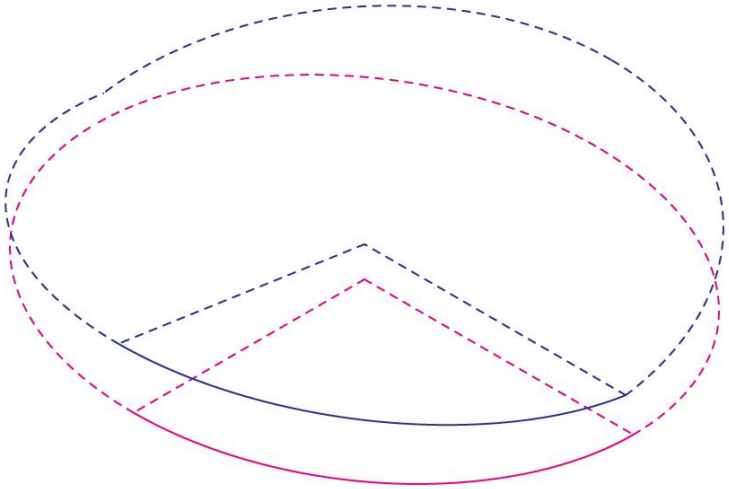
AXONOMETRIC



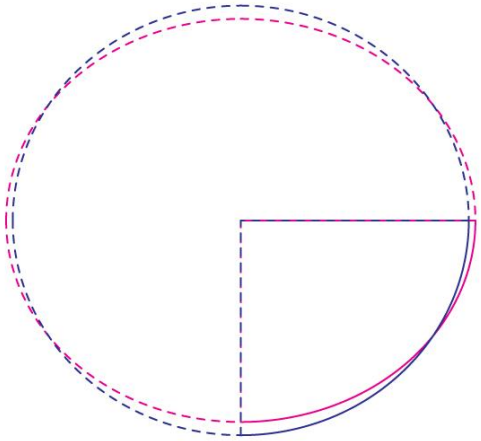
PLAN

THE SKIN GEOMETRY

ELEVATION



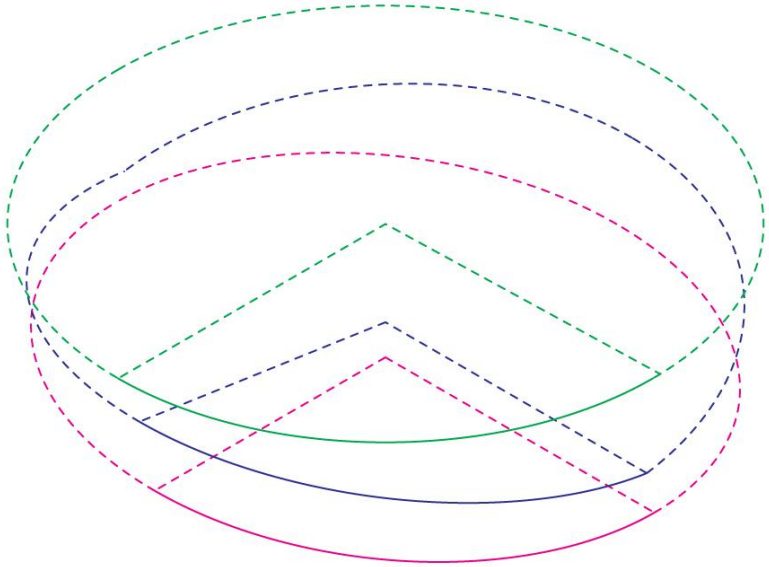
AXONOMETRIC



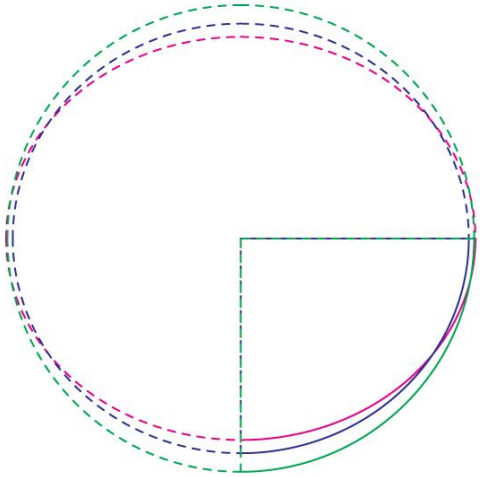
PLAN

THE SKIN GEOMETRY

ELEVATION



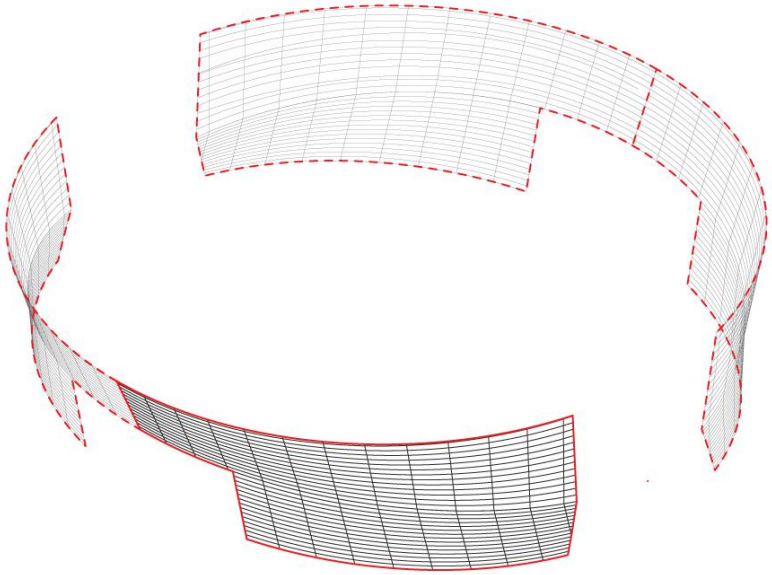
AXONOMETRIC



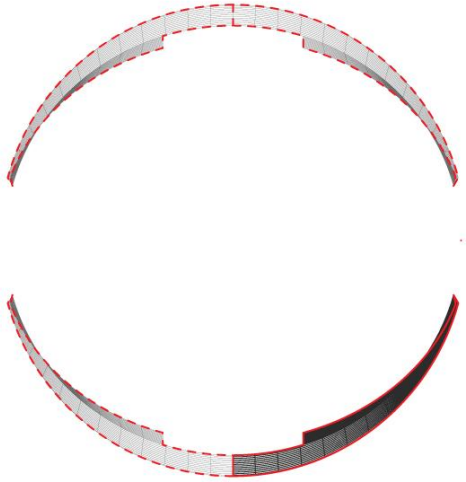
PLAN

THE SKIN GEOMETRY

ELEVATION

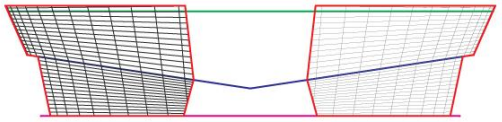


AXONOMETRIC

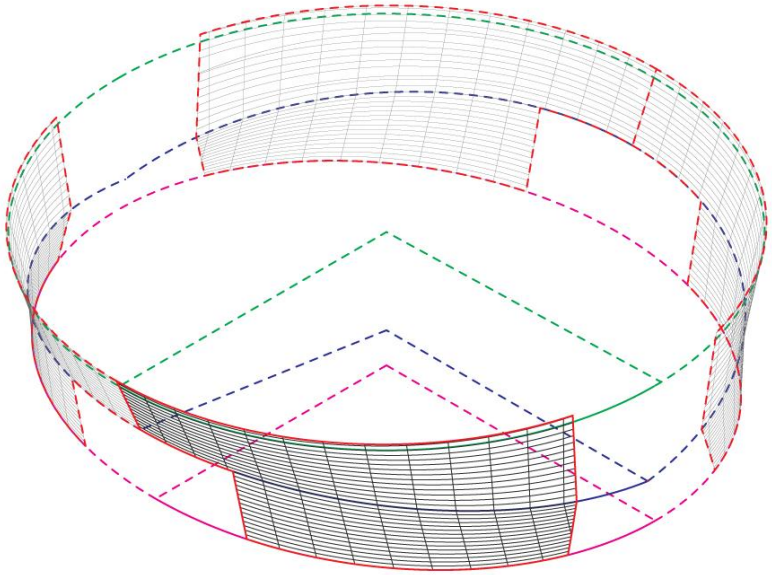


PLAN

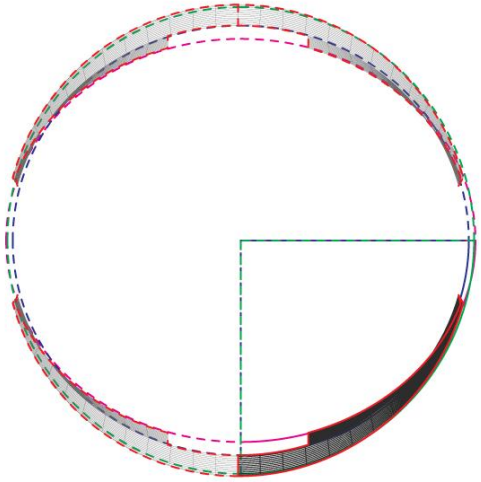
THE SKIN GEOMETRY



ELEVATION



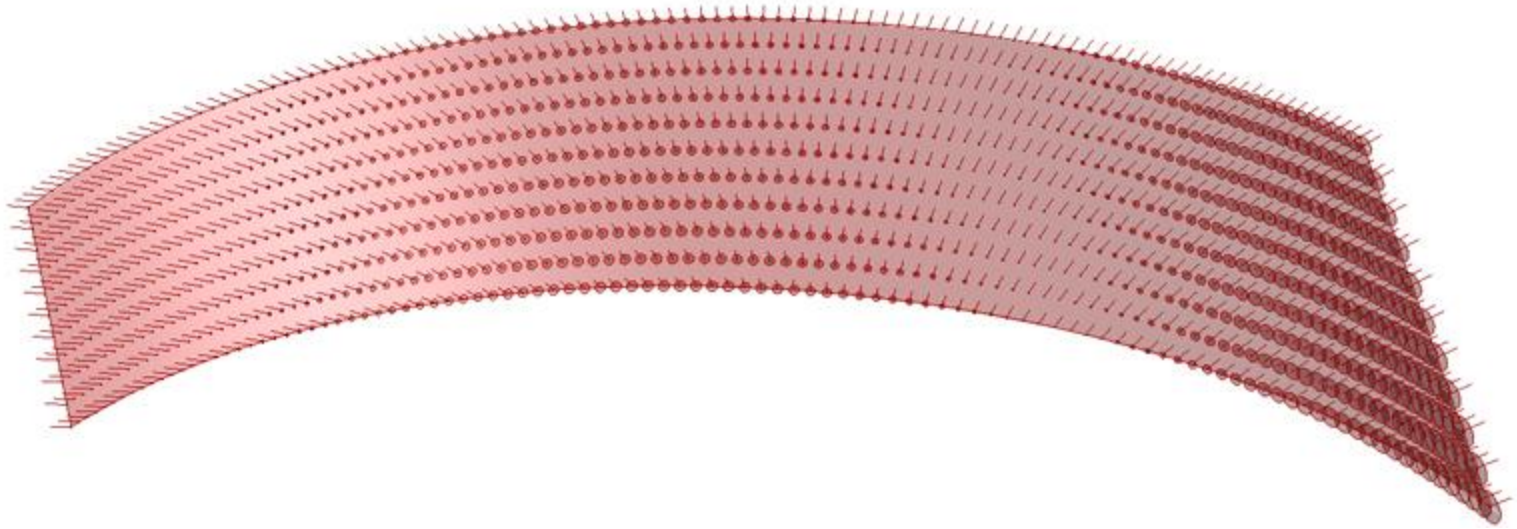
AXONOMETRIC



PLAN

PARAMETRIC CONTROL

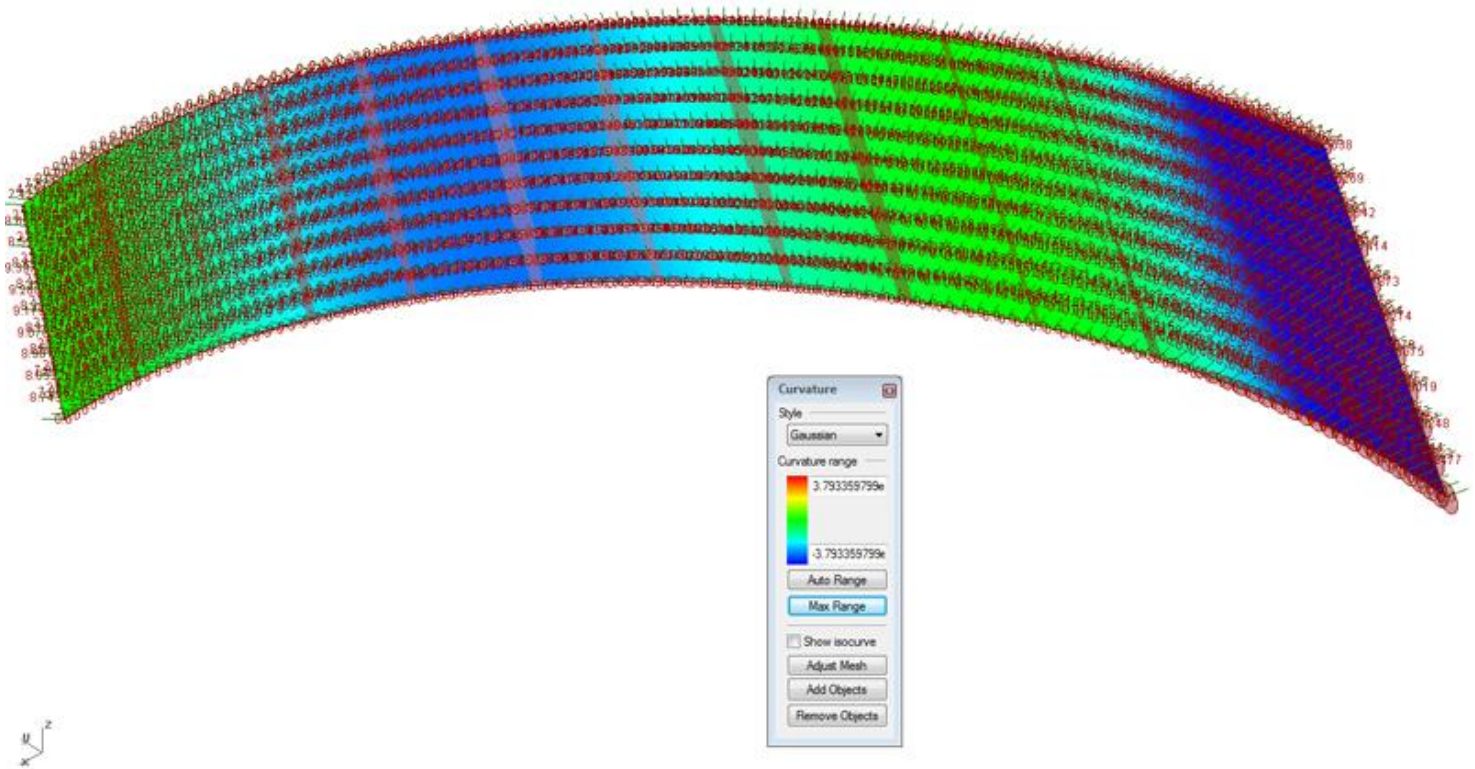
HOW TO NUMERICALLY DETERMINE THAT THE SURFACE IS NOT *DEVELOPABLE.*
Using parametric tools it is possible to determine in mathematical terms the amount of curvature at each point across a surface.



BY CALCULATING THE *MEAN CURVATURE* AT UV POINTS. The red circles are a visual datum that determines the amount of curvature in that spot.

PARAMETRIC CONTROL

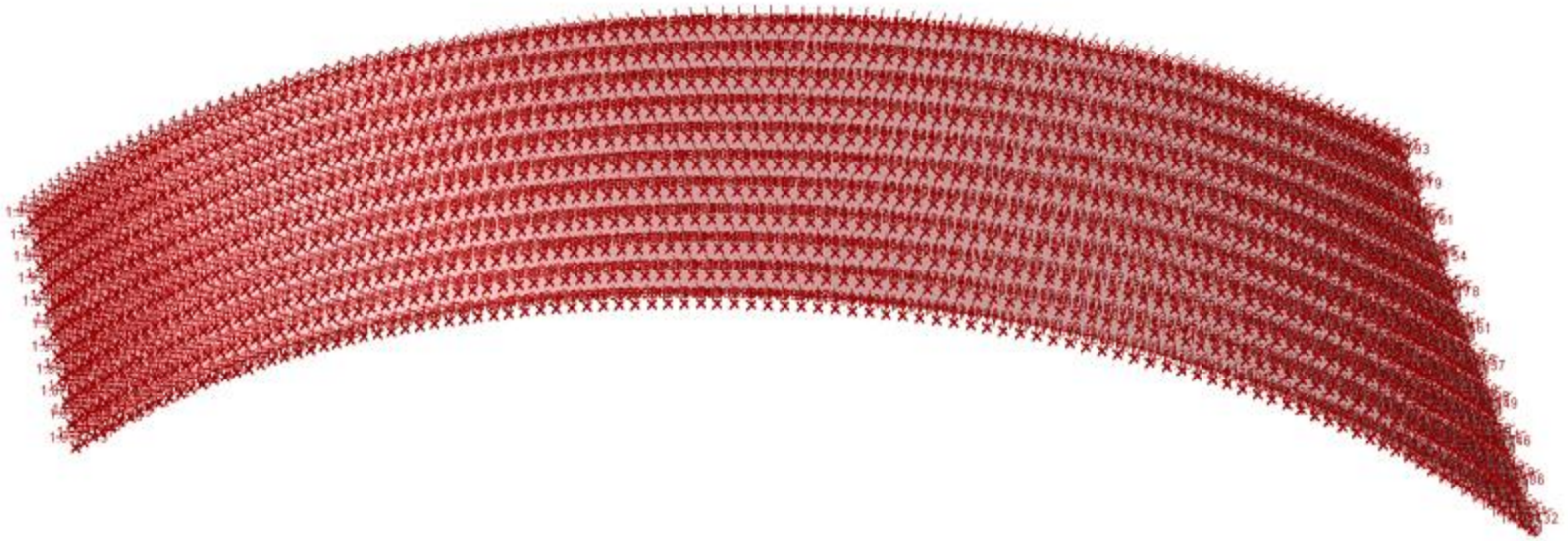
HOW TO NUMERICALLY DETERMINE THAT THE SURFACE IS NOT *DEVELOPABLE.*
Using parametric tools it is possible to determine in mathematical terms the amount of curvature at each point across a surface.



BY CALCULATING THE *GAUSSIAN CURVATURE* AT UV POINTS. Condition for Developable Surfaces is Gaussian Curvature to be equal to Zero in all points across the surface. The color coding reveals the amount of curvature.

