

A white L-shaped frame consisting of two horizontal bars and two vertical bars at the ends, forming a rectangular border around the central text.

# BIM and the Engineer

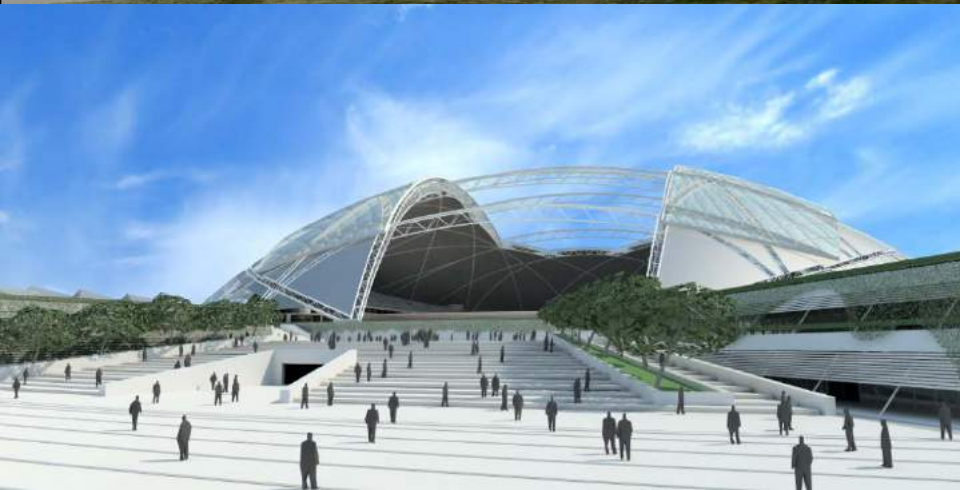
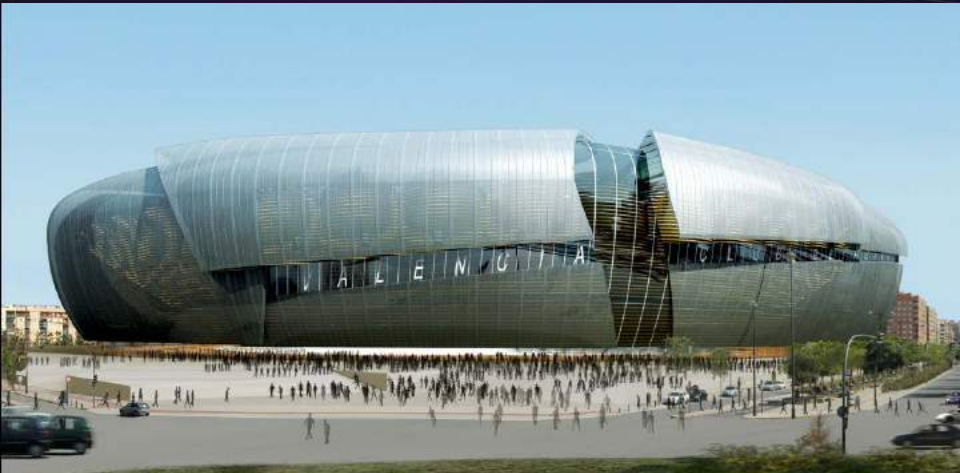
Martin Simpson

Associate Director Arup

Manchester

RAEng Visiting Professor of Innovation

University of Salford





# China Comic & Animation Museum MVRDV







Why do things differently?



# Because the government tells you to?

**"This Government's four year strategy for BIM implementation will change the dynamics and behaviours of the construction supply chain, unlocking new, more efficient and collaborative ways of working. This whole sector adoption of BIM will put us at the vanguard of a new digital construction era and position the UK to become the world leaders in BIM."**

**Francis Maude**  
Minister for the Cabinet Office



Before you start some work always ask yourself three questions:

- Why am I doing it
- What the results might be
- Will I be successful

Only when you think deeply and find satisfactory answers to these questions, go ahead.

Chanakya, 370 BC – 283 BC



## Why BIM – Ask the right questions...

- Reduce Capital Cost
- Reduce Carbon Emission
- Decrease time to practical completion
- Improved continuity of Information / Audit Trail
- Improve whole life asset management
- Improve consistency in delivery (reduction of errors)
- Improve level of performance and constructability
- Improve Safety
- Reduce of Waste
- Reduce the consumption of resources



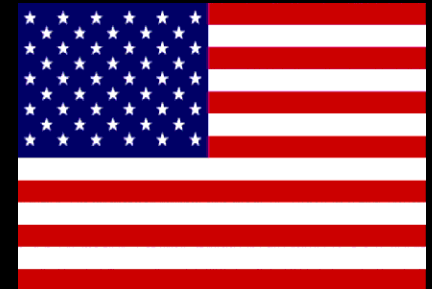
# Global Consumption of Resources



=



=



x ?

=





## World set to treble consumption by 2050.



If the world continues using its natural resources at the current rates we will be getting through 140 billion tonnes of minerals, ores, fossil fuels and biomass by 2050

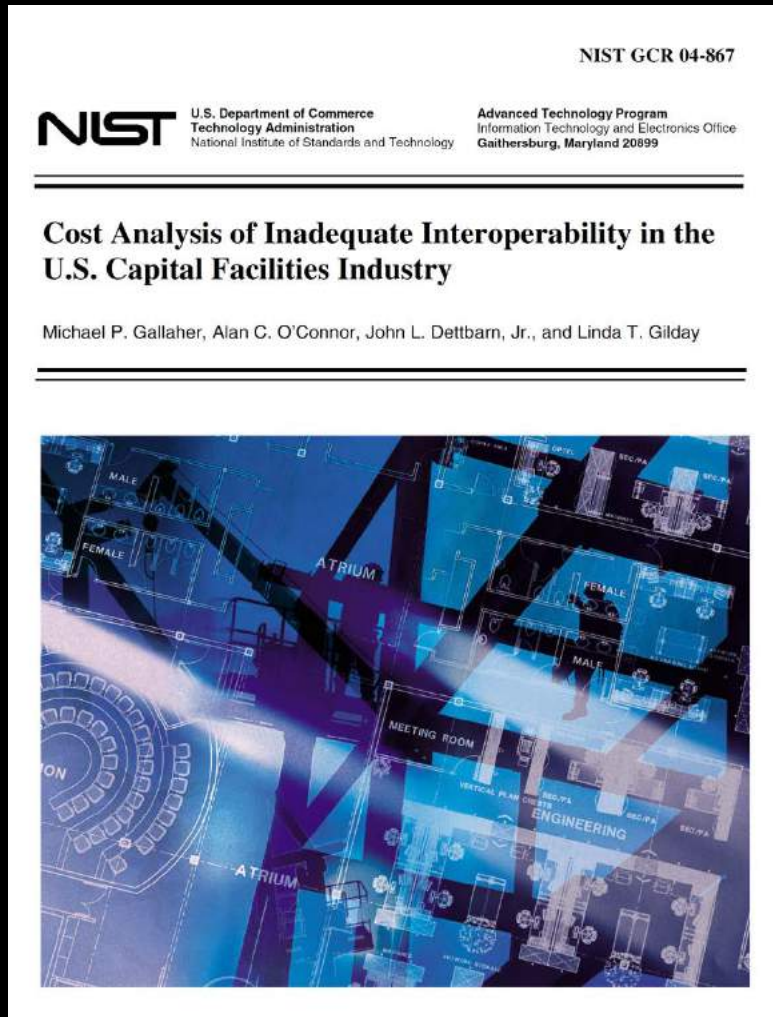
# Waste in the Construction Industry

“Rethinking Construction” by Sir John Egan - 1998.

- 30% of construction is rework
- 40% of the manpower used on construction sites can be wasted
- At least 10% materials are wasted
- Over 40% of projects are completed late or over budget.



# Duplication of Work



The cost of inadequate interoperability in the U.S. capital facilities industry estimated at: **\$15.8 billion per year**



# The Project Life-Cycle

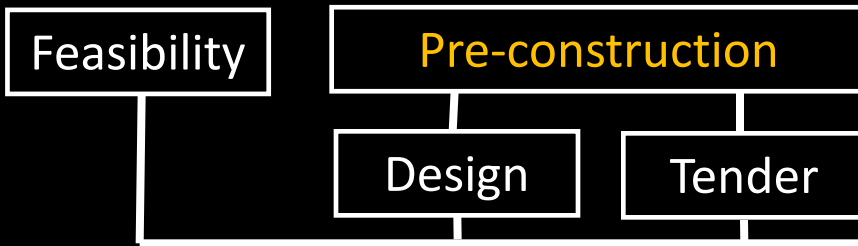
Feasibility

## The Stages of a project

- Feasibility

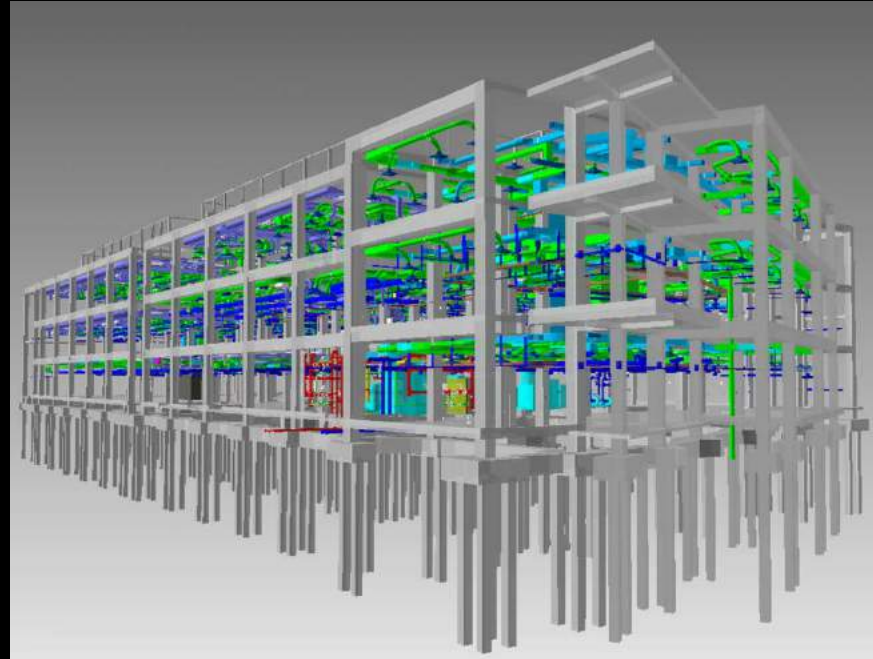


# The Project Life-Cycle



## The Stages of a project

- Feasibility
- Pre-construction



# The Project Life-Cycle

Feasibility

Pre-construction

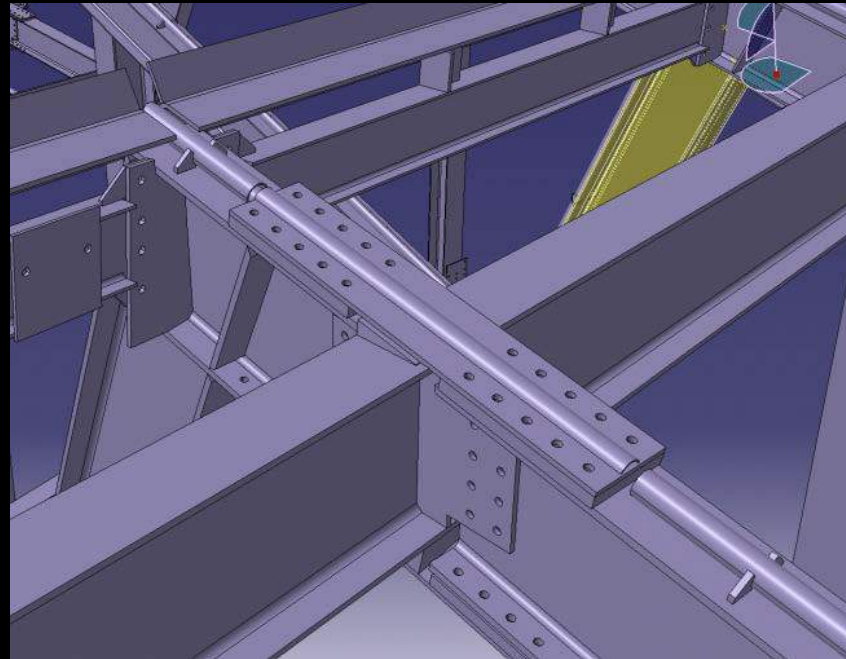
Construction

Design

Tender

## The Stages of a project

- Feasibility
- Pre-construction
- Construction





# The Project Life-Cycle

Feasibility

Pre-construction

Construction

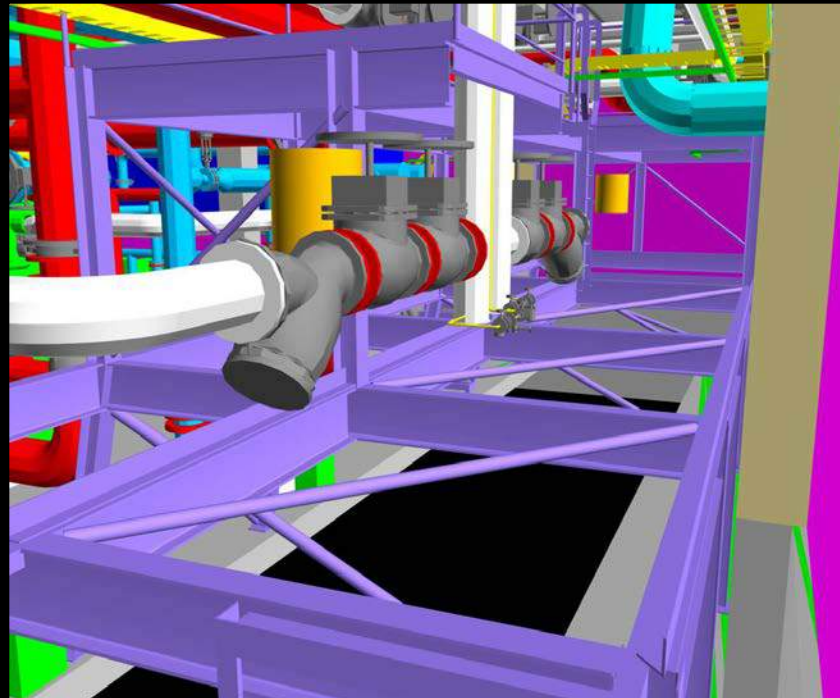
Operation

Design

Tender

## The Stages of a project

- Feasibility