PARAMETRIC CONTROL

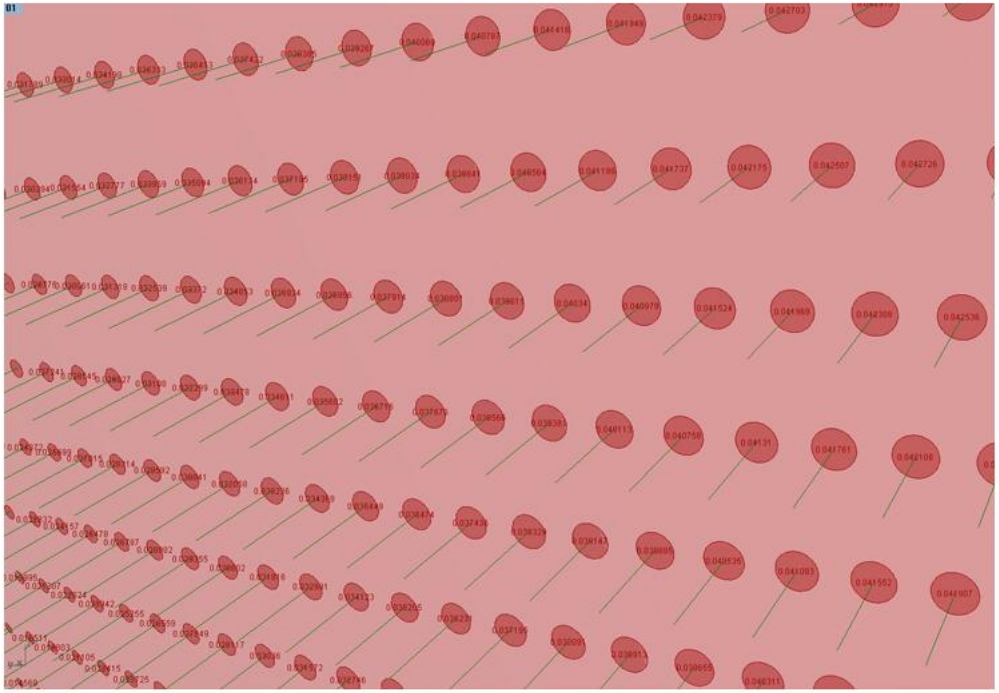
HOW TO NUMERICALLY DETERMINE THAT THE SURFACE IS NOT *DEVELOPABLE.*
Using parametric tools it is possible to determine in mathematical terms the amount of curvature at each point across a surface.



CALCULATION OF ANGLE BETWEEN NORMALS ON RULING LINES. If the angle between the normals is different from zero the surface is NOT developable.

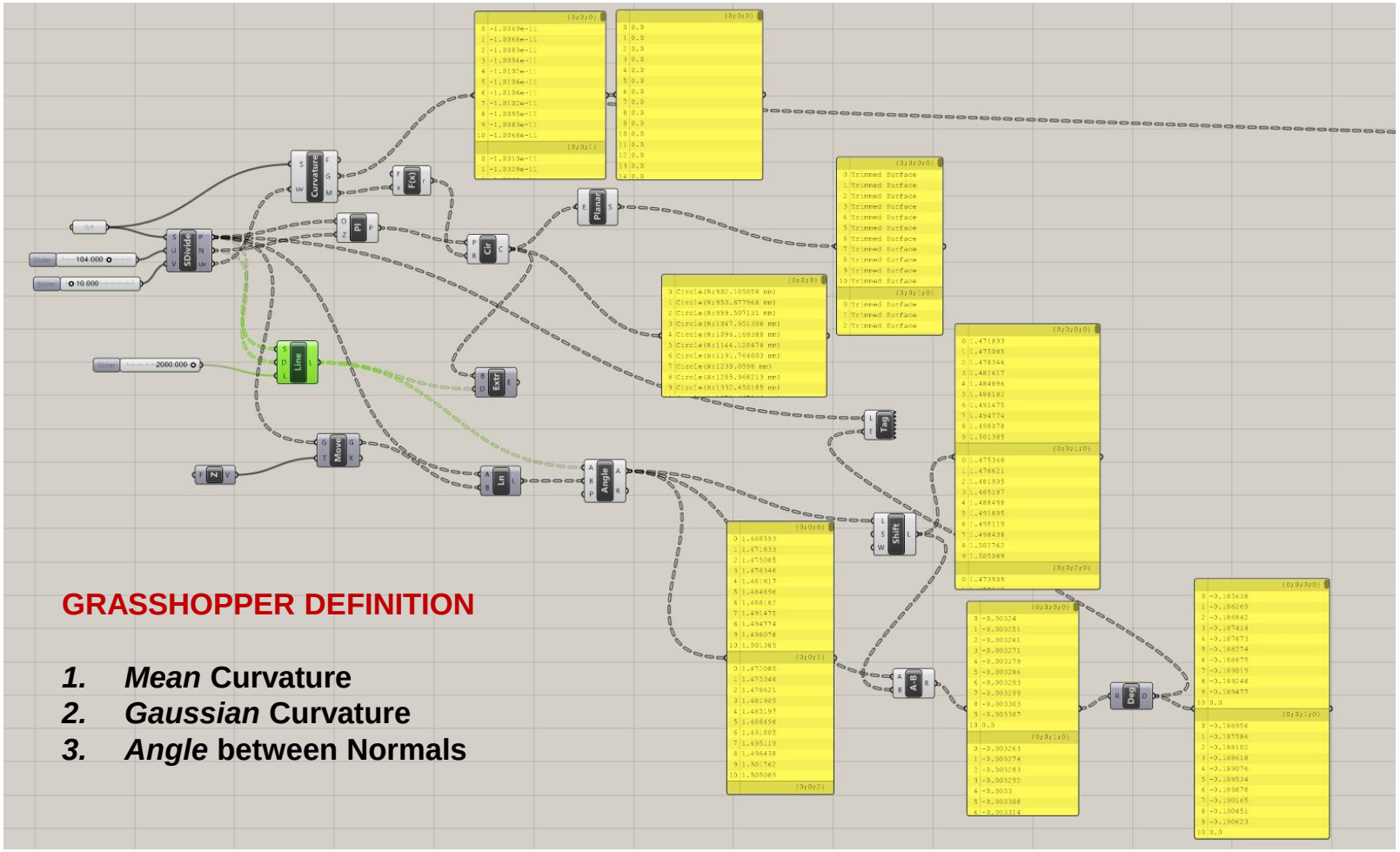
PARAMETRIC CONTROL

HOW TO NUMERICALLY DETERMINE THAT THE SURFACE IS NOT *DEVELOPABLE.*
Using parametric tools it is possible to determine in mathematical terms the amount of curvature at each point across a surface.

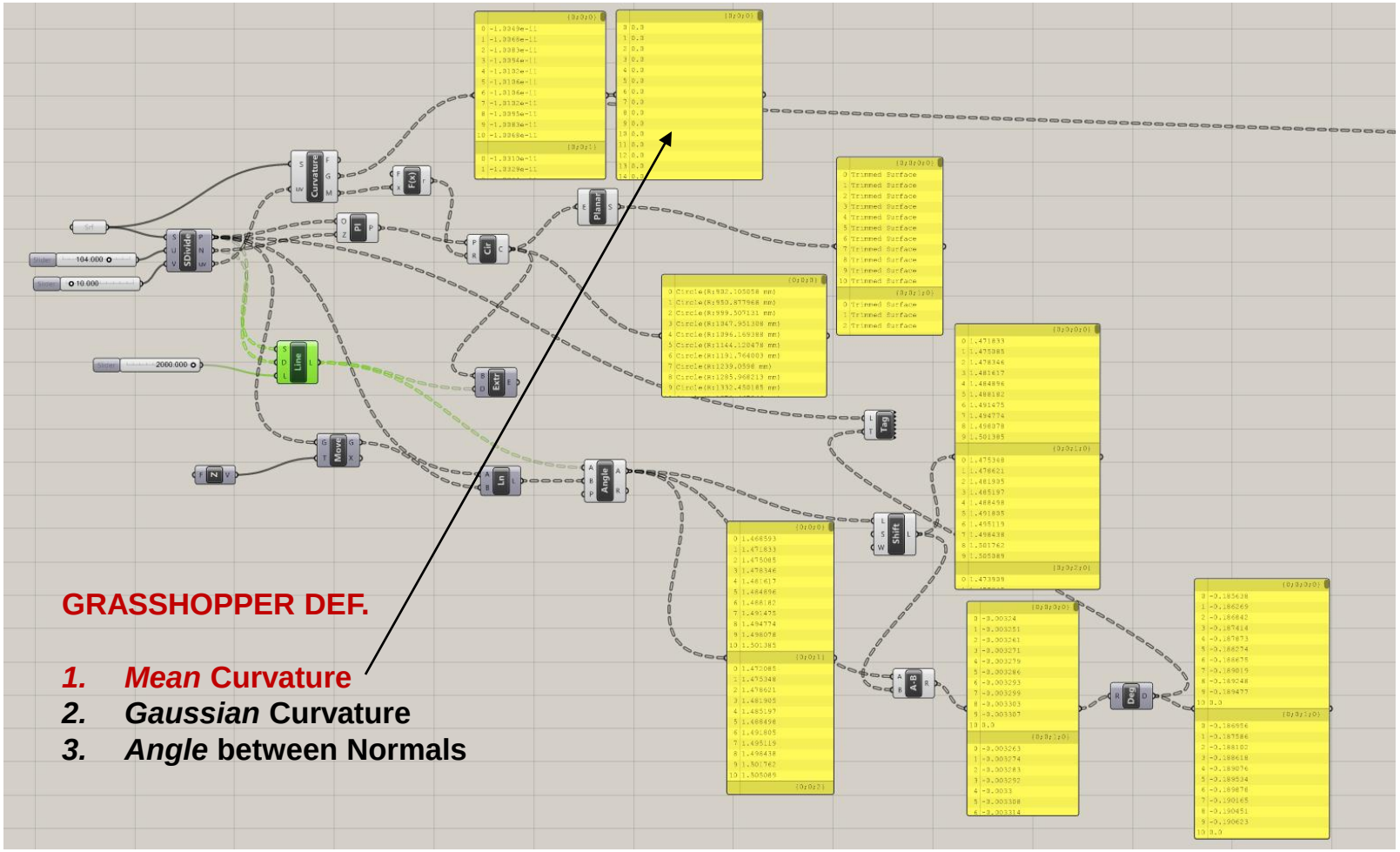


CALCULATION OF ANGLE BETWEEN NORMALS ON RULING LINES. If the angle between the normals is different from zero the surface is NOT developable.