- Pre-construction
- Construction
- Operation



# The Project Life-Cycle

Feasibility

Pre-construction

Construction

Operation

Decommission

Design

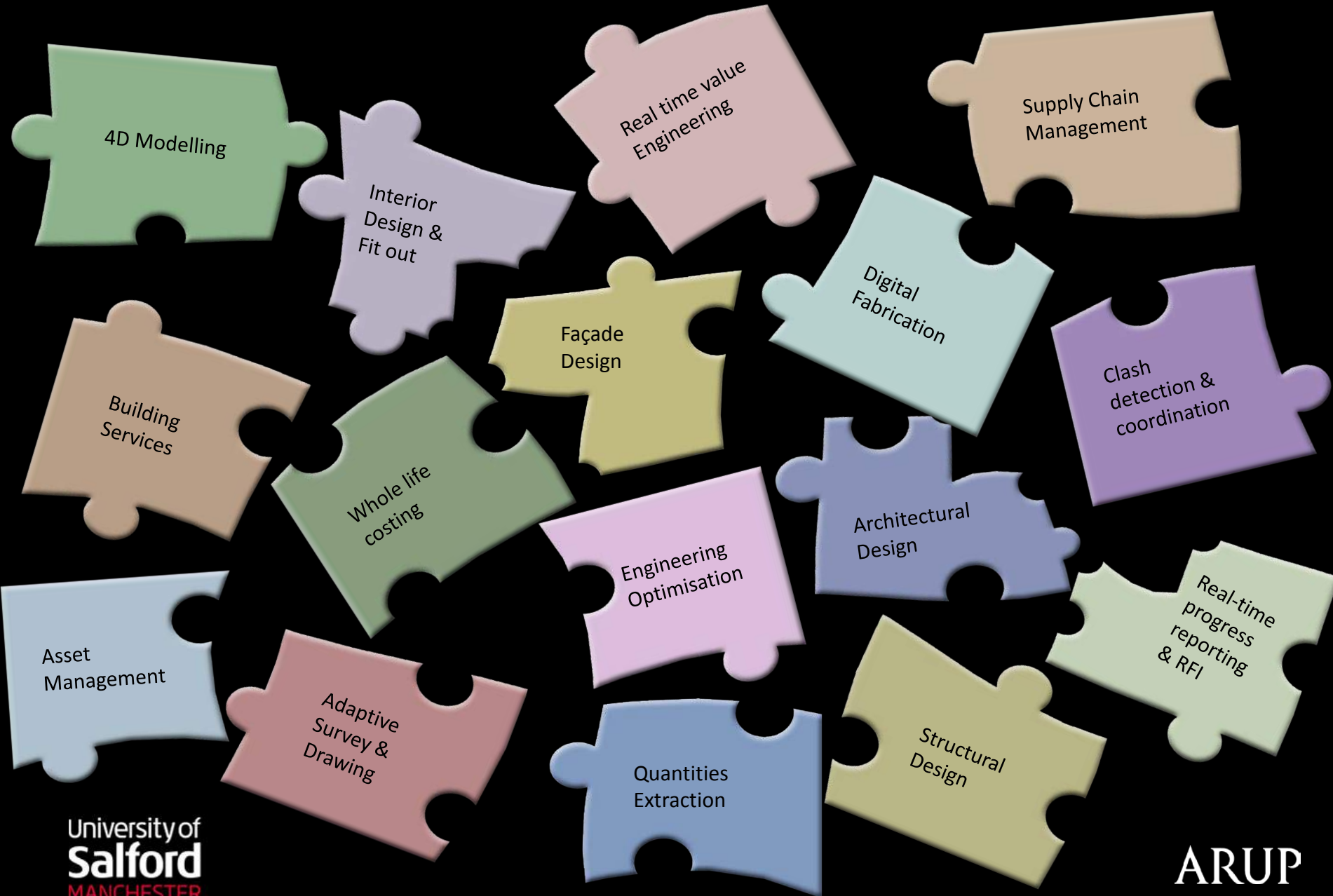
Tender

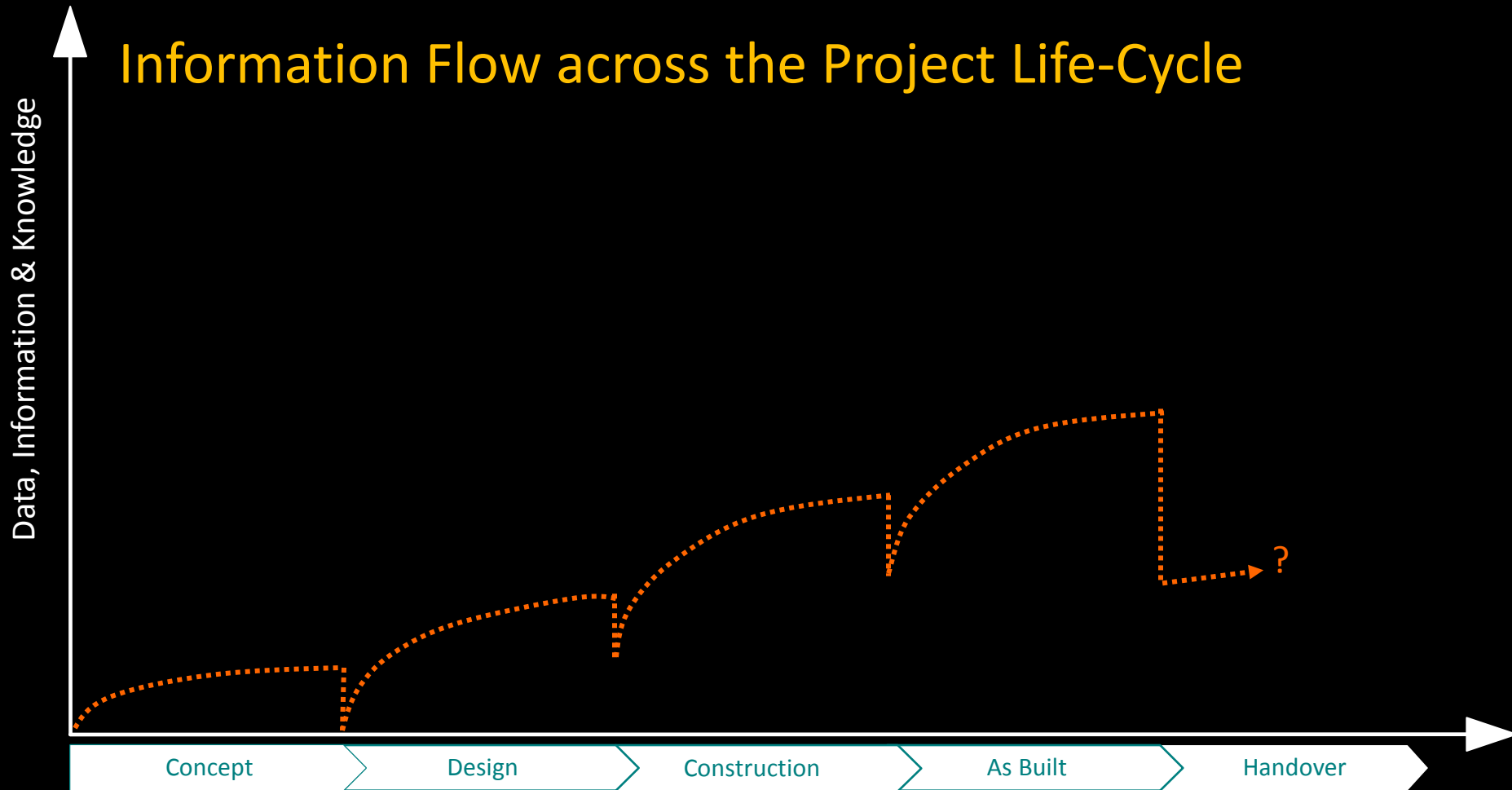
## The Stages of a project

- Feasibility
- Pre-construction
- Construction
- Operation
- Decommission



# Fractured Processes within the Construction Industry



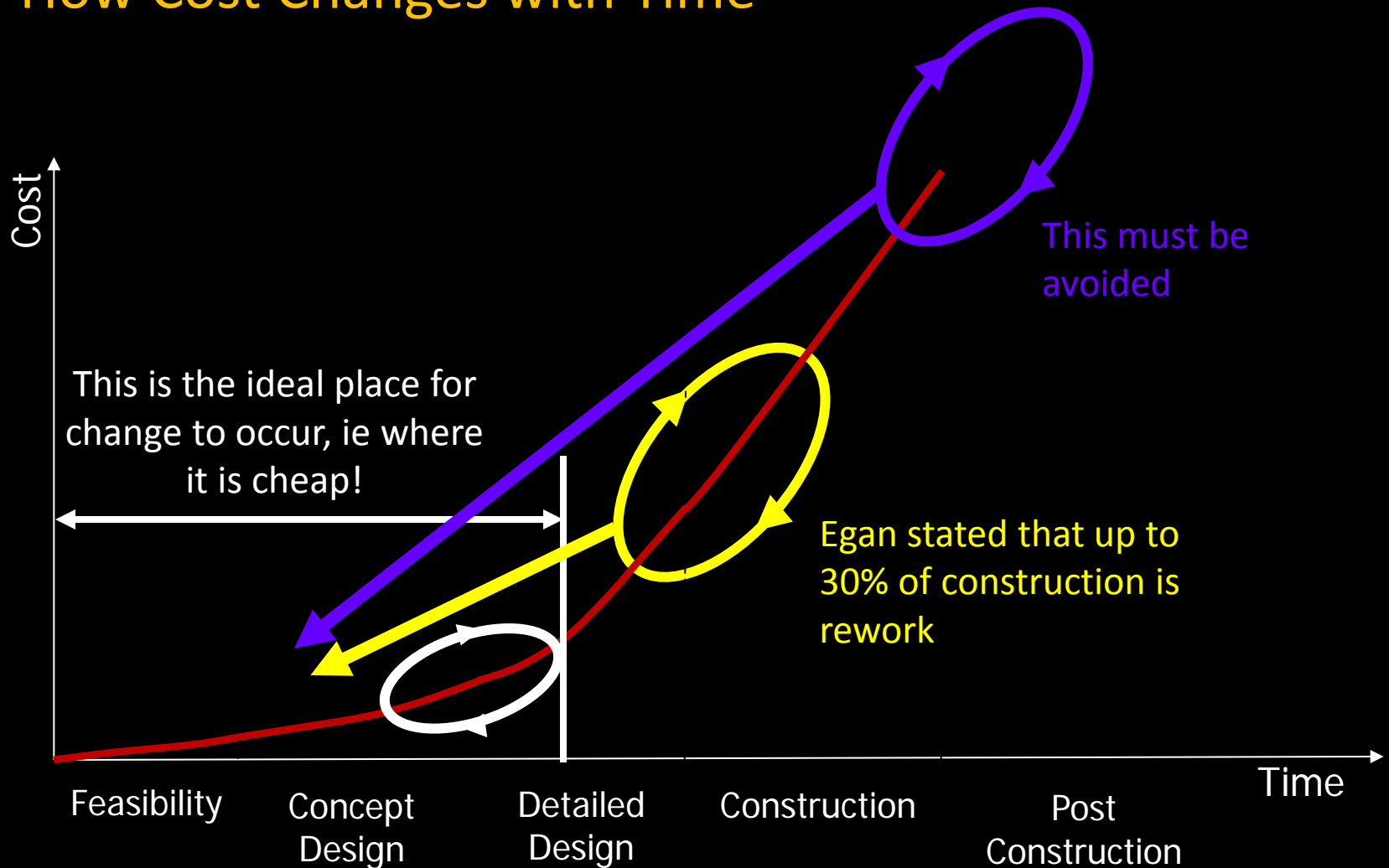


Date atrophy during project lifecycle due to:

- Information exchange via 2D drawings/Sketches/Reports/Conversations...
- Upfront simulation is limited and for some disciplines simulation is not accurate
- We start the final production phase commence before design is complete.
- Often without production of prototypes (Most buildings are unique!)

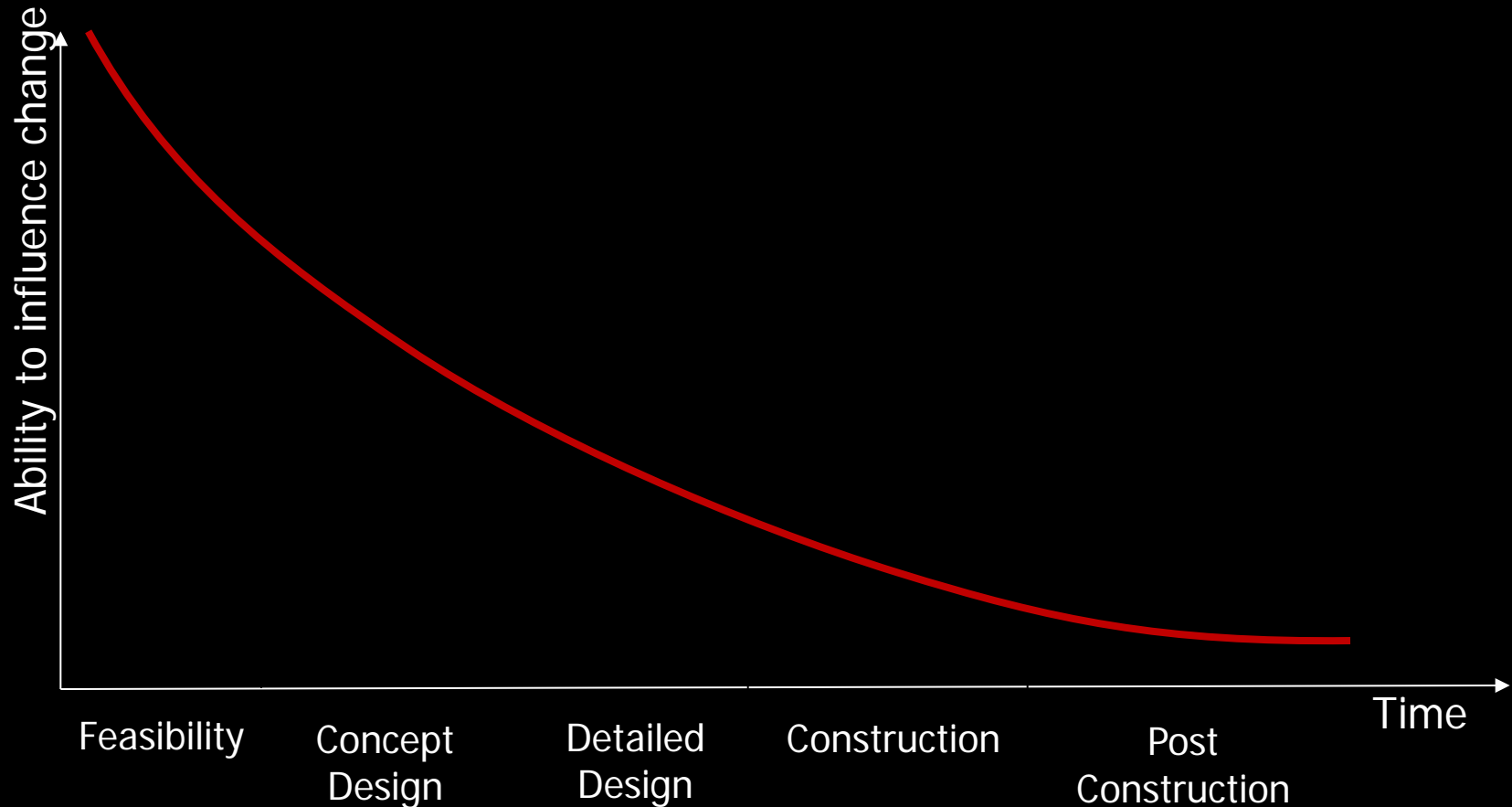


# How Cost Changes with Time



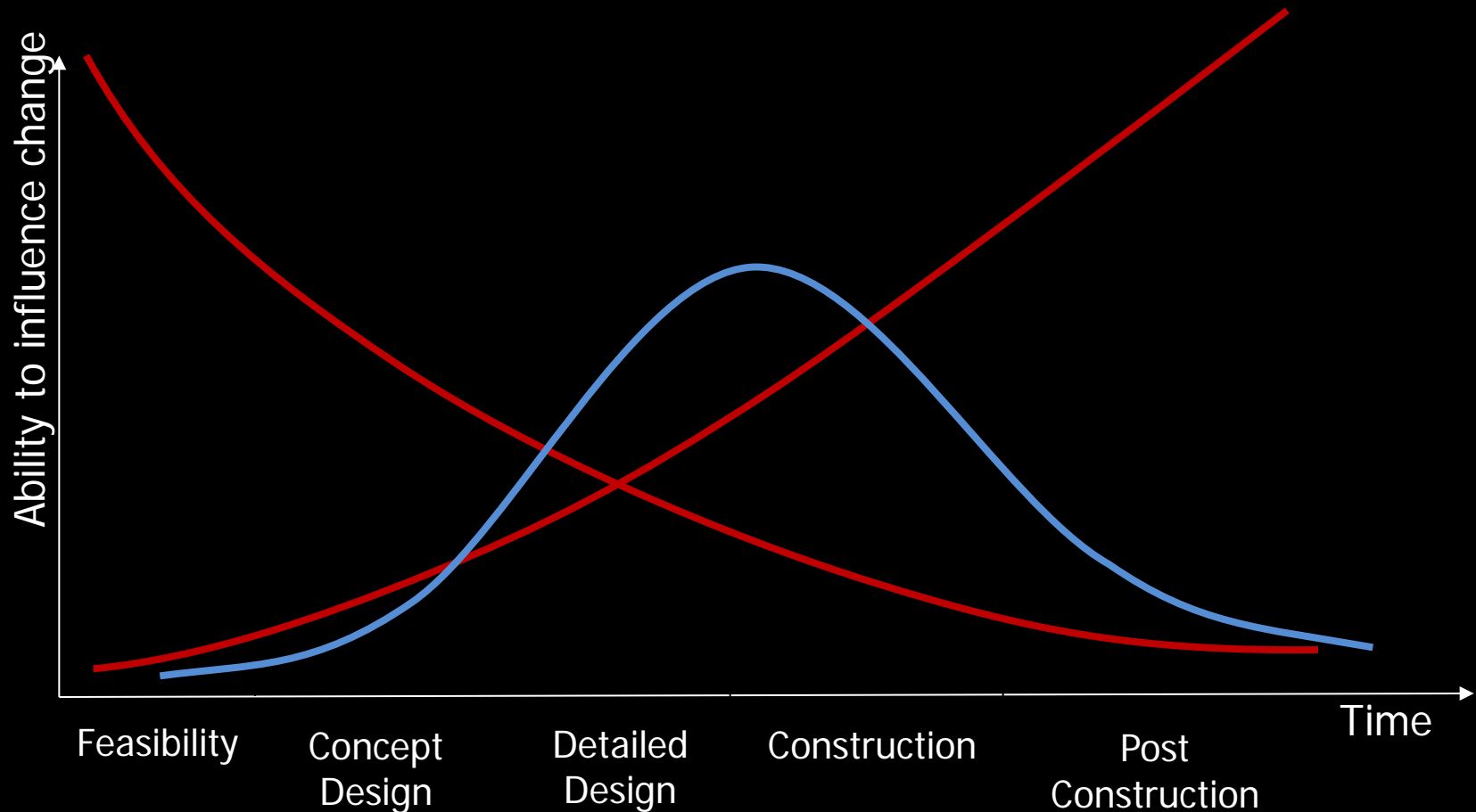
To cost of post construction change is many times the cost of change during design