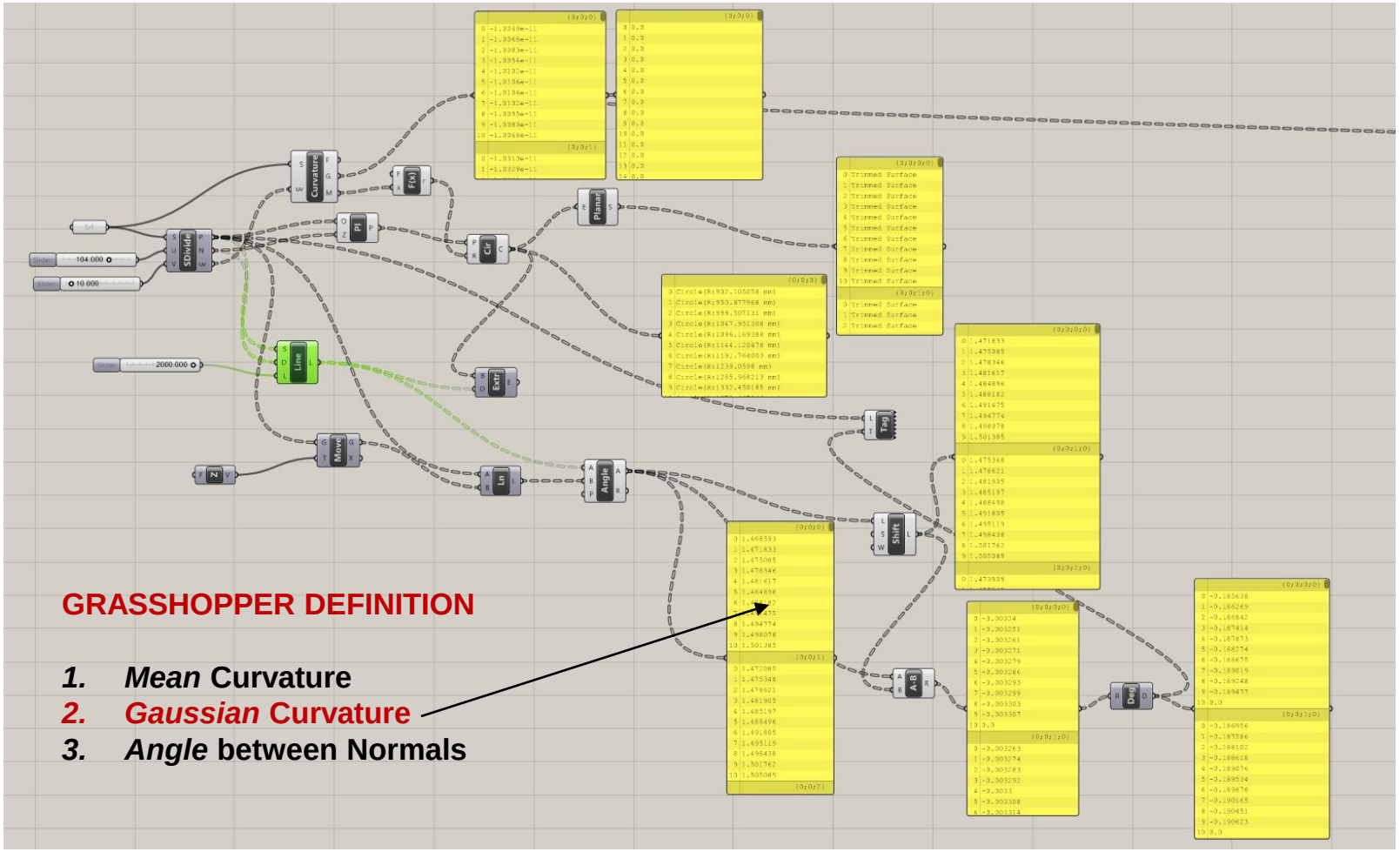
PARAMETRIC CONTROL



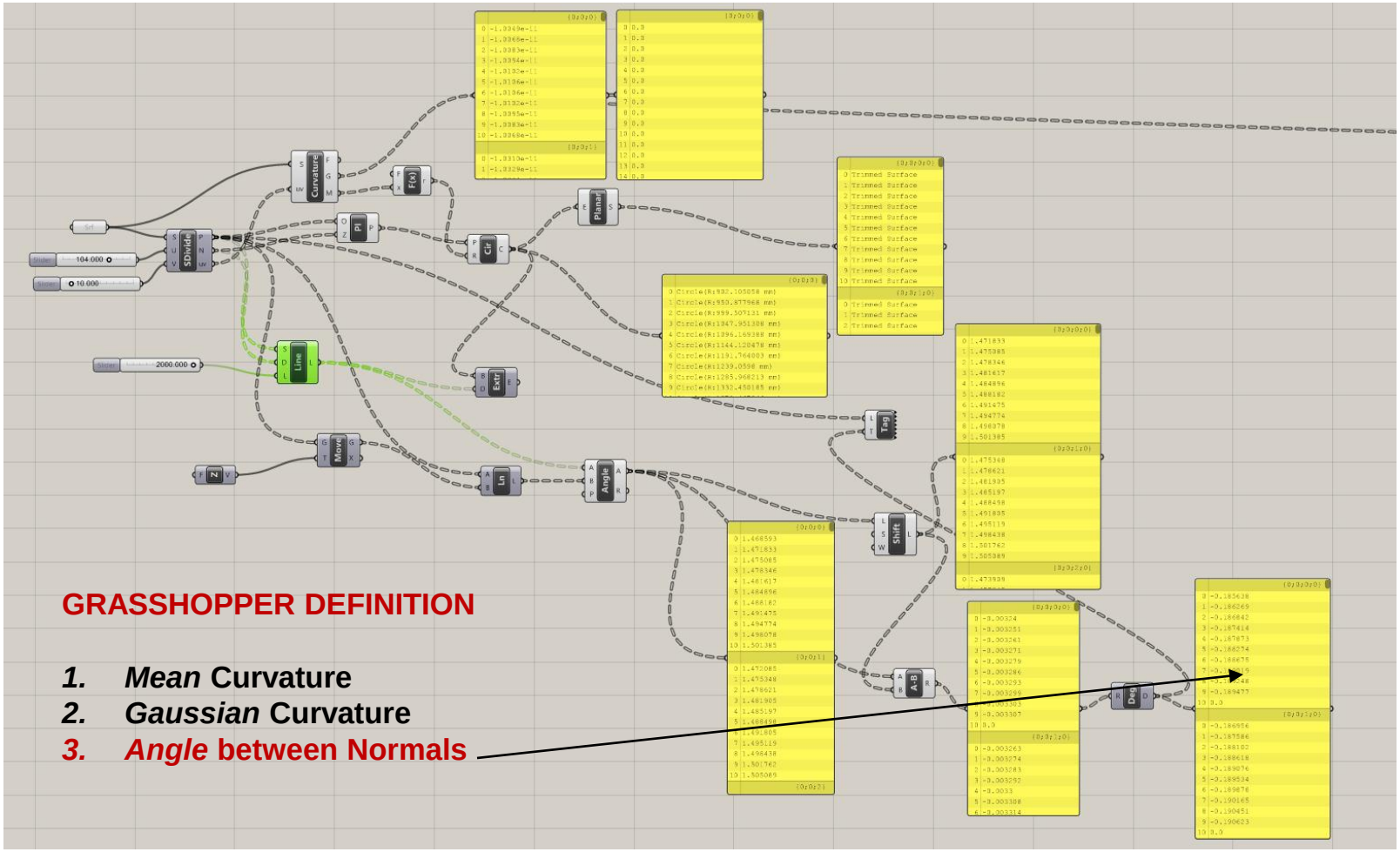
PARAMETRIC CONTROL



PARAMETRIC CONTROL



PARAMETRIC CONTROL

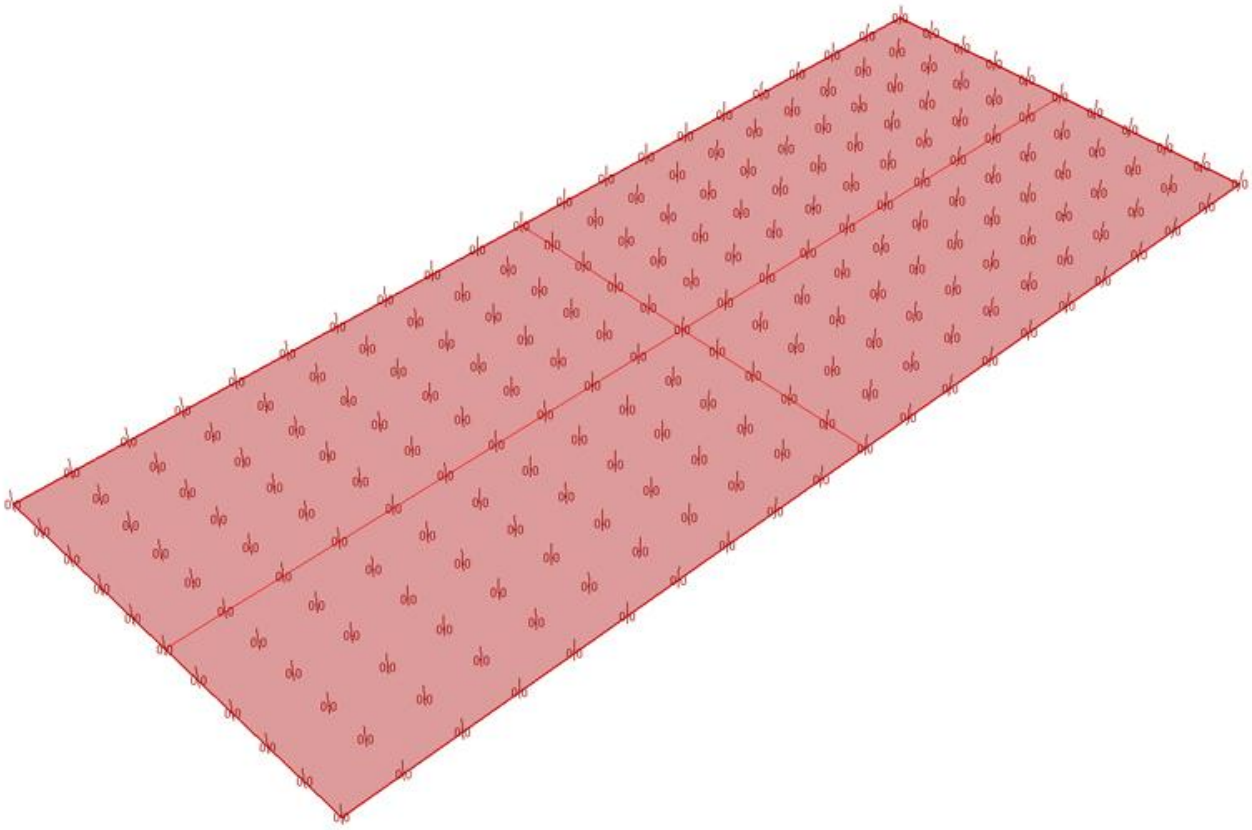


Cost-effective strategy to panelize a double curved surface

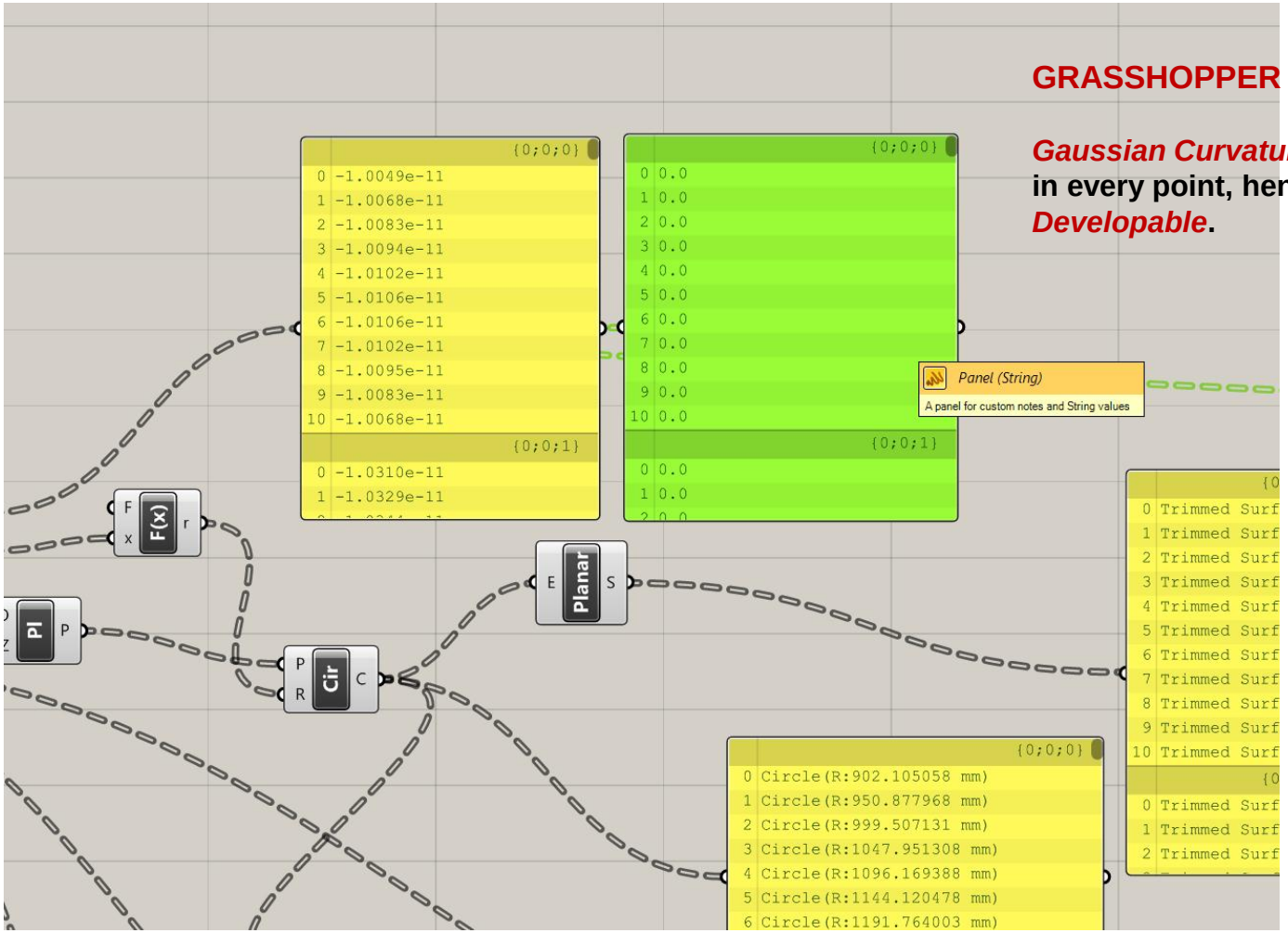
Lorenzo Marasso – Gensler Los Angeles

PARAMETRIC CONTROL

Application of Parametric Control to a Flat Surface



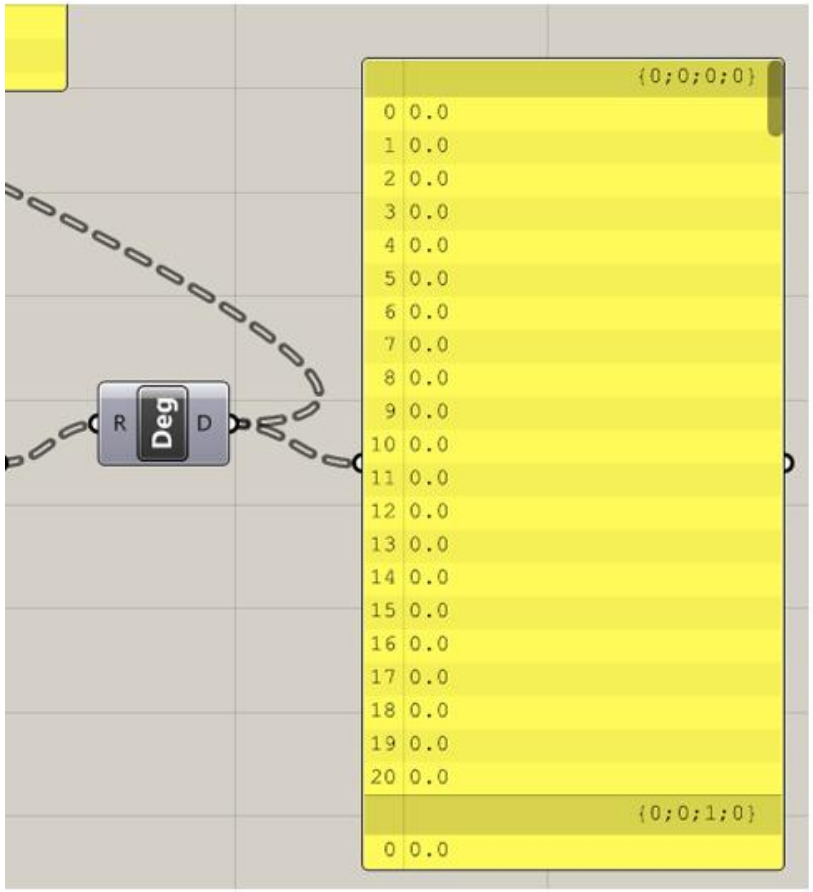
PARAMETRIC CONTROL



GRASSHOPPER DEFINITION

Gaussian Curvature **is equal to ZERO in every point, hence the surface IS** ***Developable*****.**

PARAMETRIC CONTROL

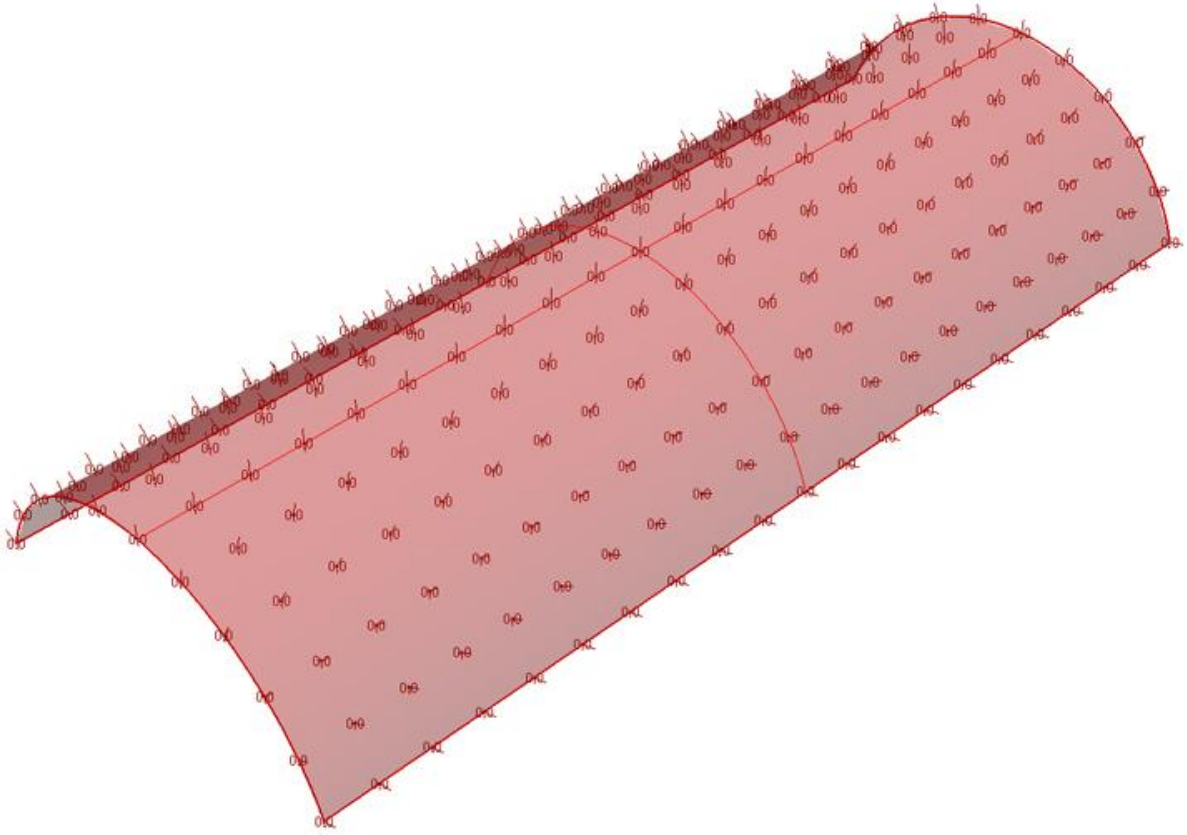


GRASSHOPPER DEFINITION

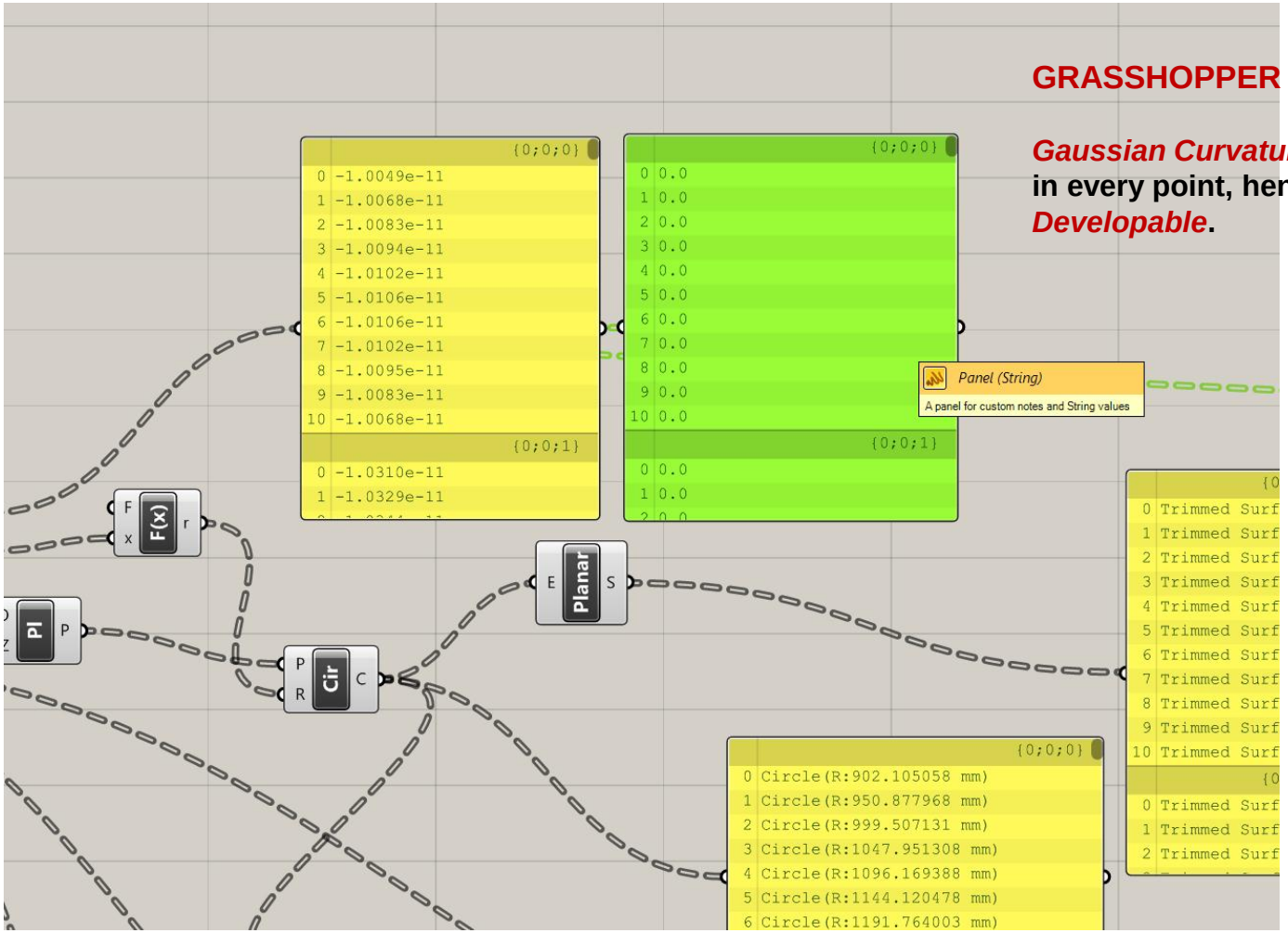
Angle between the normals **is equal to ZERO, hence the surface IS** ***Developable*****.**

PARAMETRIC CONTROL

Application of Parametric Control to a Linear Extruded Surface



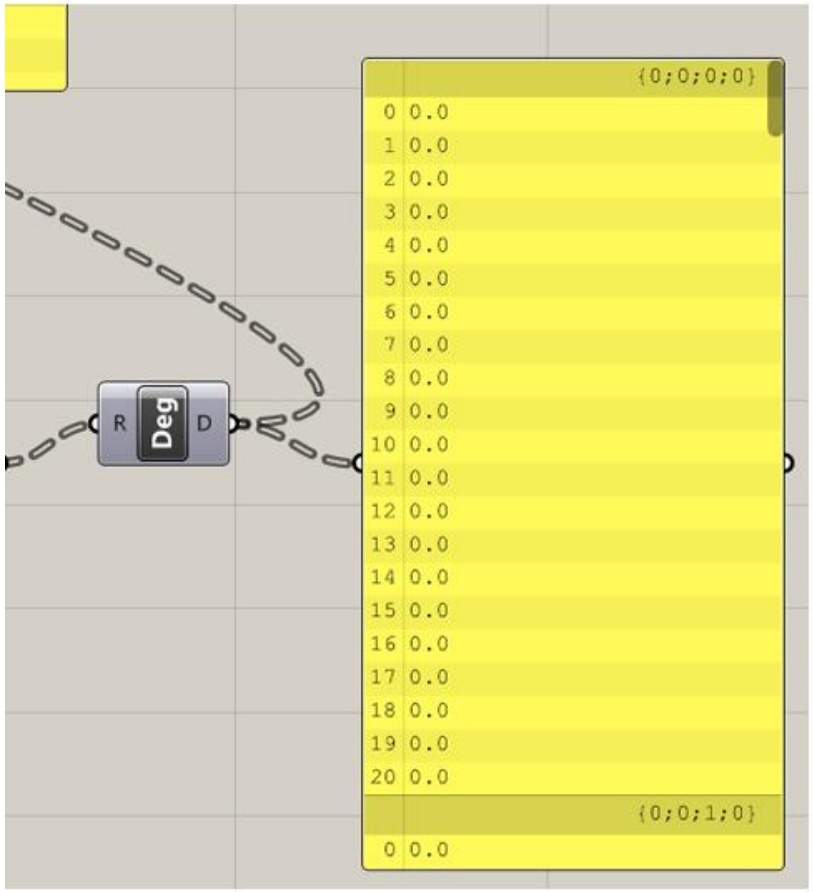
PARAMETRIC CONTROL



GRASSHOPPER DEFINITION

Gaussian Curvature **is equal to ZERO in every point, hence the surface IS** ***Developable*****.**