# How the ability to influence change varies with time

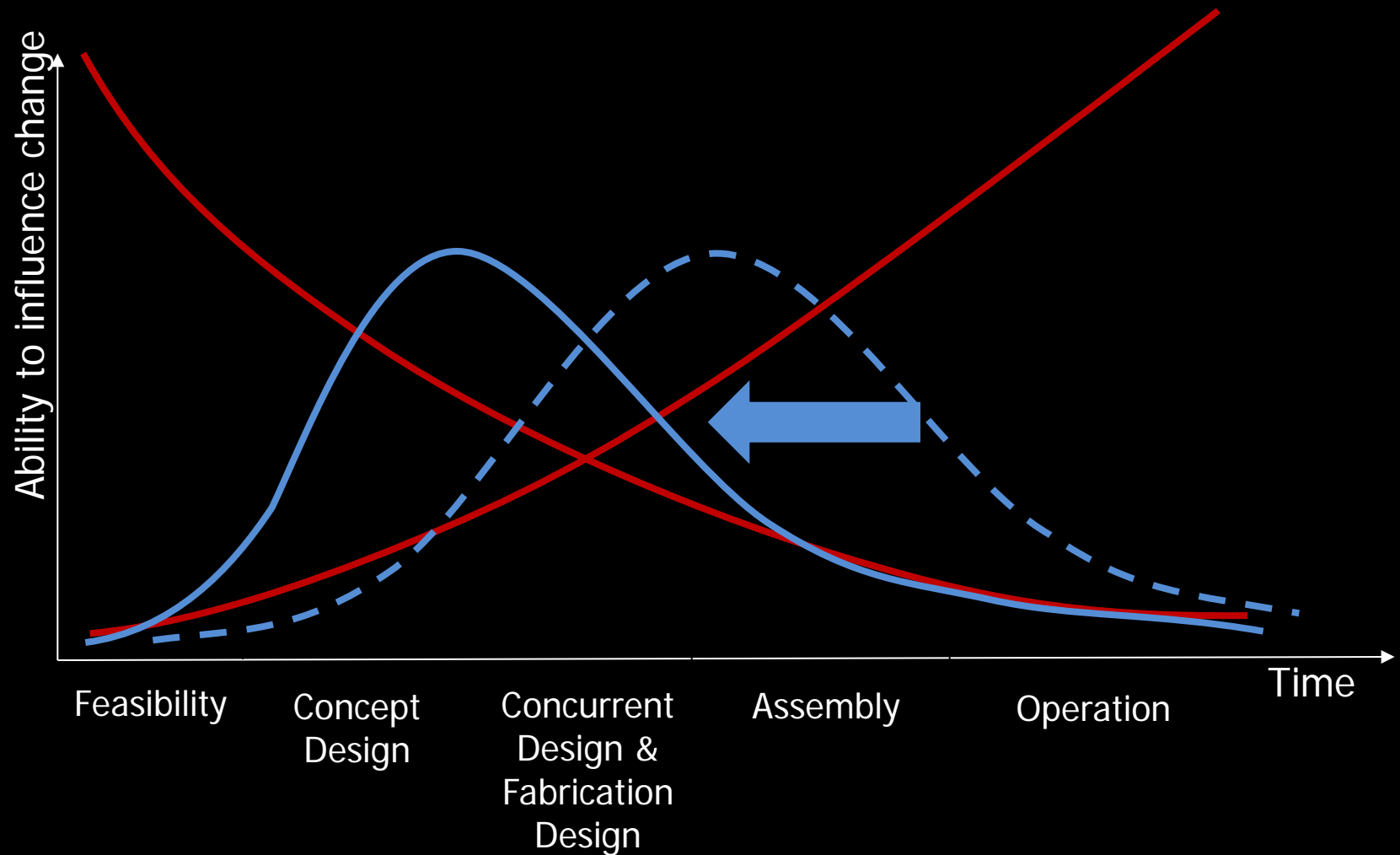


Macleamy's

# MacLeamy's Curves showing commitment of resource to design (including final fabrication design)



# MacLeamy's Curve





SO THE ANSWER IS BIM!





# What is BIM?

# Defining BIM

“A coordinated digital dataset that contains appropriate computable information necessary to design, build, operate and ultimately decommission a project”

“process of designing, constructing or operating a building or infrastructure asset using electronic object-oriented information”

PAS 1192-2

## \* Sharing Structured Information

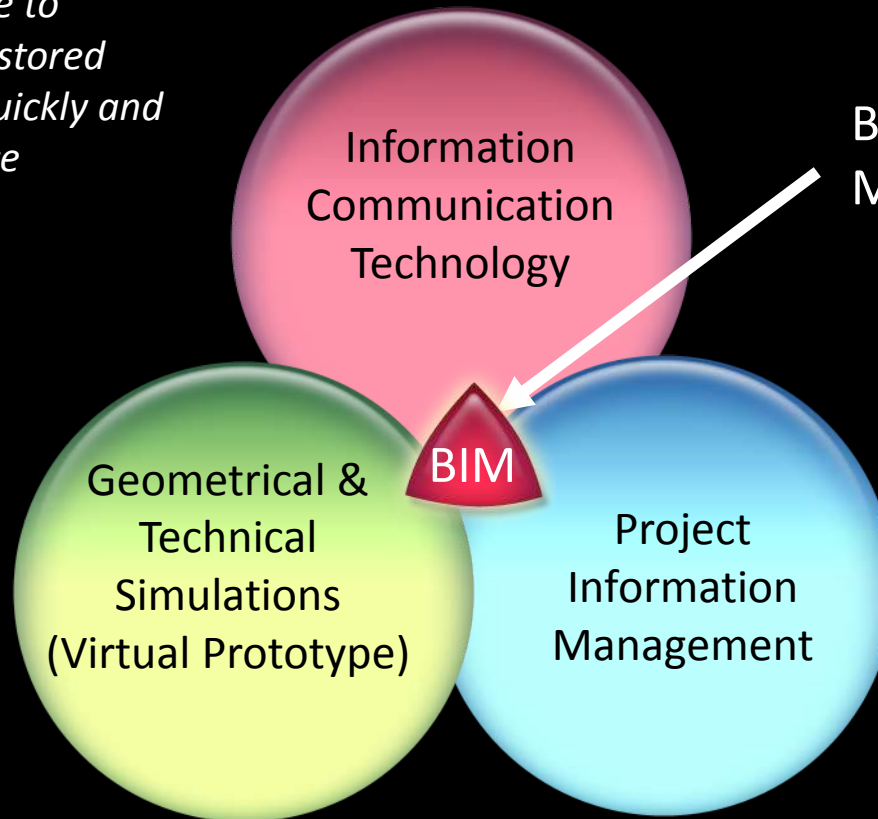
In fact...

- **BIM** is not confined to **Buildings**. It is a tool for the built environment and equally applicable to any asset. (Think **Building** as a **Verb**, “to Build”)
- **Model** does not mean 3D model. Think Financial Model or Scientific Model. It reflects the way something behaves rather than limited to physical existence.
- **Information** is key.

...Perhaps **Asset Information Management** is more appropriate!

# BIM is....

*Project Team members need to be able to exchange and stored project data quickly and with confidence*



Building Information Model (Management)

*Project Team members need coordinated up to date information to be able to do modelling & calculations*

*Project Team members need carry out tasks in such a way that they are easily coordinated, recorded and verified*

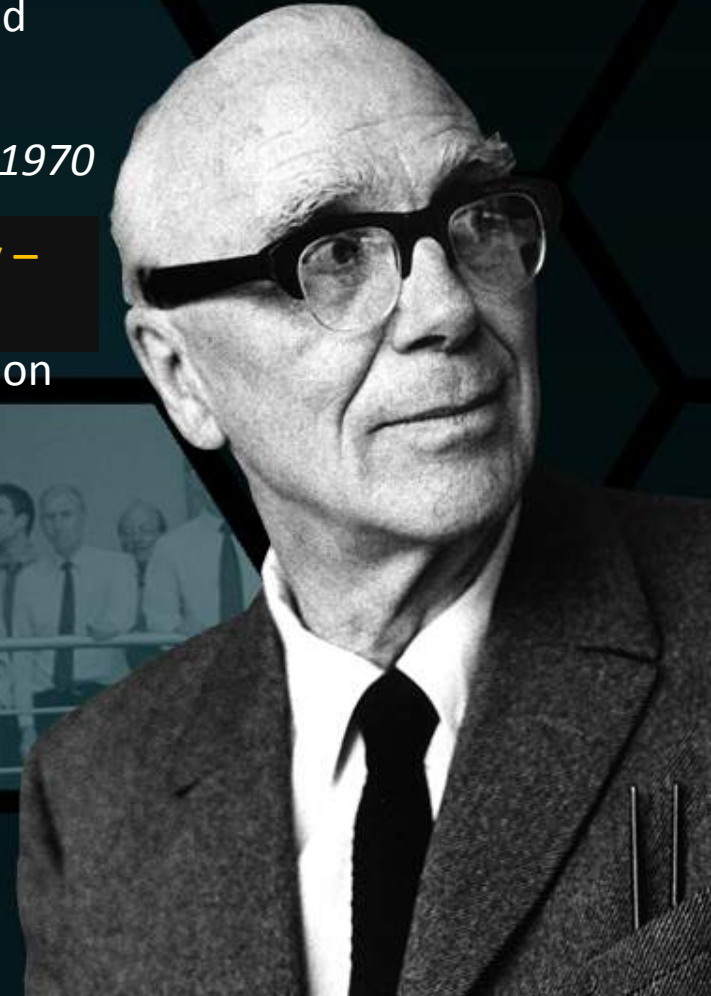
## ...Sharing Structured Information

# BIM = Total Architecture

“The term ‘Total Architecture’ implies that all relevant design decisions have been considered together and have been integrated into a whole by a well organised team empowered to fix priorities”

*Sir Ove Arup – The Key Speech - 1970*

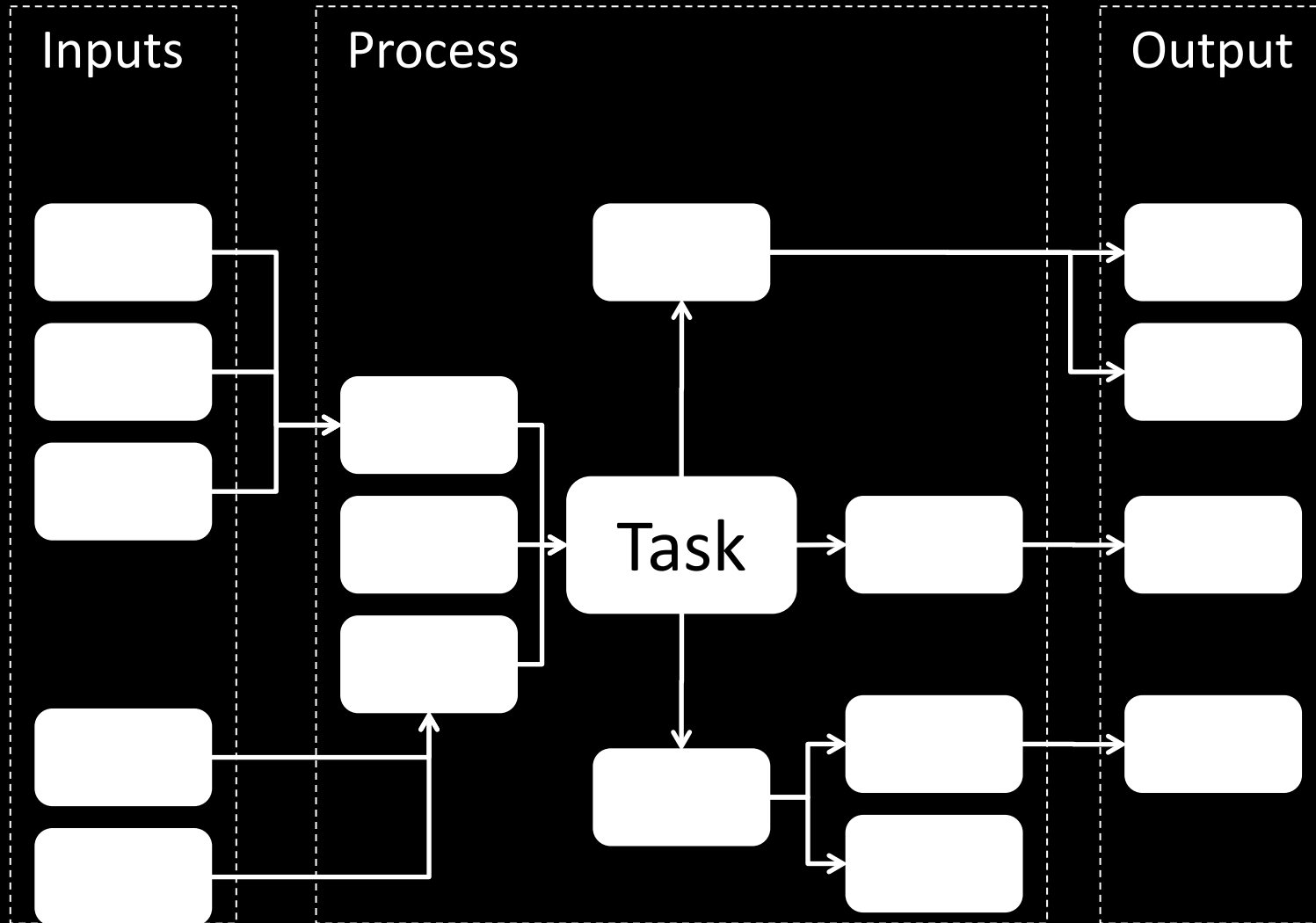
“This is an ideal which can never – or only very rarely – be fully realised in practise, but which is well worth striving for artistic wholeness or excellence depends on it, and for our own sake we need the stimulation produced by excellence”