PARAMETRIC CONTROL

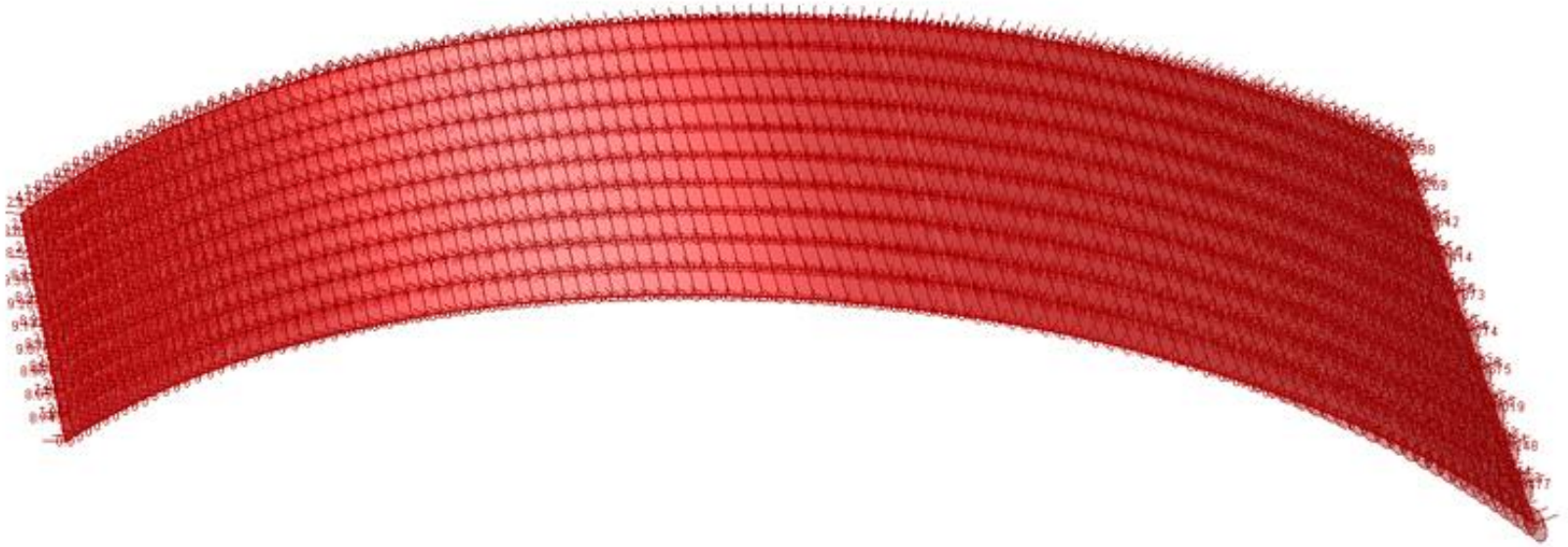


GRASSHOPPER DEFINITION

Angle between the normals **is equal to ZERO, hence the surface IS** ***Developable*****.**

PANELING DEFINITION – FROM SURFACE TO COMPONENT

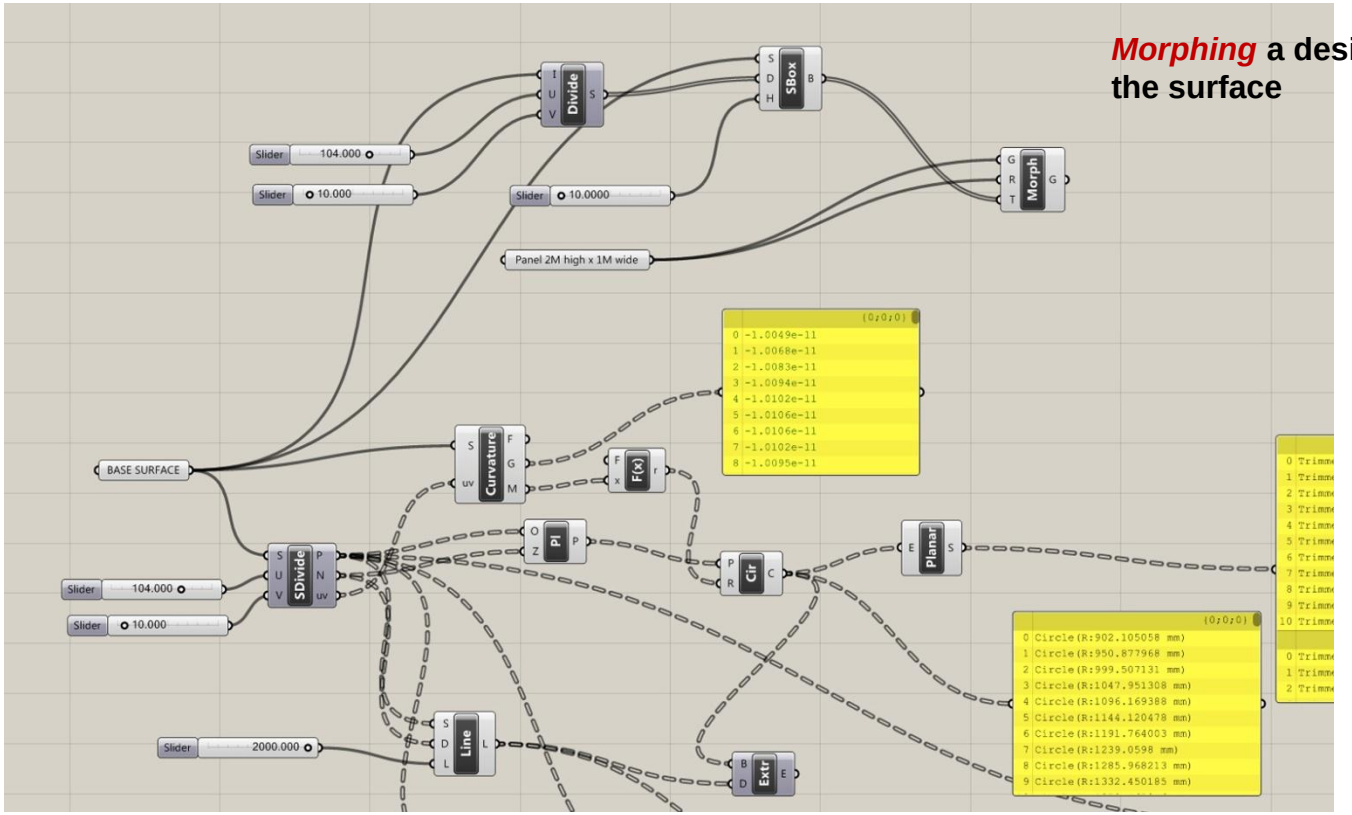
GRASSHOPPER DEFINITION



PANELING DEFINITION

GRASSHOPPER DEFINITION

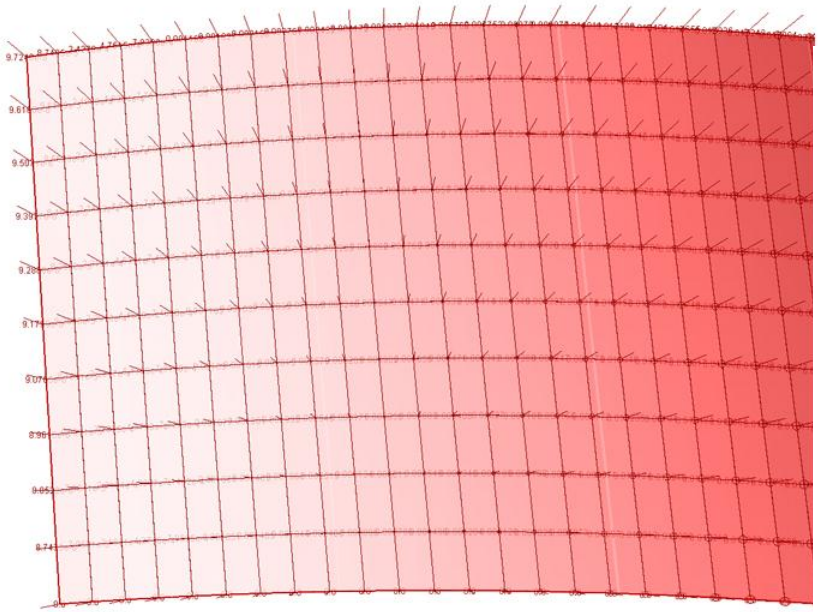
Morphing **a desired component across the surface**

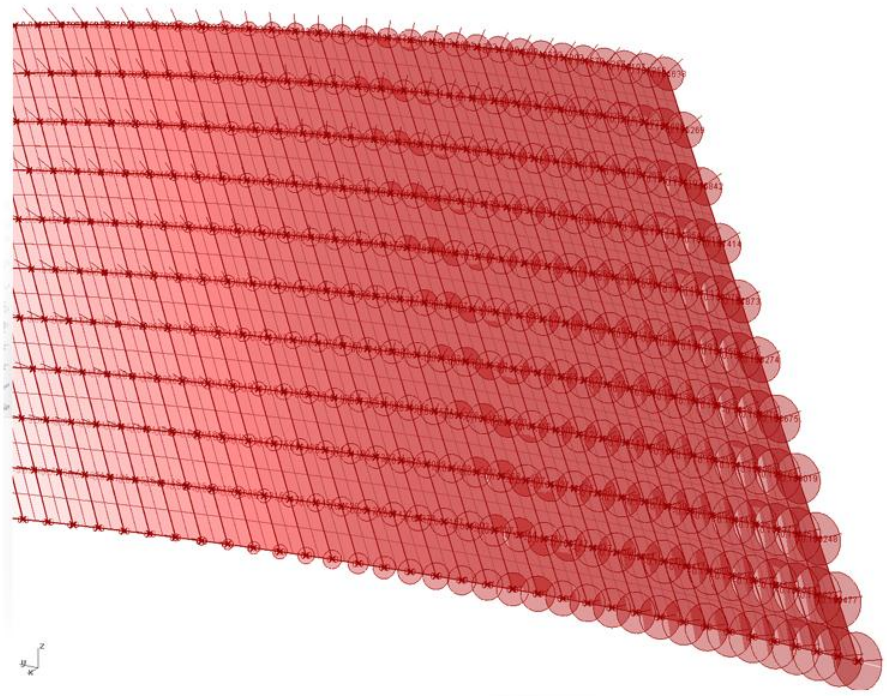


PANELING DEFINITION

GRASSHOPPER DEFINITION

Morphing **a desired component across the surface….results in unique panels that drift oblique when reaching one end**





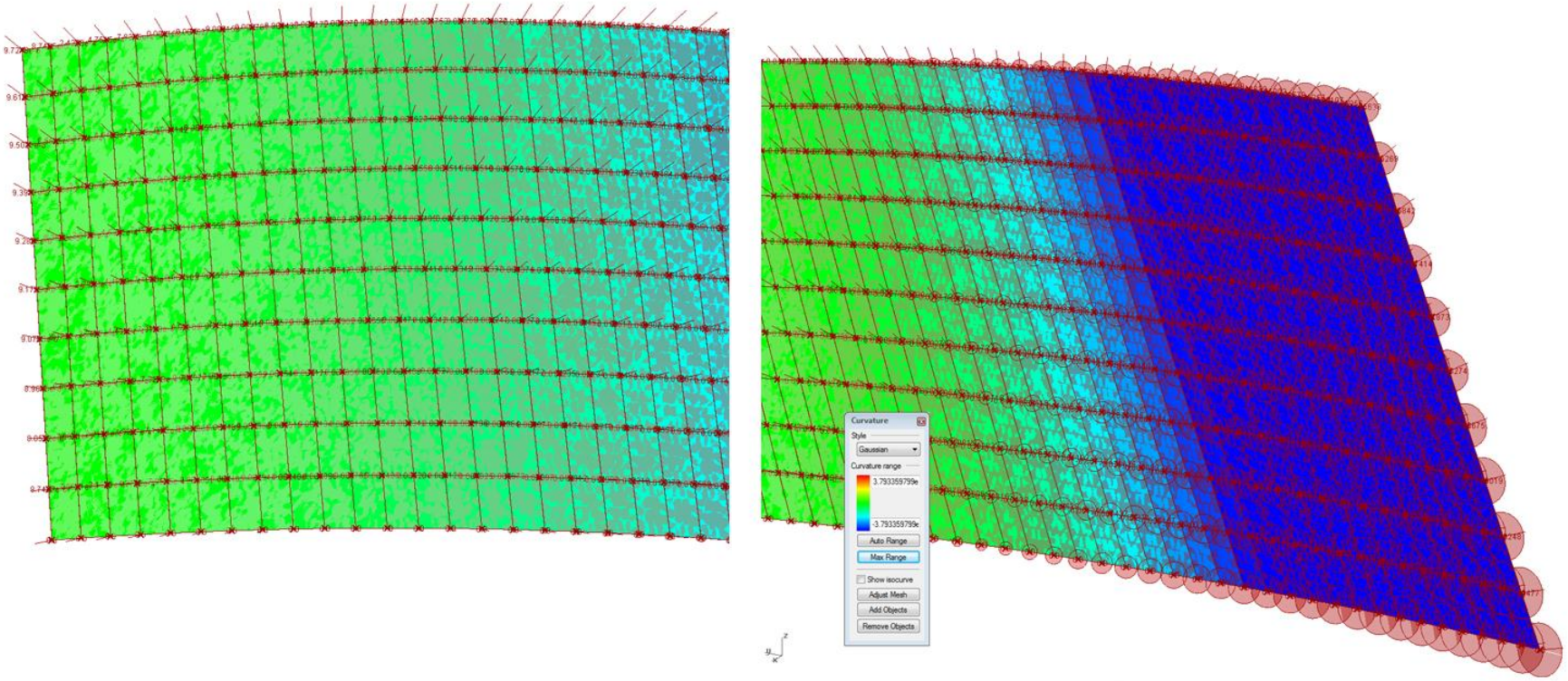
Cost-effective strategy to panelize a double curved surface

Lorenzo Marasso – Gensler Los Angeles

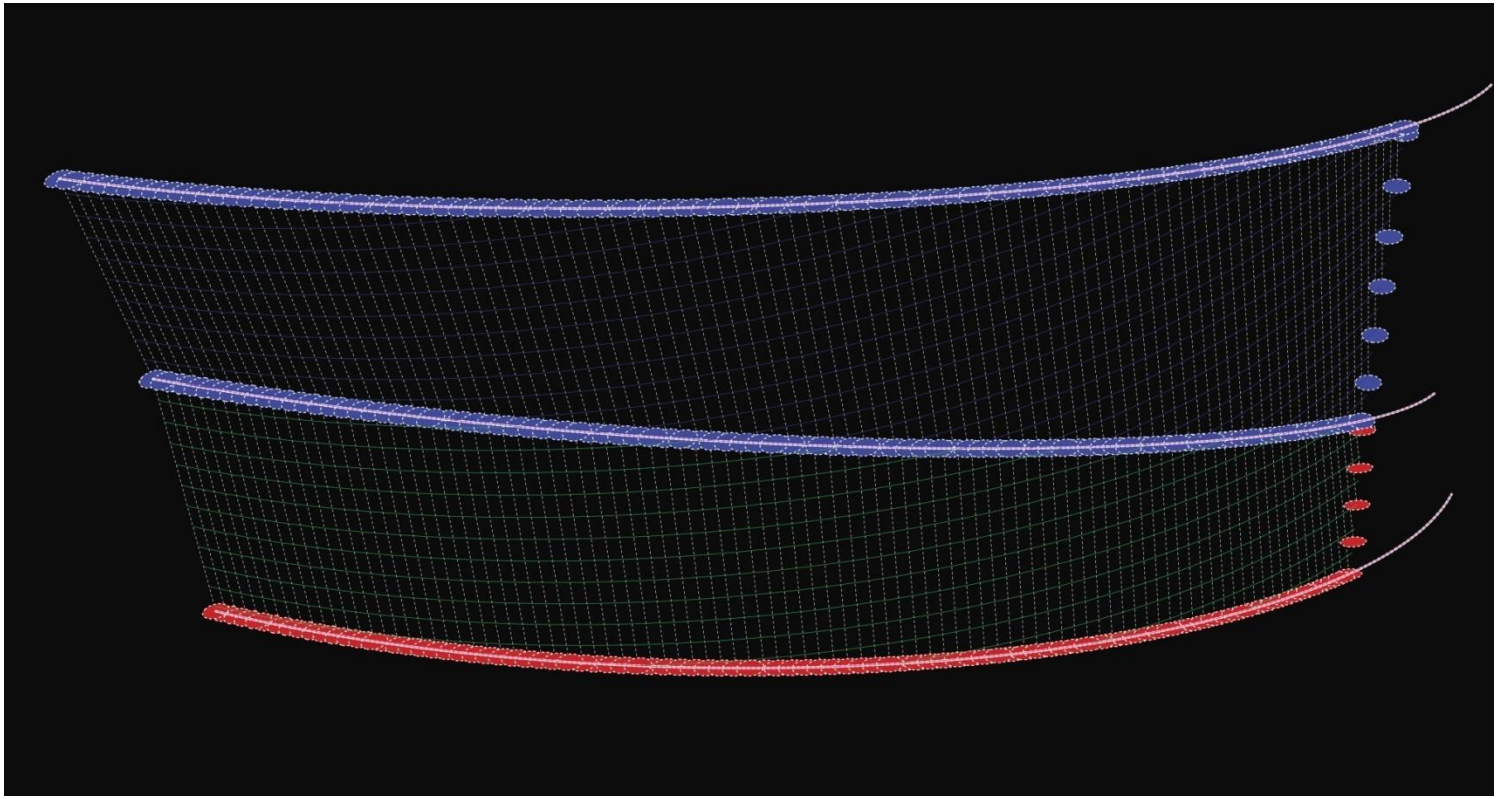
PANELING DEFINITION

PARAMETRIC CONTROL

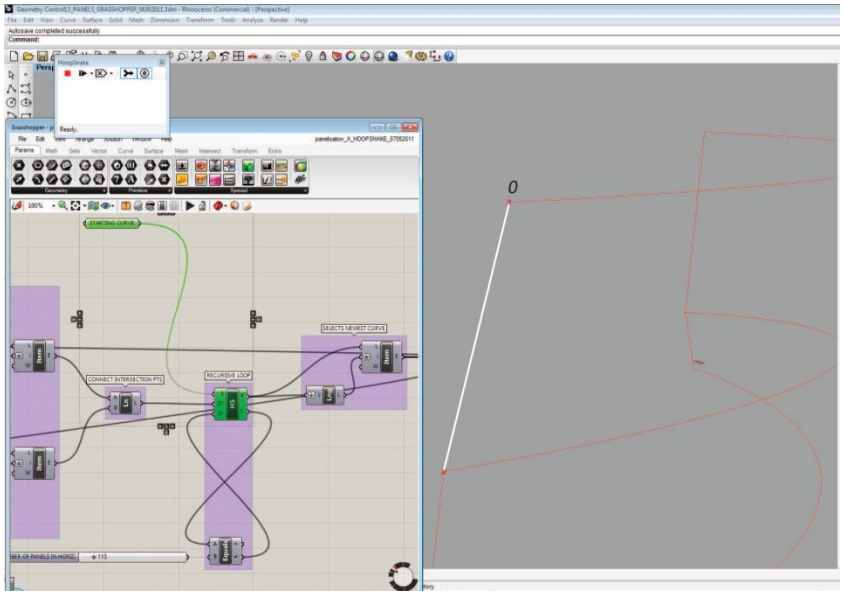
Gaussian Curvature **visually colors different values of curvature**



REBUILDING THE SURFACE'S WIREFRAME

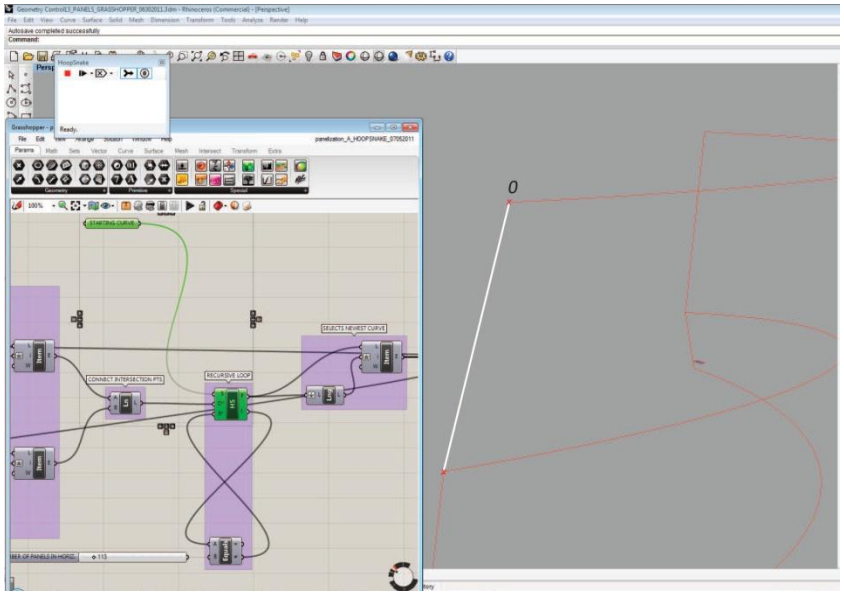


REBUILDING THE SURFACE'S WIREFRAME



STEP 1: Start with edge curve from surface

REBUILDING THE SURFACE'S WIREFRAME



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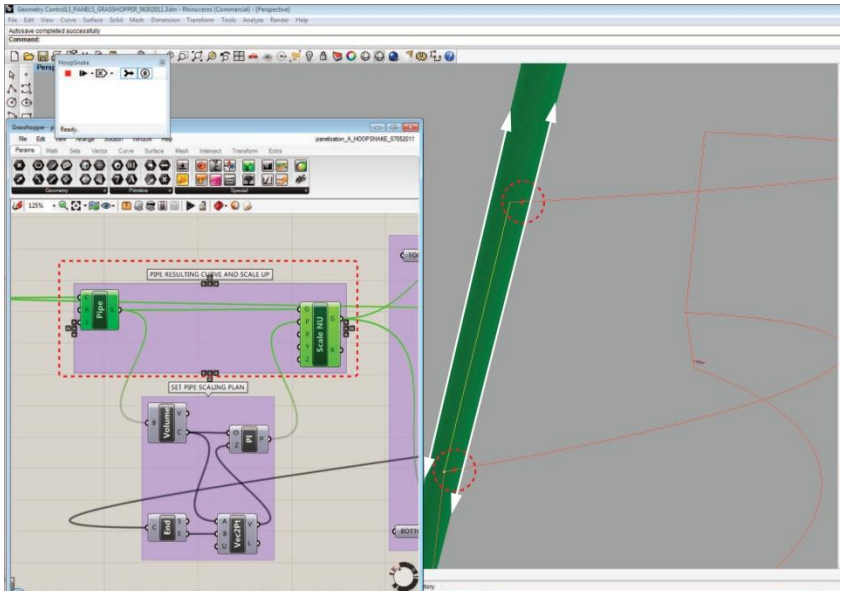
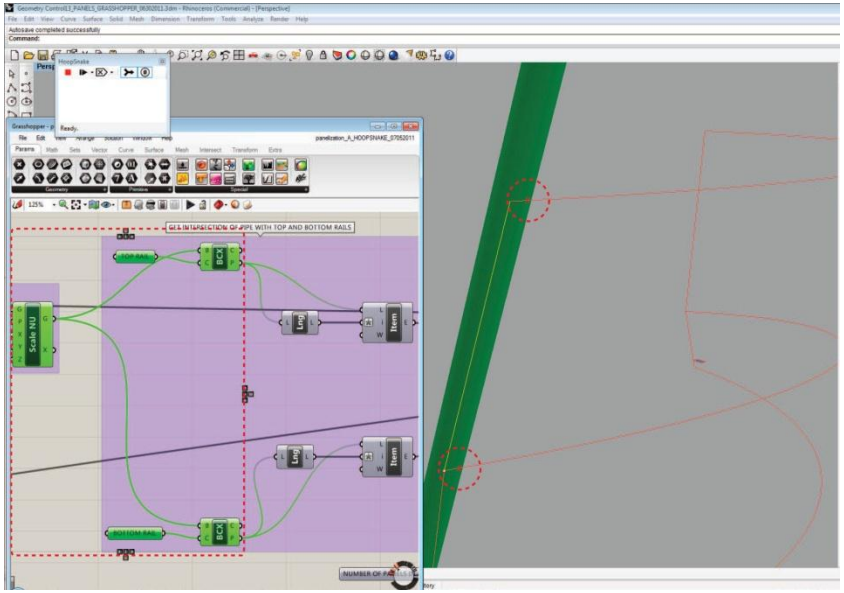


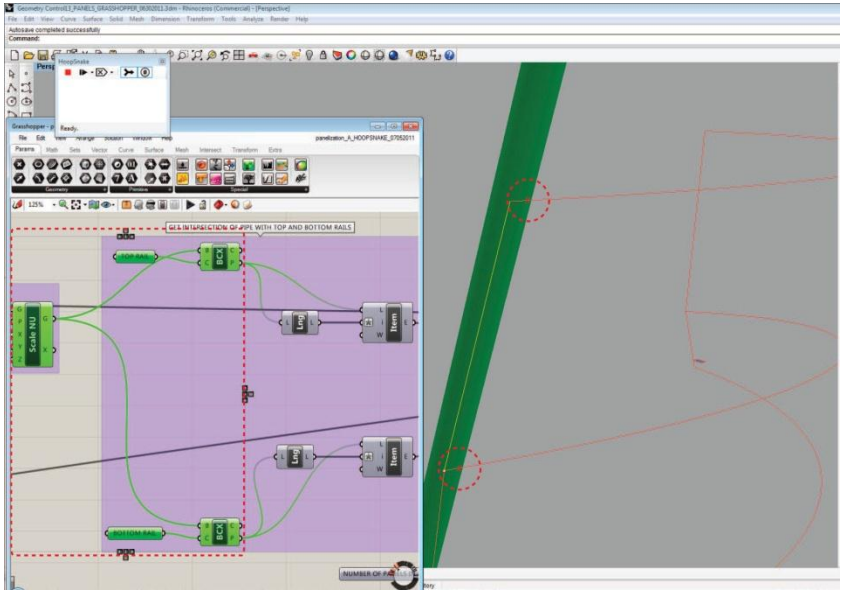
STEP 2: Pipe curve and scale it up so that the surface intersects with the top and bottom rail curves

REBUILDING THE SURFACE'S WIREFRAME

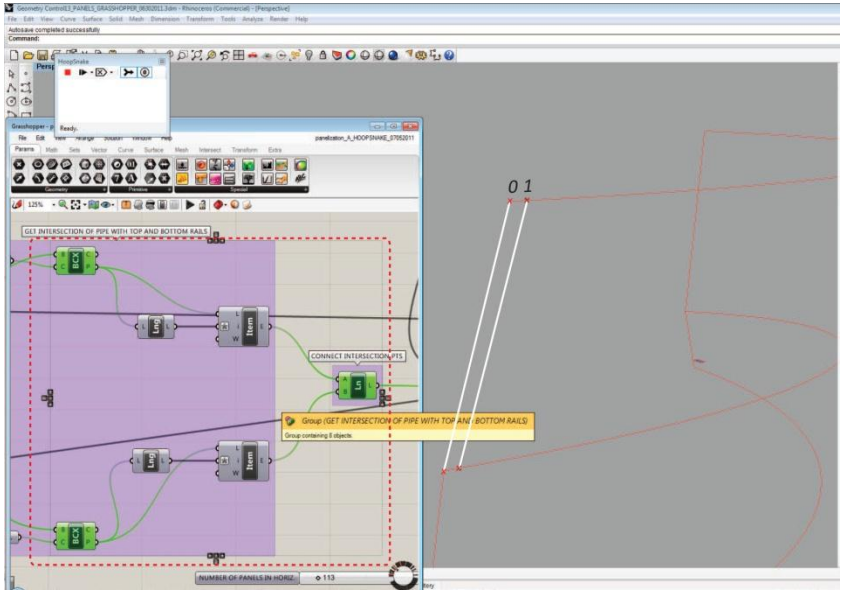


STEP 3: Get intersection points between top and bottom rail and pipe

REBUILDING THE SURFACE'S WIREFRAME

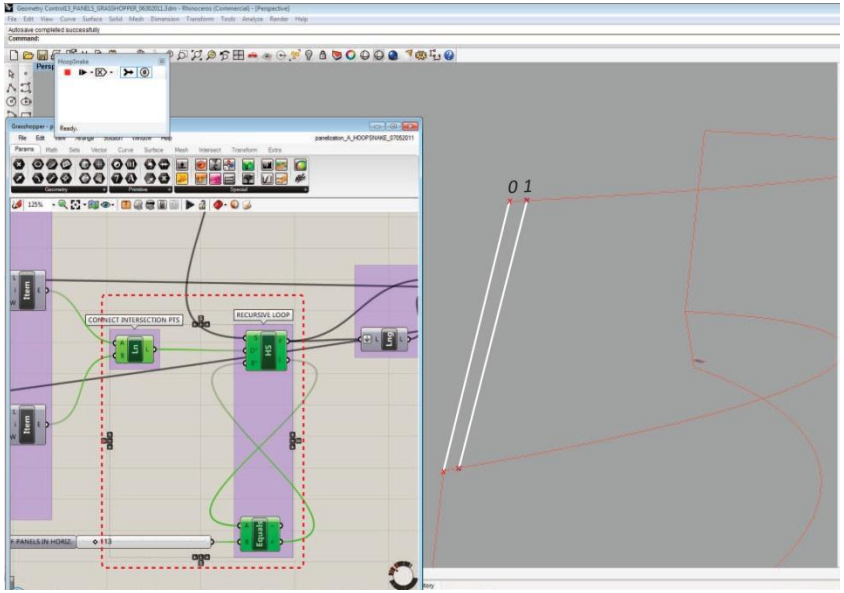


STEP 3: Get intersection points between top and bottom rail and pipe



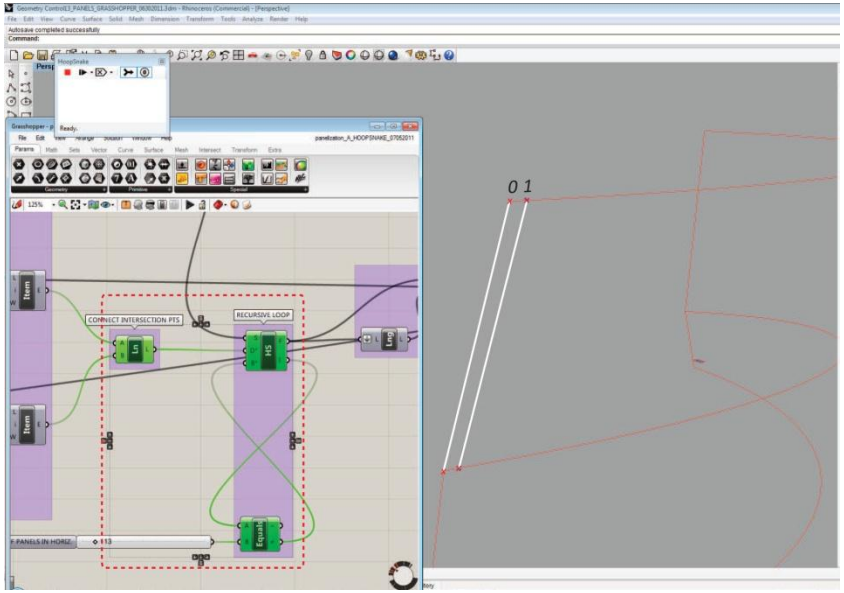
STEP 4: Draw new curve between intersection points

REBUILDING THE SURFACE'S WIREFRAME

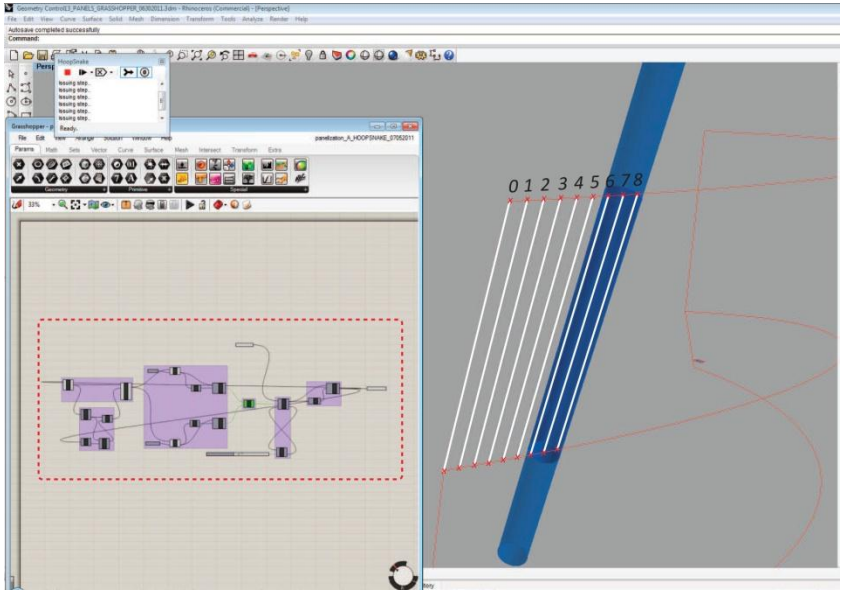


STEP 5: New curve goes into *RECURSIVE LOOP* function

REBUILDING THE SURFACE'S WIREFRAME

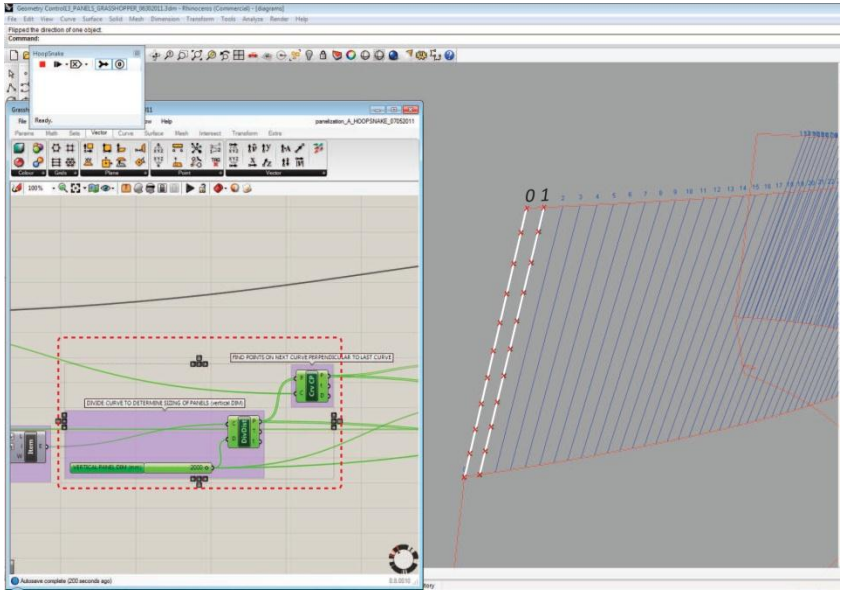


STEP 5: New curve goes into *RECURSIVE LOOP* function



STEP 6: REPEAT

REBUILDING THE SURFACE'S WIREFRAME



STEP 7: Use generated curves to begin paneling. The 1st crv is divide into 2000mm segments, then the closest point (perpendicular) on the next curve is found.

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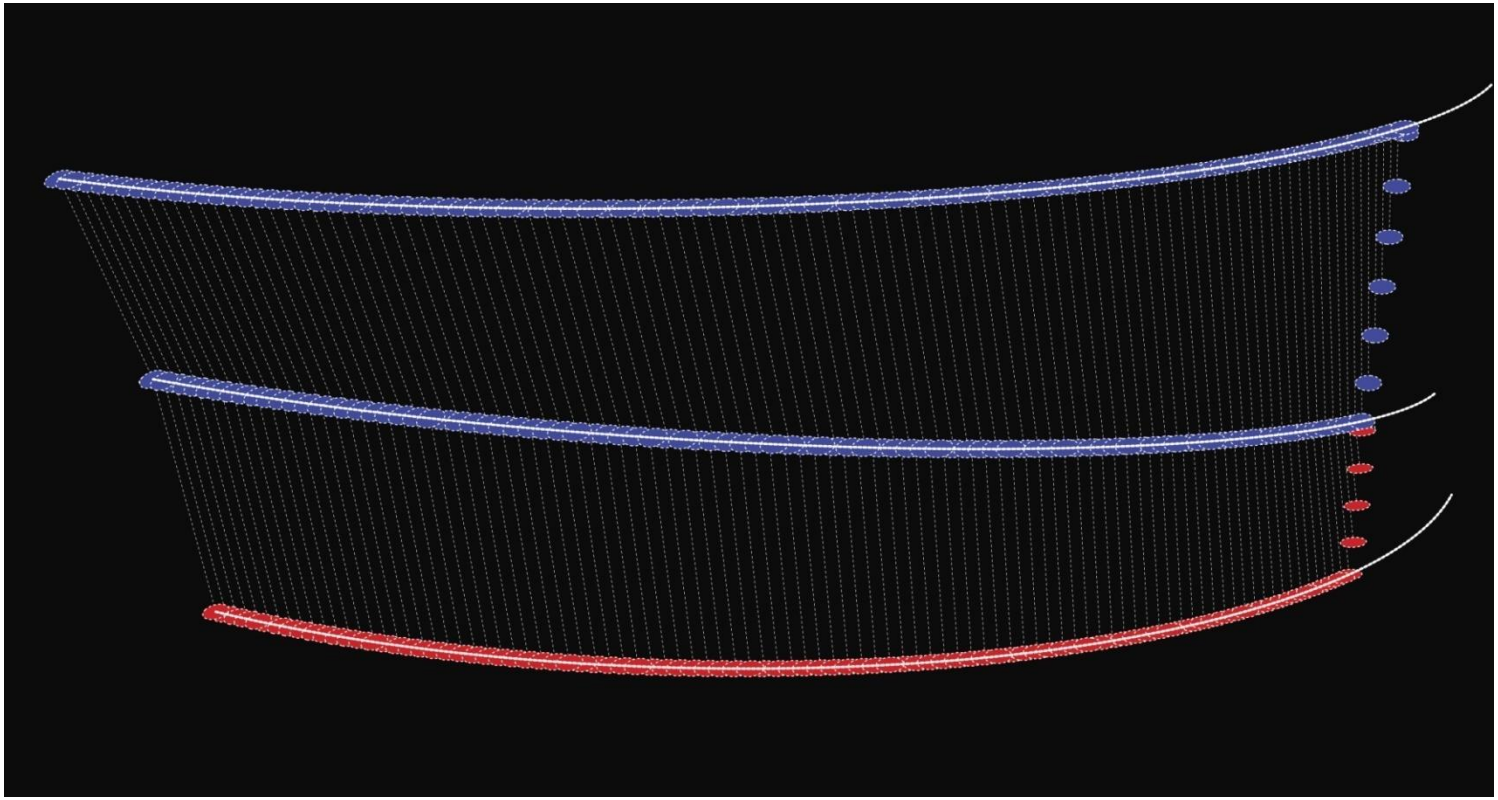