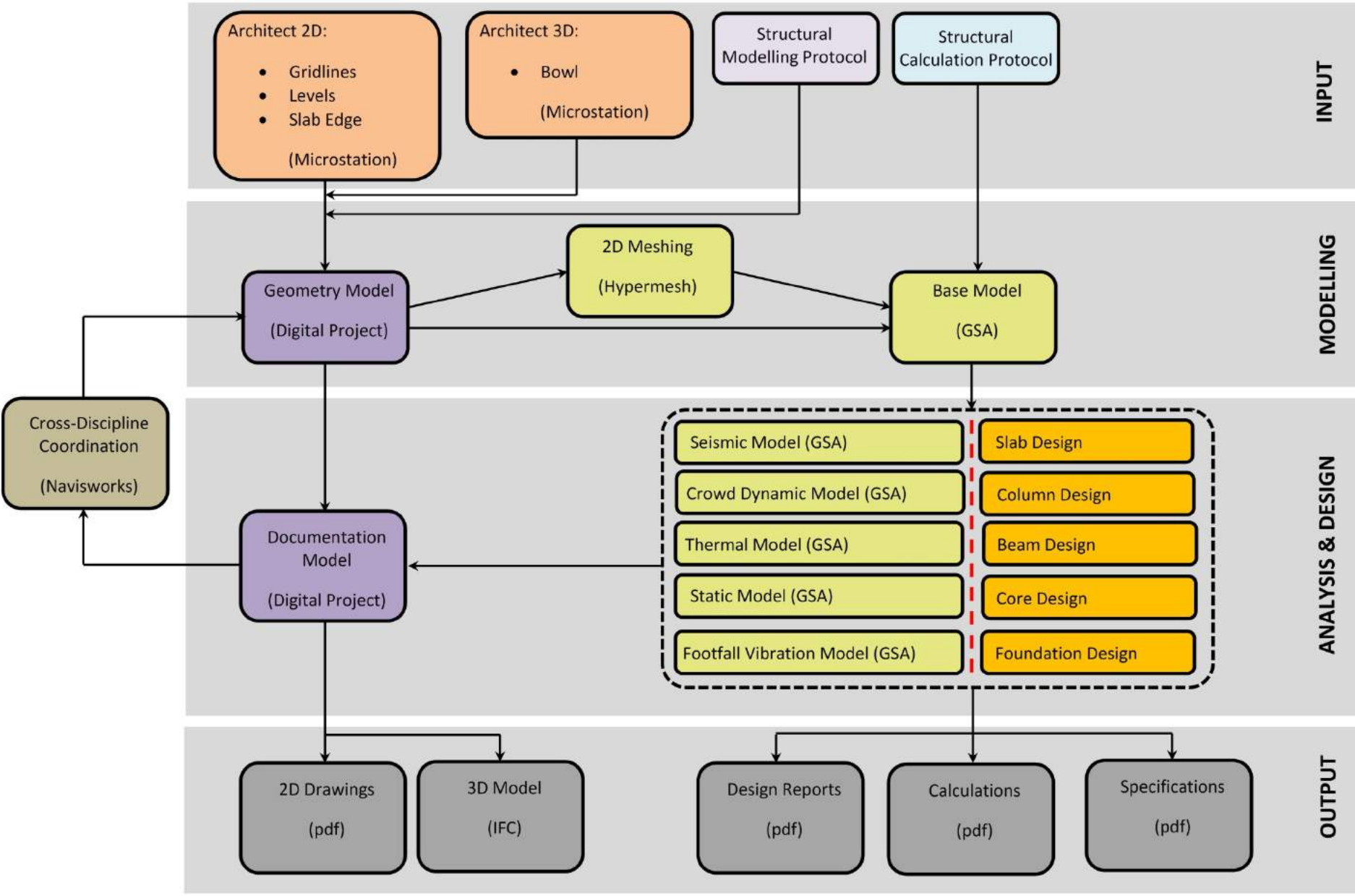




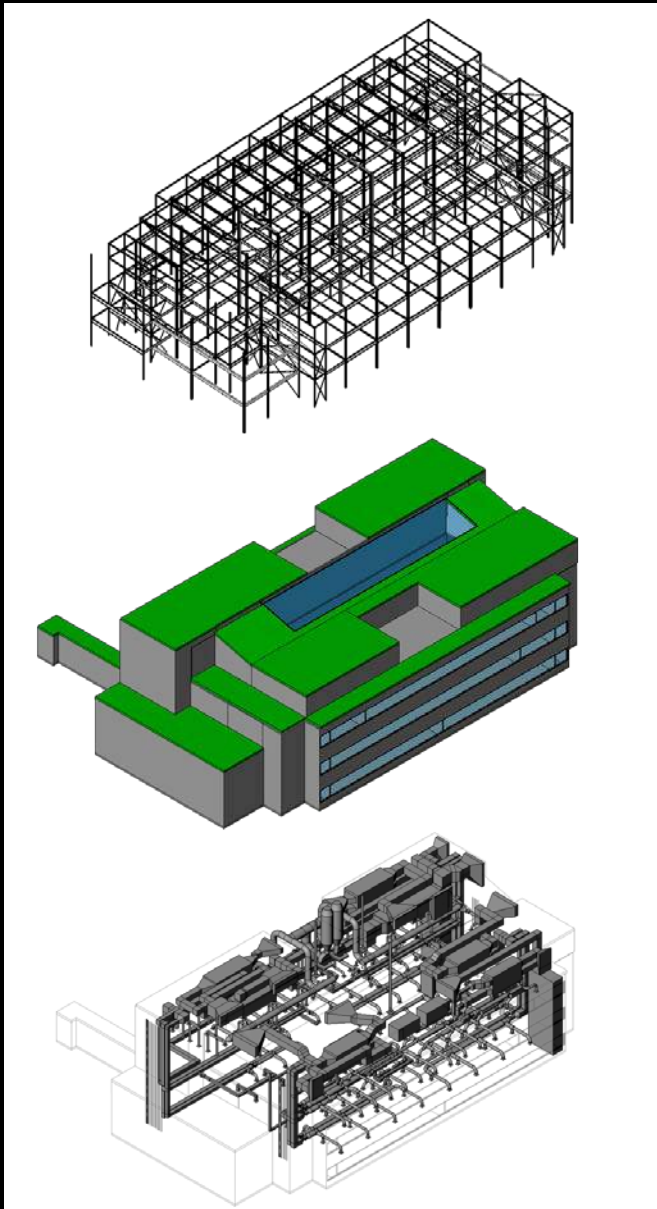
# Defining the framework for BIM

# Process is essential to successful BIM





# Main Players at the Design Stage



## Structural model

- Framing elements
- Foundations
- Typical details

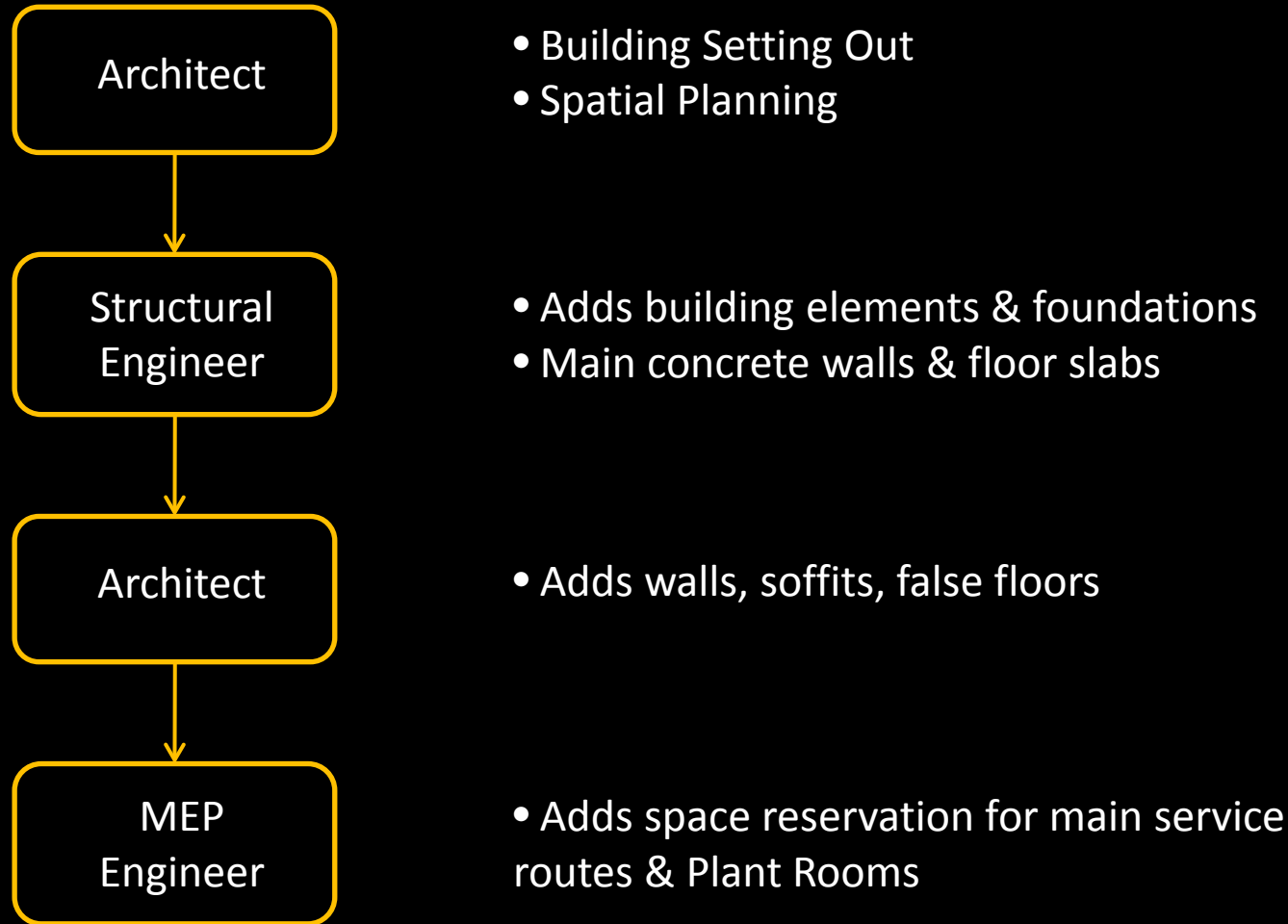
## Architectural model

- Walls & ceilings
- Room spaces
- Materials and finishes

## MEP Services model

- Space reservation
- Plant rooms
- Plant systems

# Main Players at the Design Stage







BIM is not about Geometry





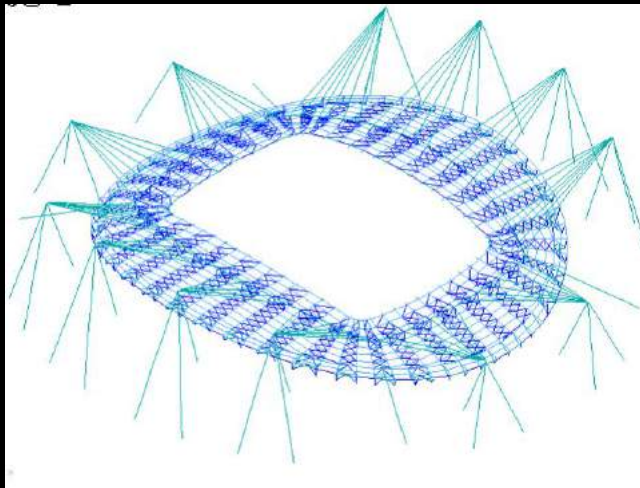
© Dennis Gilbert/VIEW

# City of Manchester Stadium 1998-2002

Architect: Arup Associates

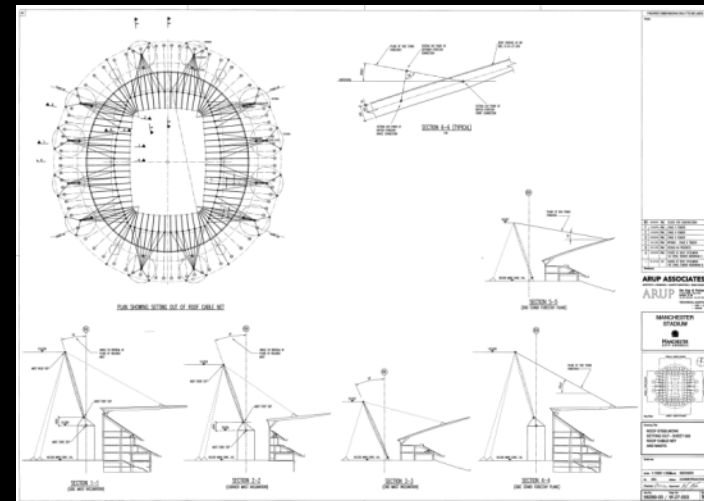
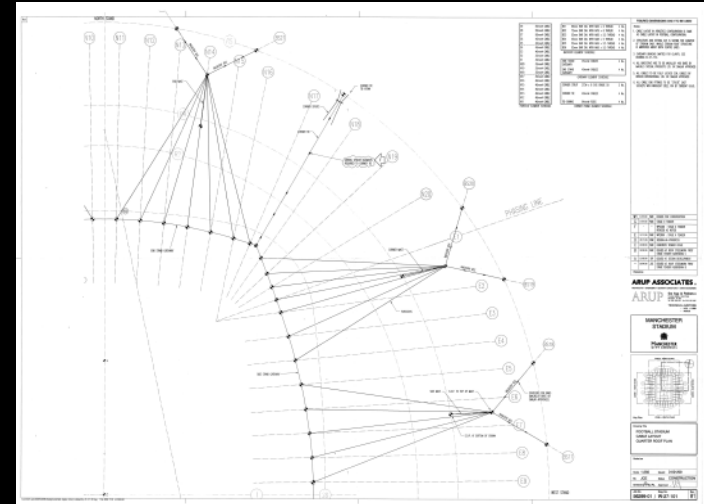
# City of Manchester Stadium – Information Flow