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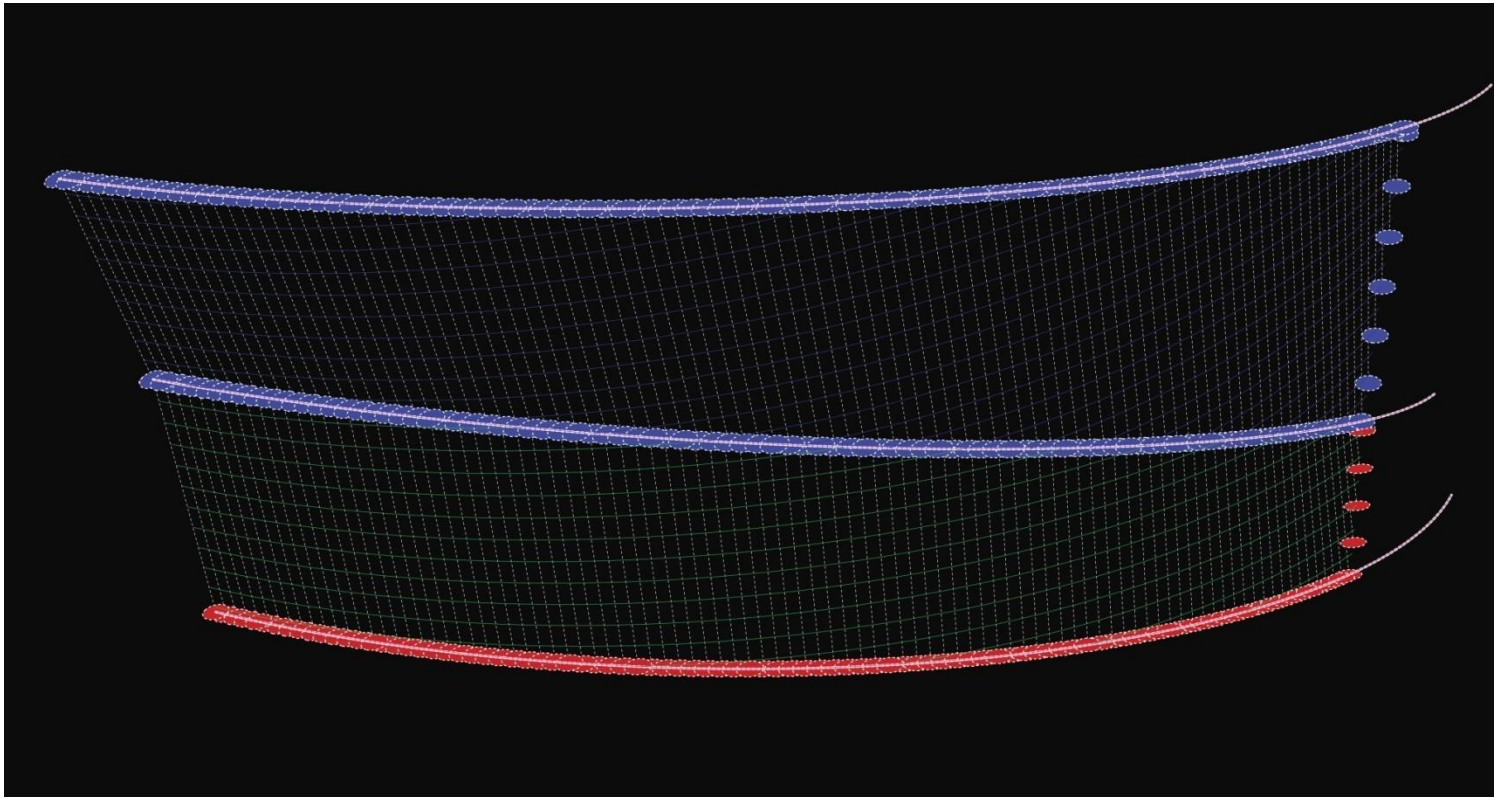
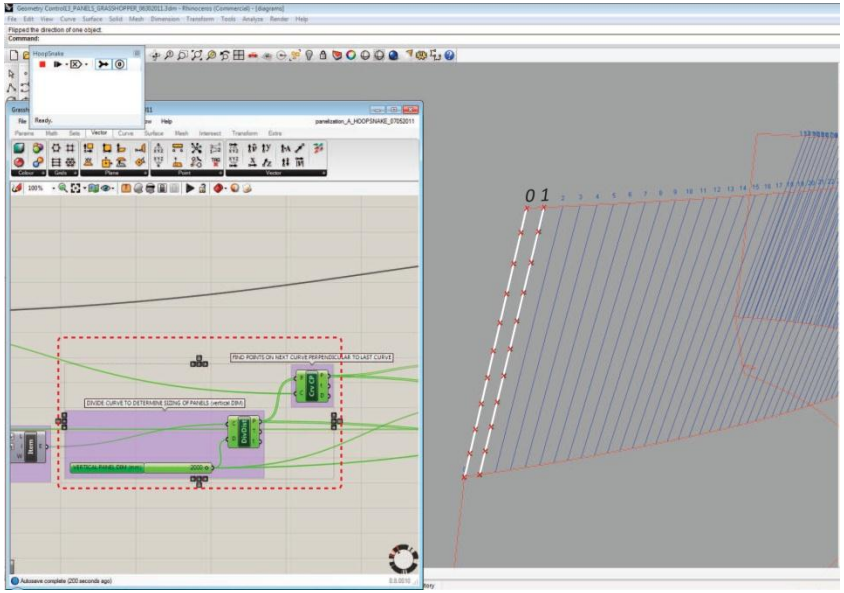


ARRAYING PANELS OVER THE SURFACE



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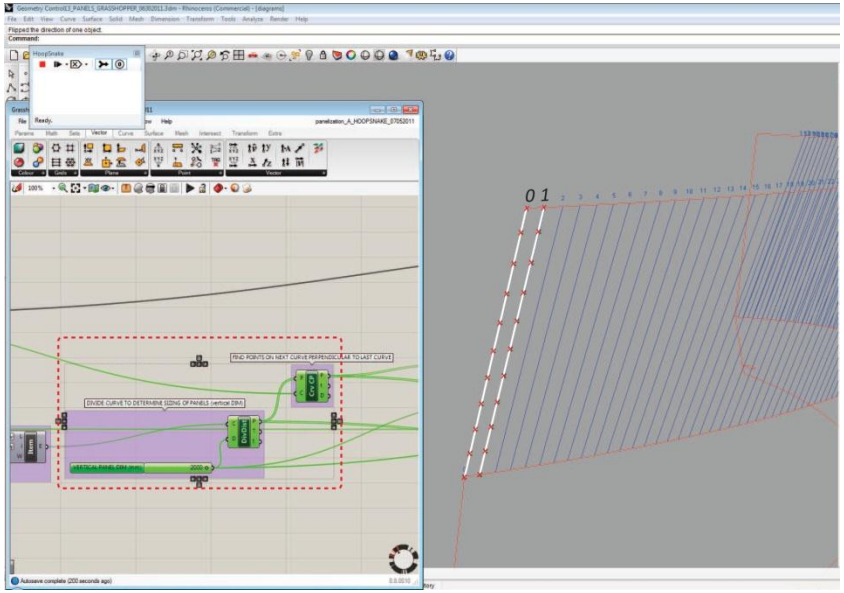

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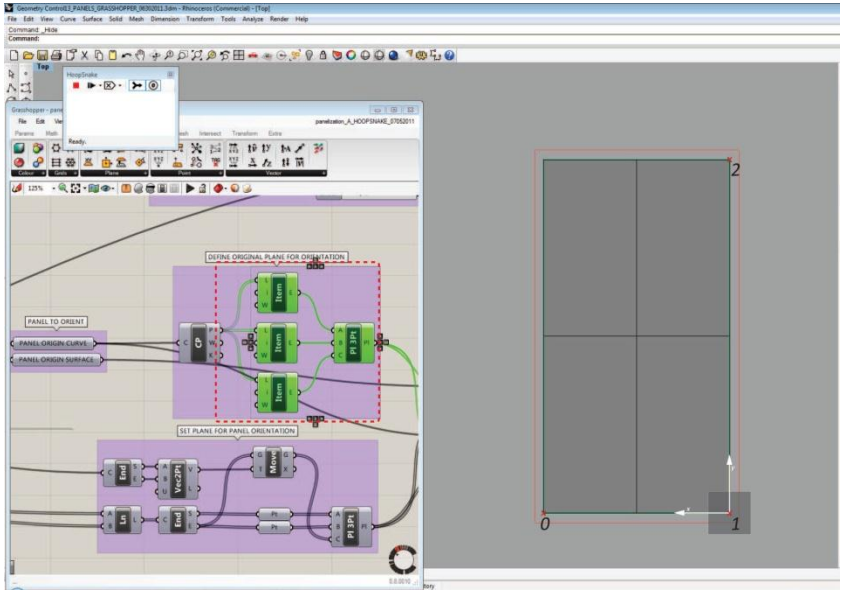
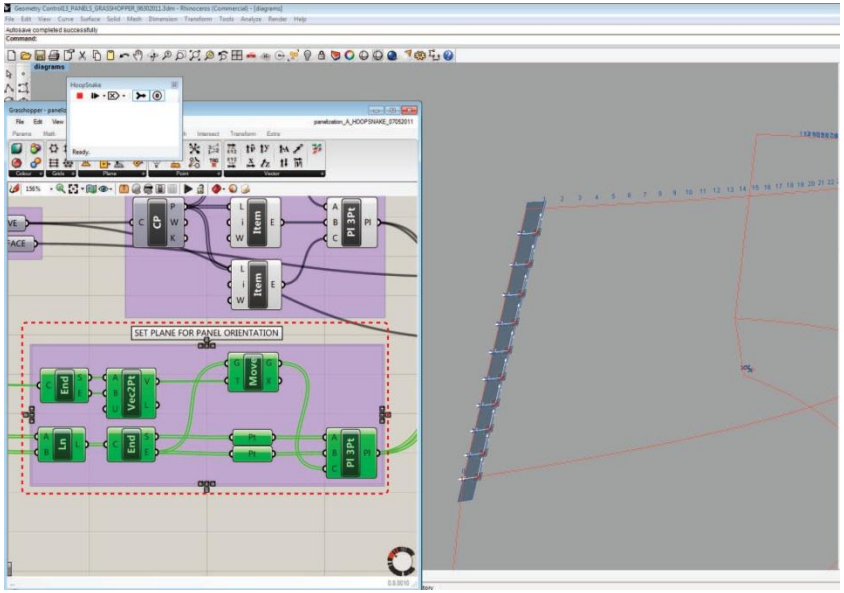
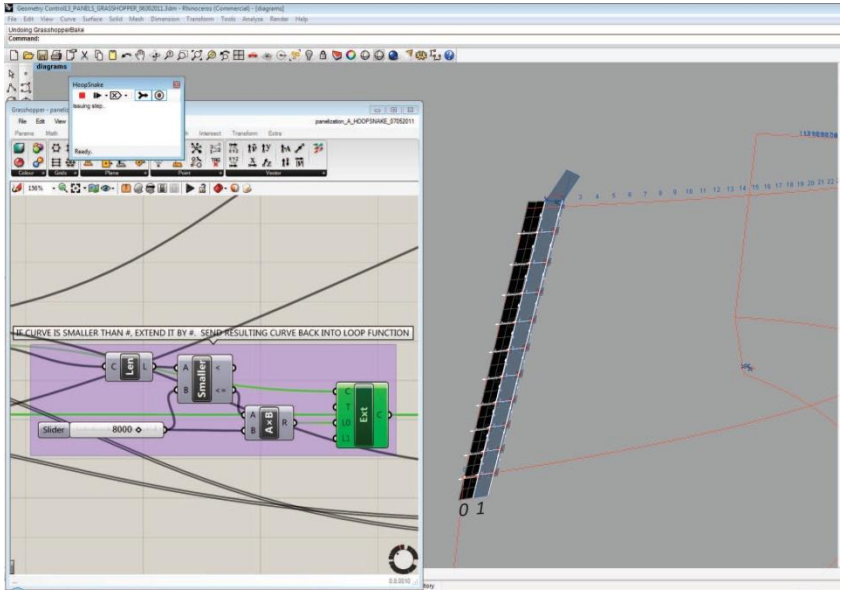


STEP 8: Define a reference plane to orient the panel from .

ARRAYING PANELS OVER THE SURFACE

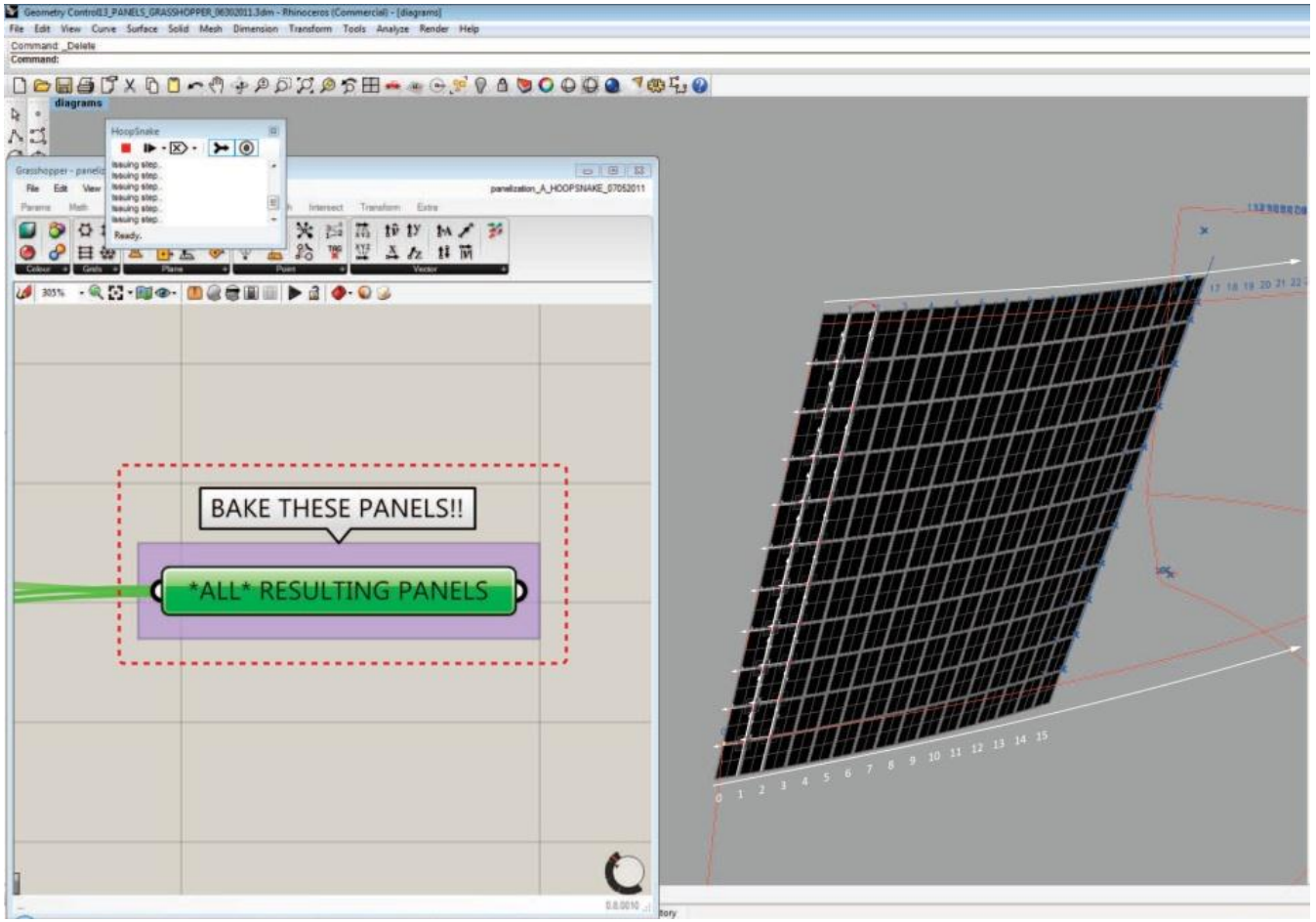


STEP 9: Orient panels to generated points. This ensures that each panel is perpendicular to its adjacent panels.



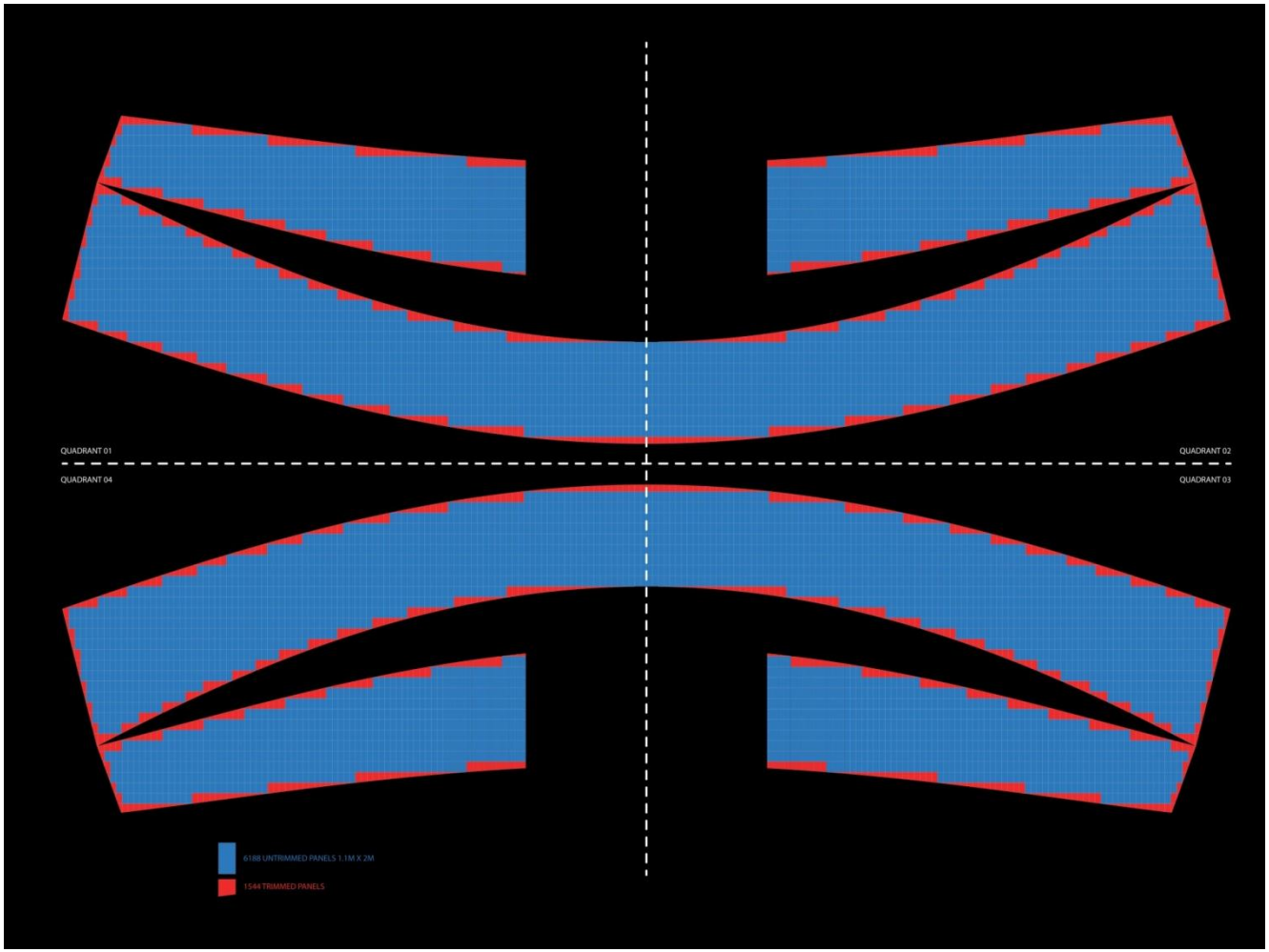
STEP 10: Take the last vertical curve and send it back to the *RECURSIVE LOOP*.

ARRAYING PANELS OVER THE SURFACE



STEP 11: REPEAT until all panels are arrayed over the surface

ARRAYING PANELS OVER THE SURFACE



Cost-effective strategy to panelize a double curved surface

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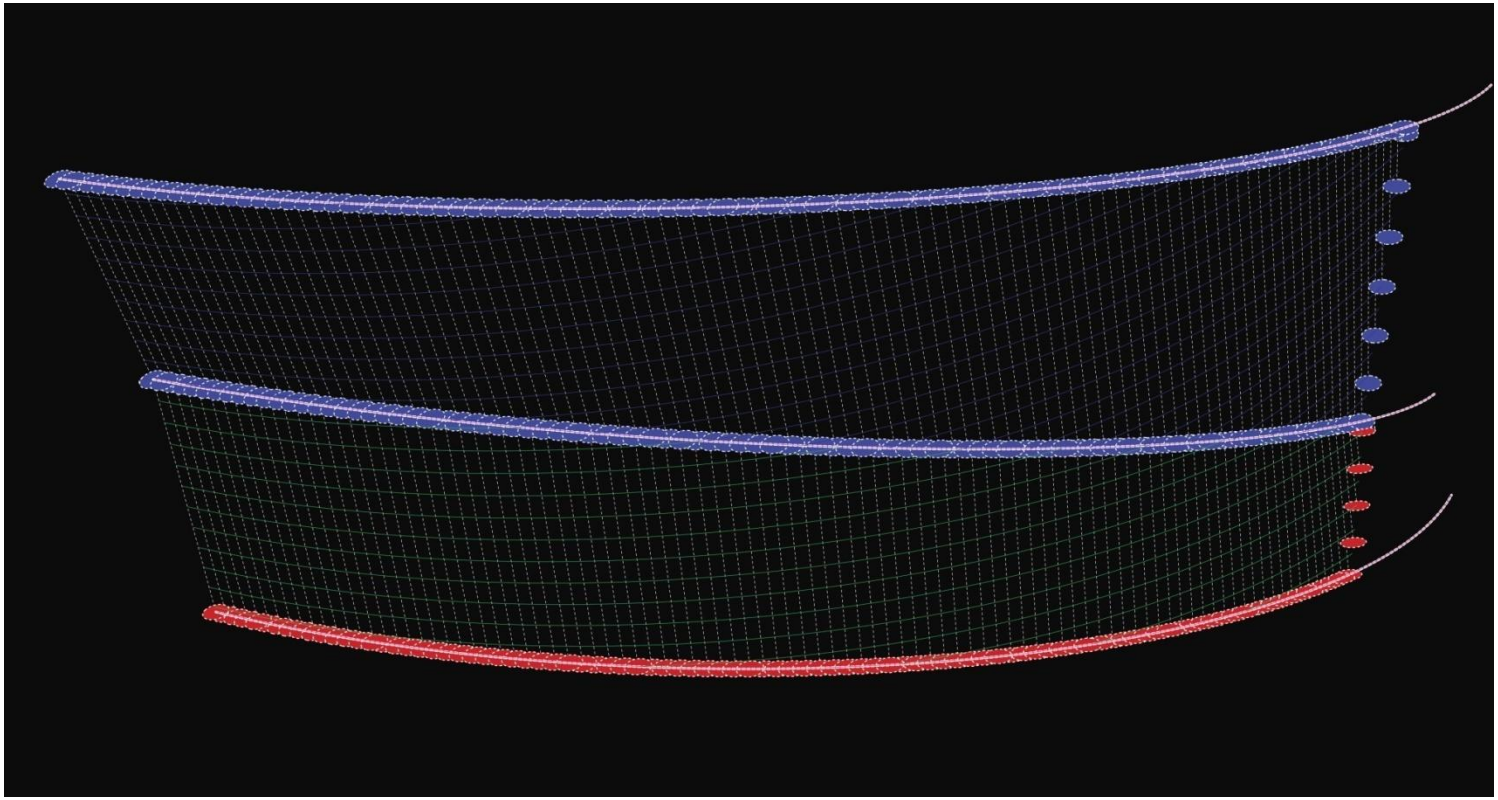
COLD BENDING



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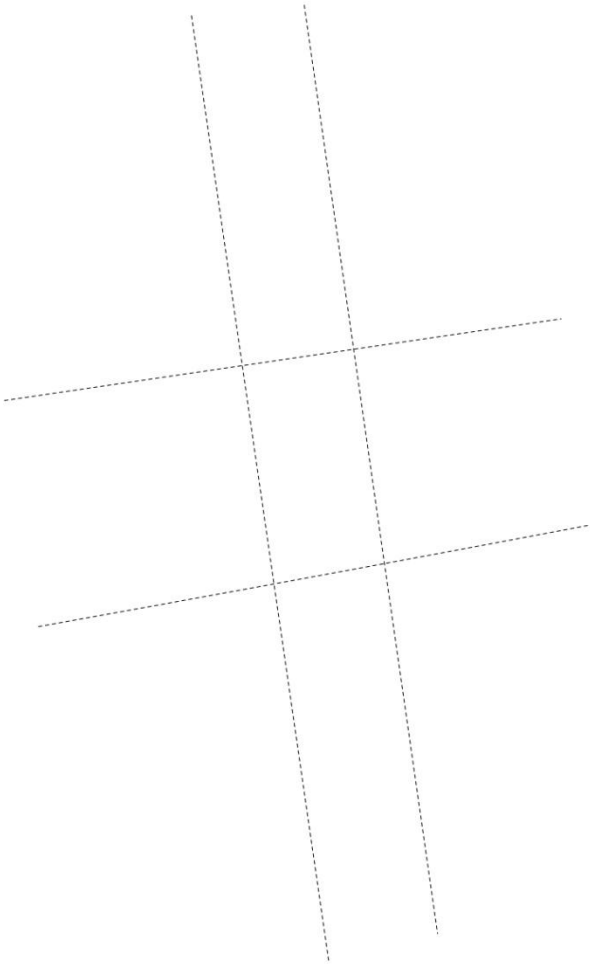

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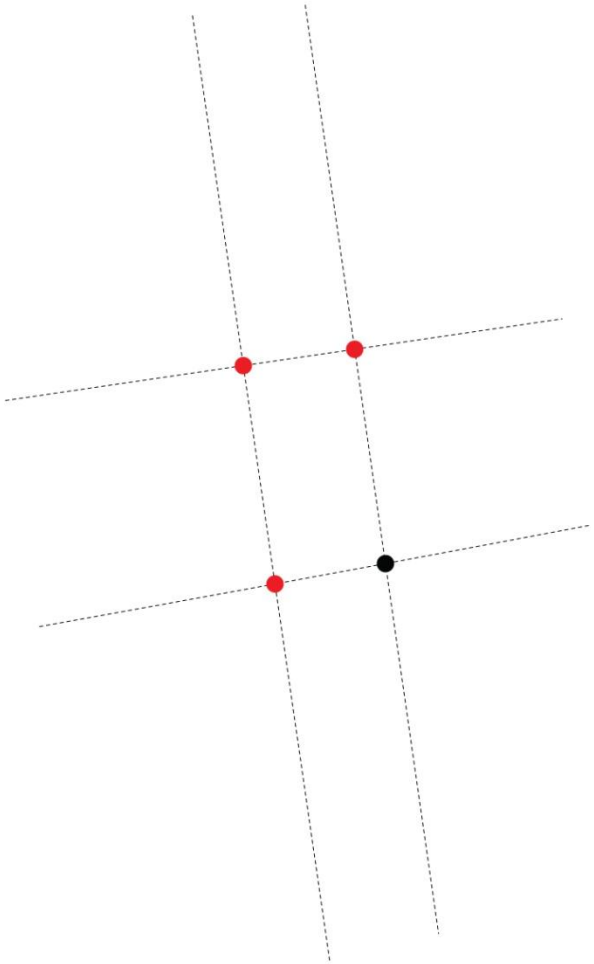

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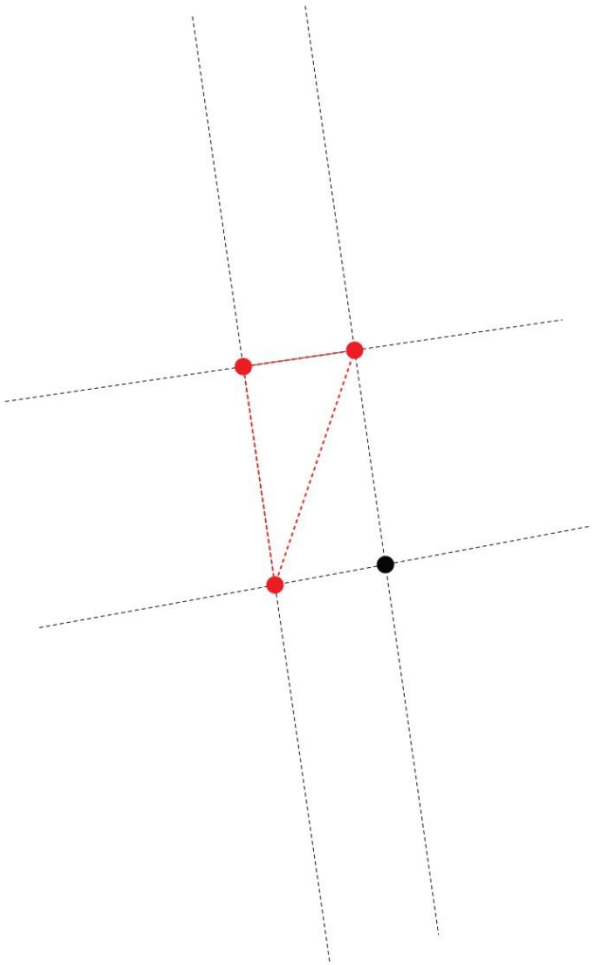

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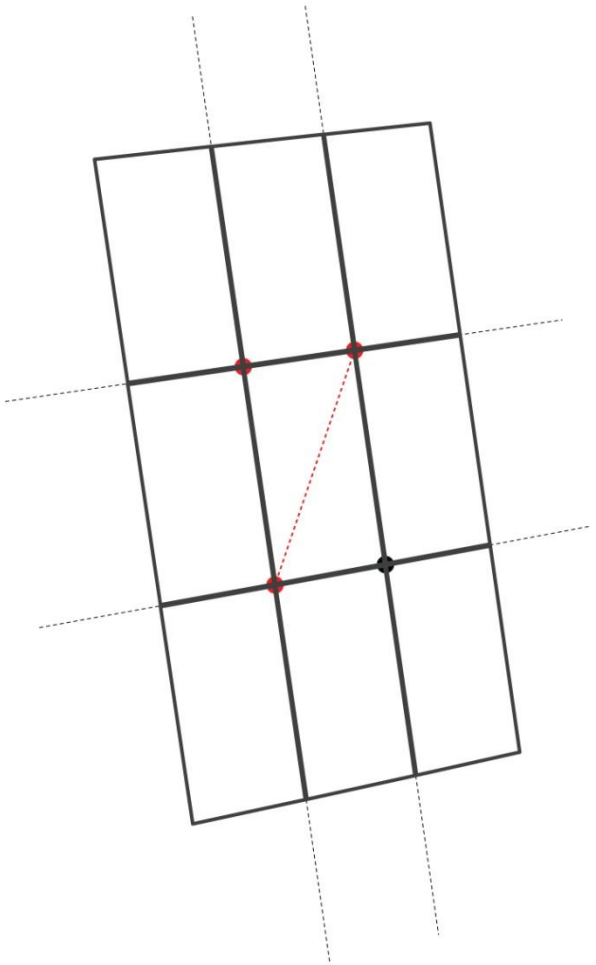

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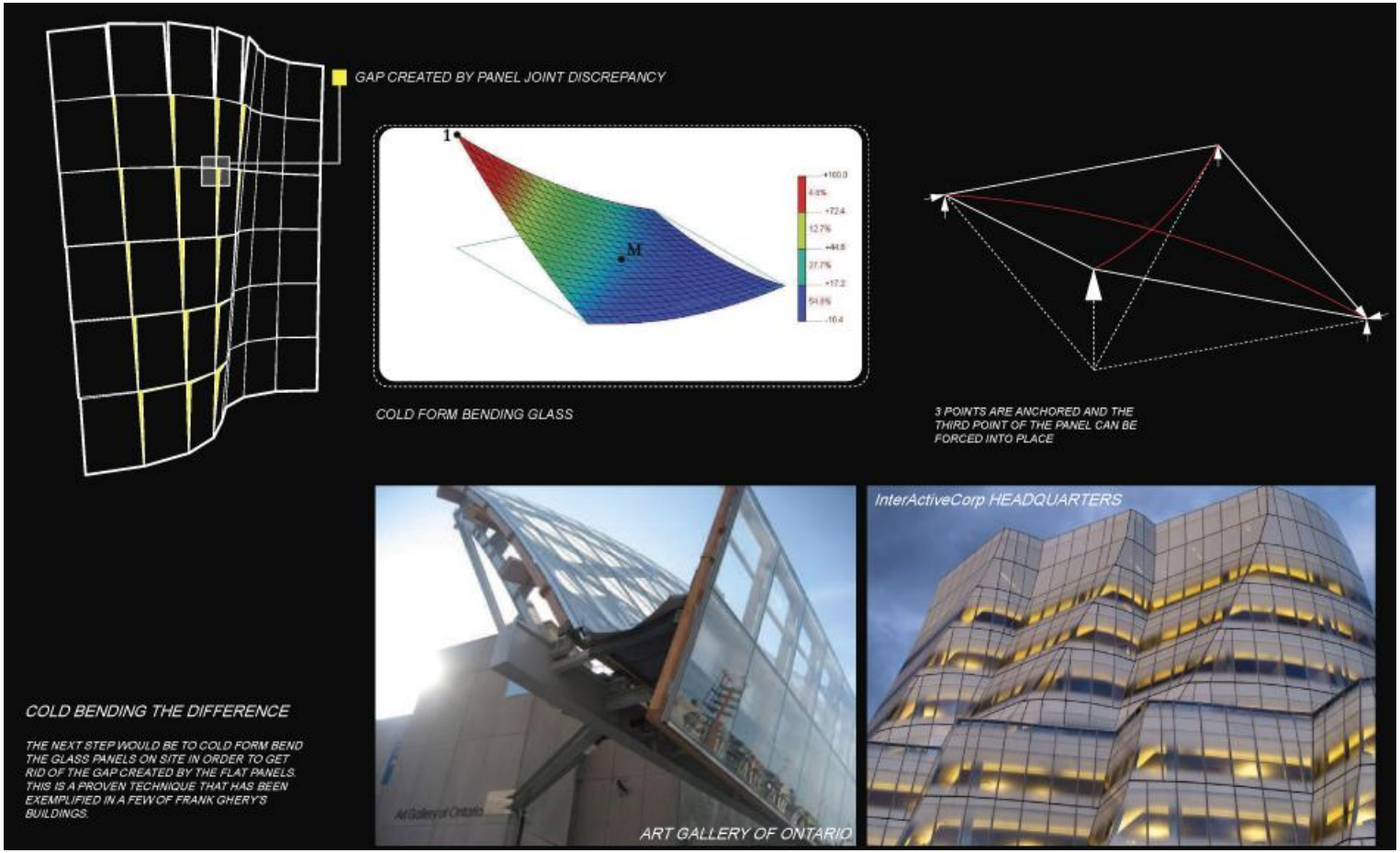
COLD BENDING



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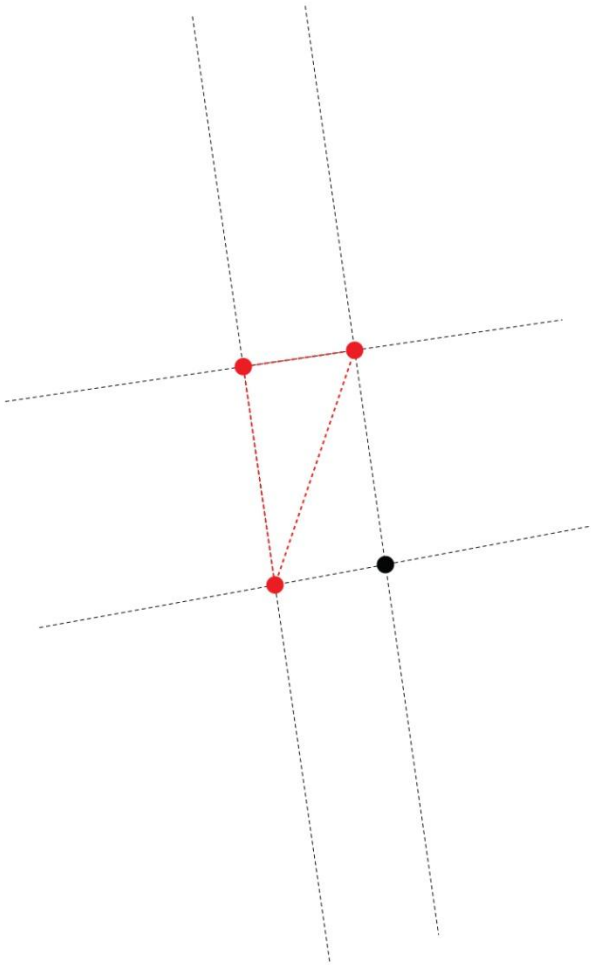

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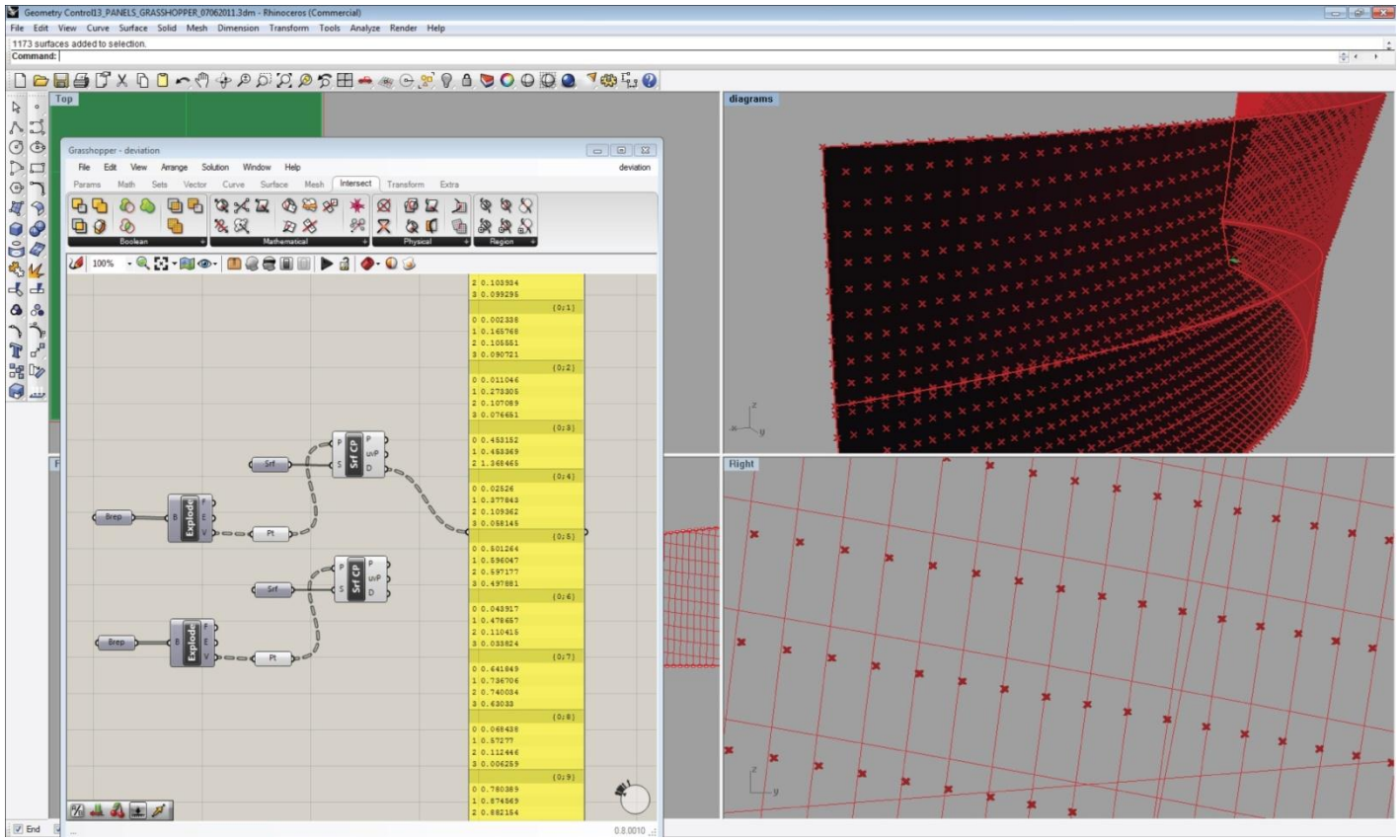

Cost-effective strategy to panelize a double curved surface

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COLD BENDING

Cost-effective strategy to panelize a double curved surface

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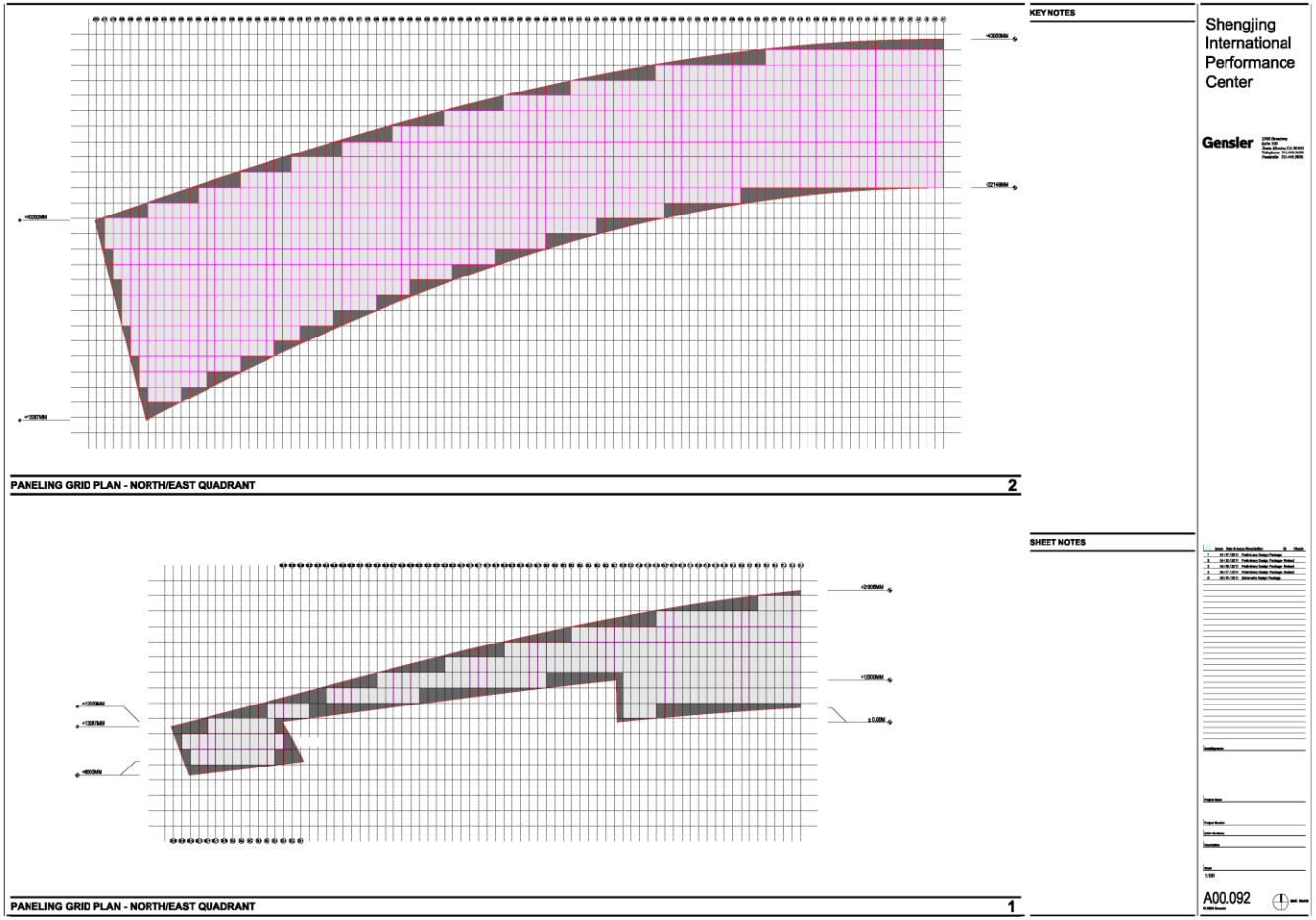
FINAL DOCUMENTATION



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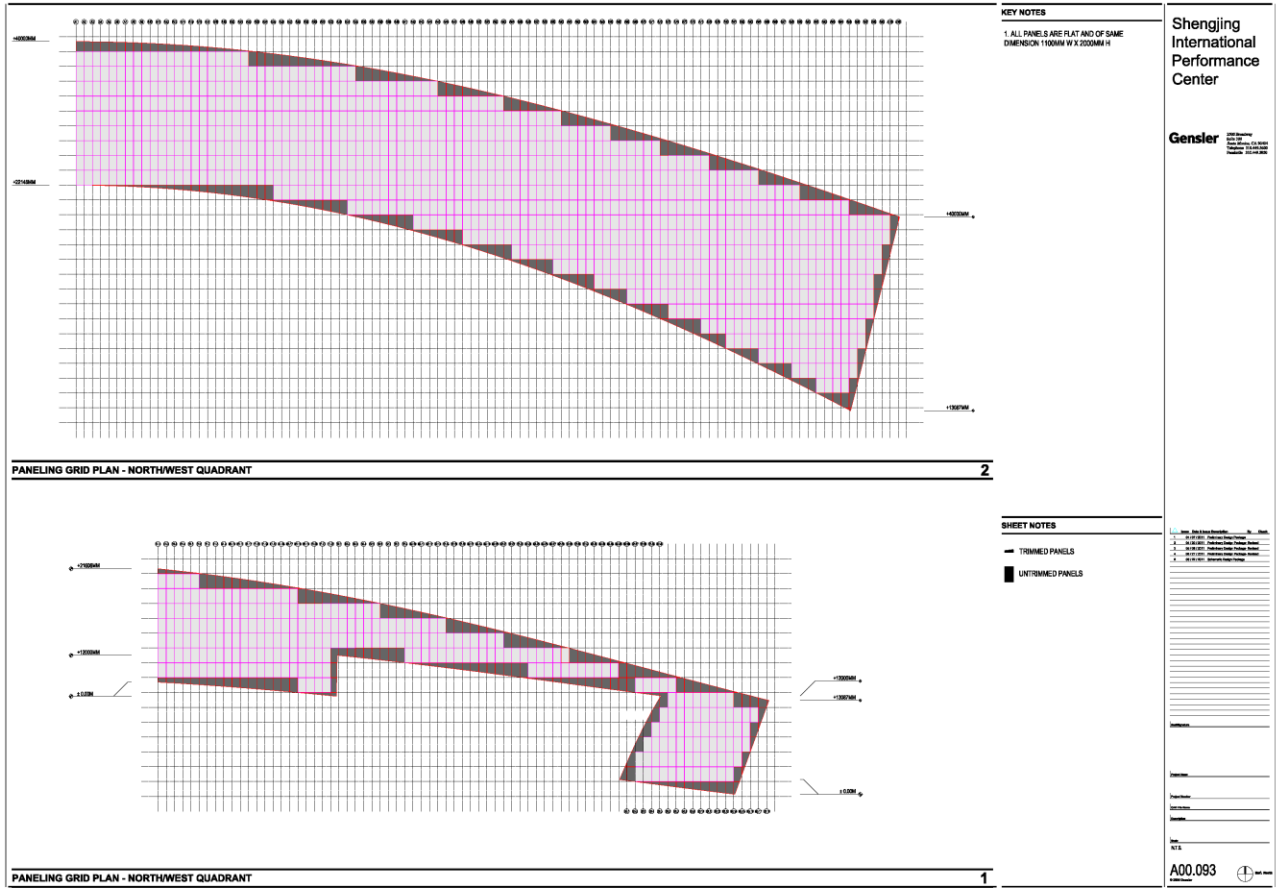

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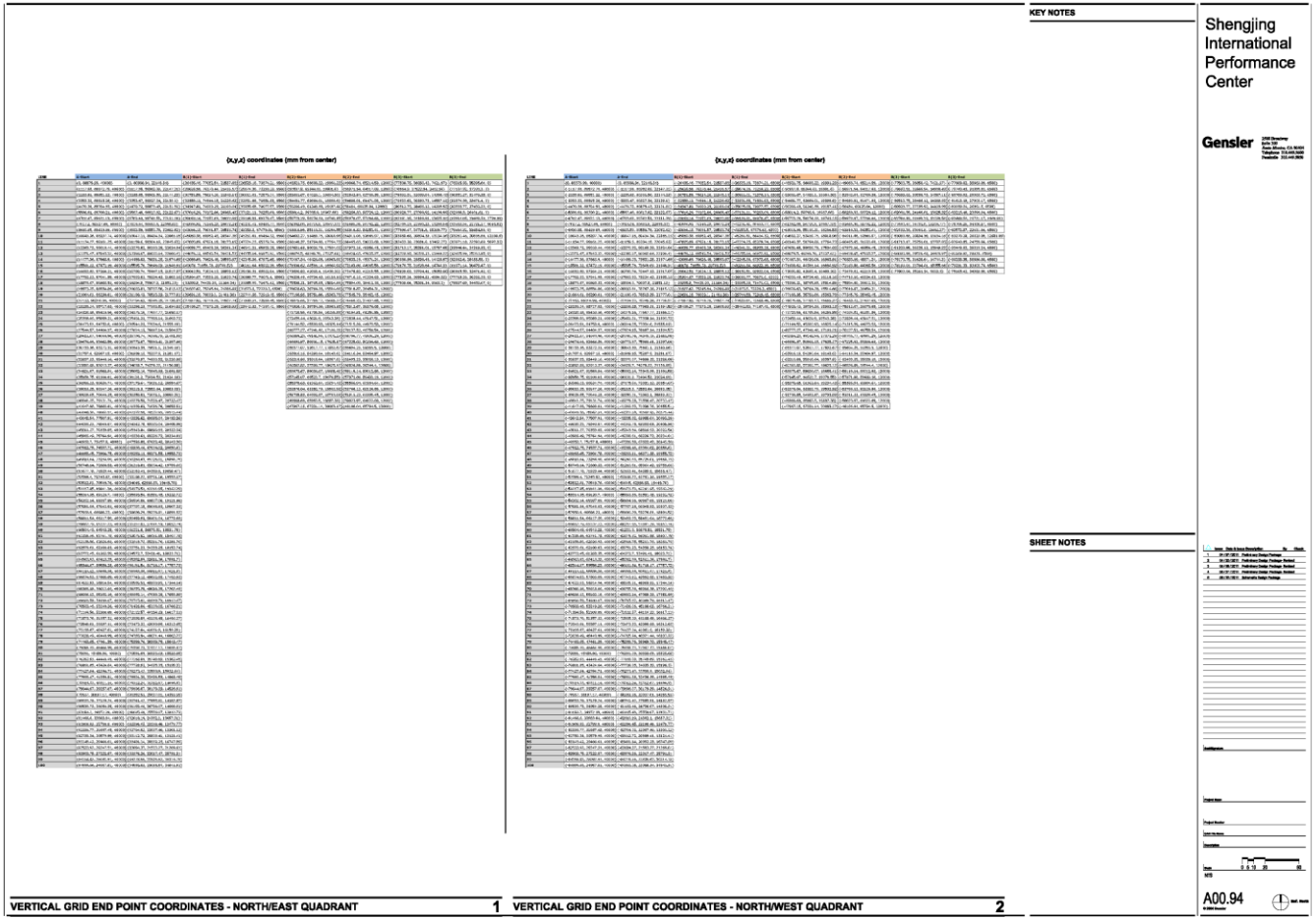

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RECAPITULATION

STEP #1:

Identify the curvature conditions through testing the "Mean Curvature", the "Gaussian Curvature" and the Angle between Normals conditions.

STEP #2:

Discuss the tolerances with your fabrication based on the material and technique used.

STEP #3:

Rebuild the surface main grid subdivisions in quads of the size of your panels

STEP #3:

Quantify the amount of cold bending in the paneling material

CONCLUSIONS

#1:

To design and implement a cost-effective paneling solution it's important to consider the geometrical properties of your design at an early stage.

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To design and implement a cost-effective paneling solution it's important to consider the geometrical properties of your design at an early stage.

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Through the use of parametric and generative design tools we can understand the numbers beyond the geometry and make the necessary changes.

CONCLUSIONS

#1:

To design and implement a cost-effective paneling solution it's important to consider the geometrical properties of your design at an early stage.

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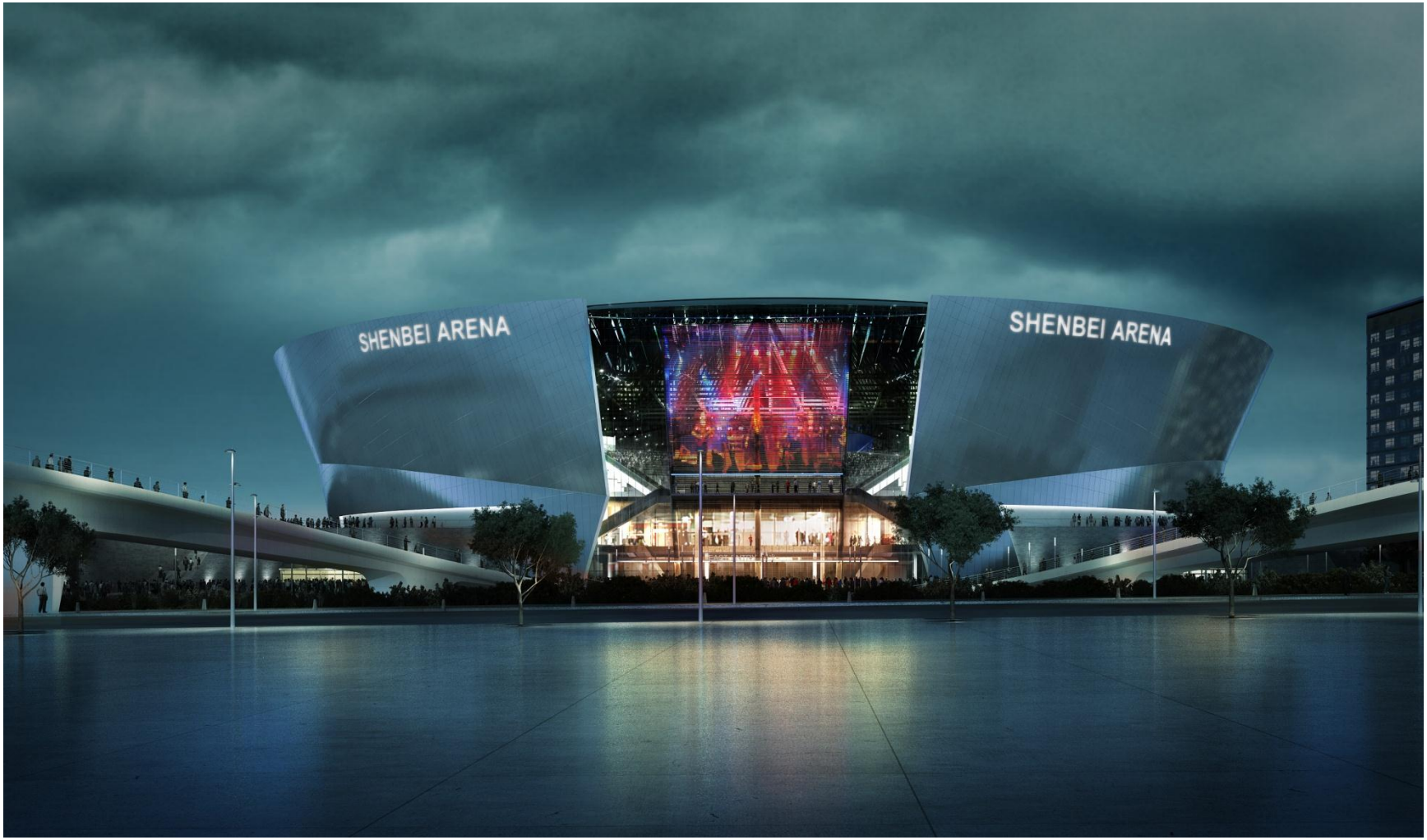
Through the use of parametric and generative design tools we can understand the numbers beyond the geometry and make the necessary changes.

#3:

More cool stuff to come from Gensler, so stay tuned!!!



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THANK YOU!

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