Geometry

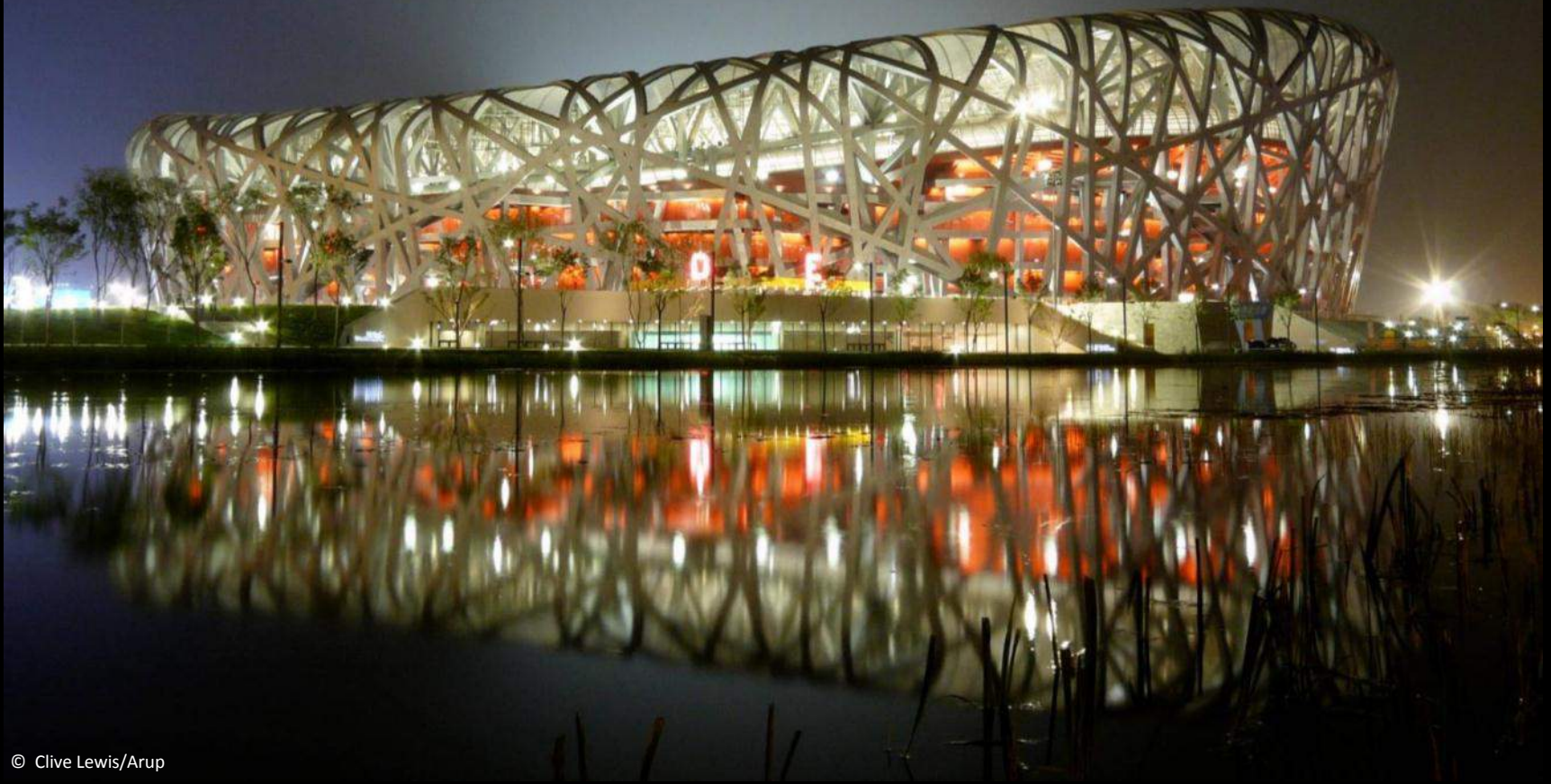


Element Design

Engineering



Documentation



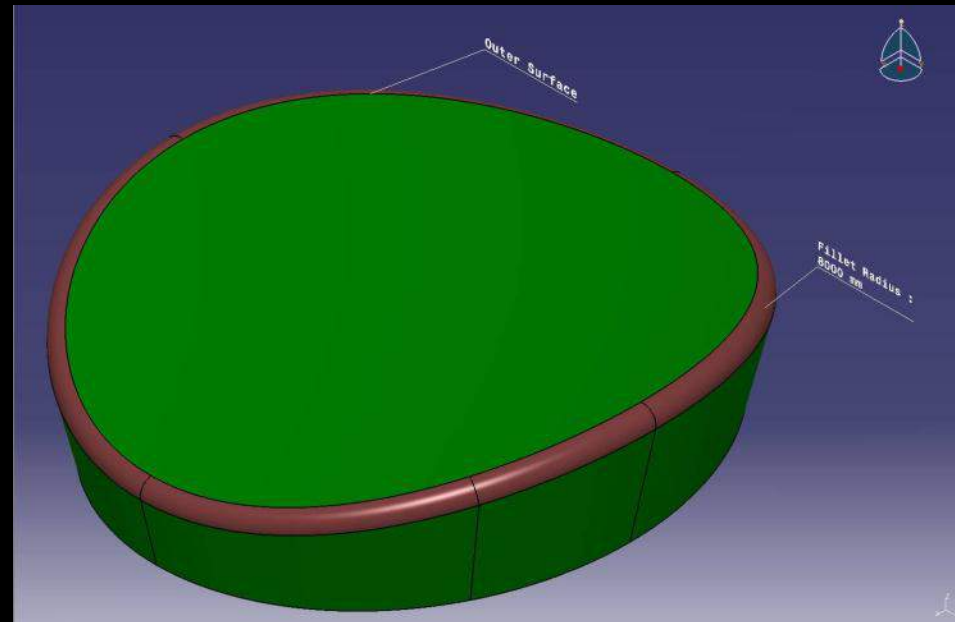
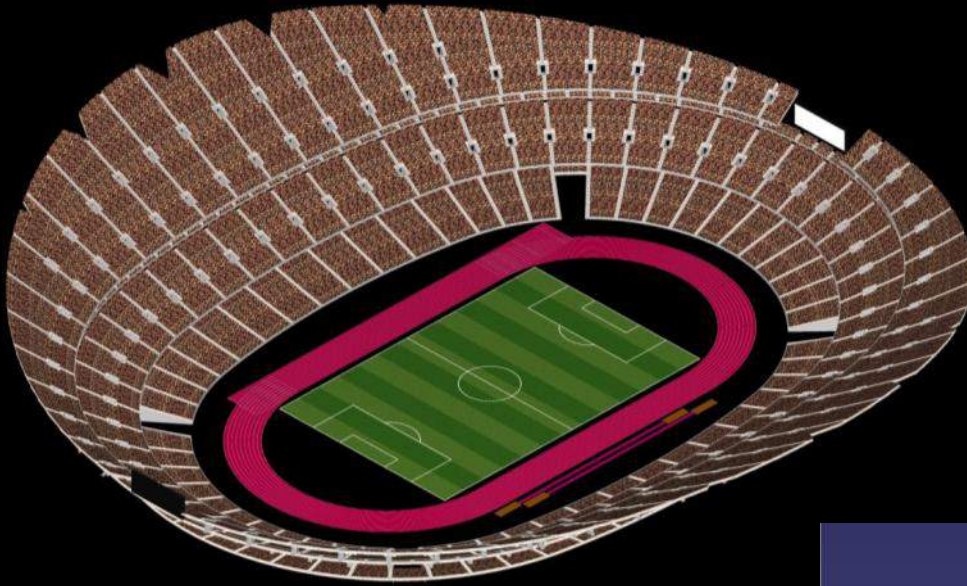
© Clive Lewis/Arup

# Beijing National Stadium 2004-2008

Architect: Herzog & de Meuron

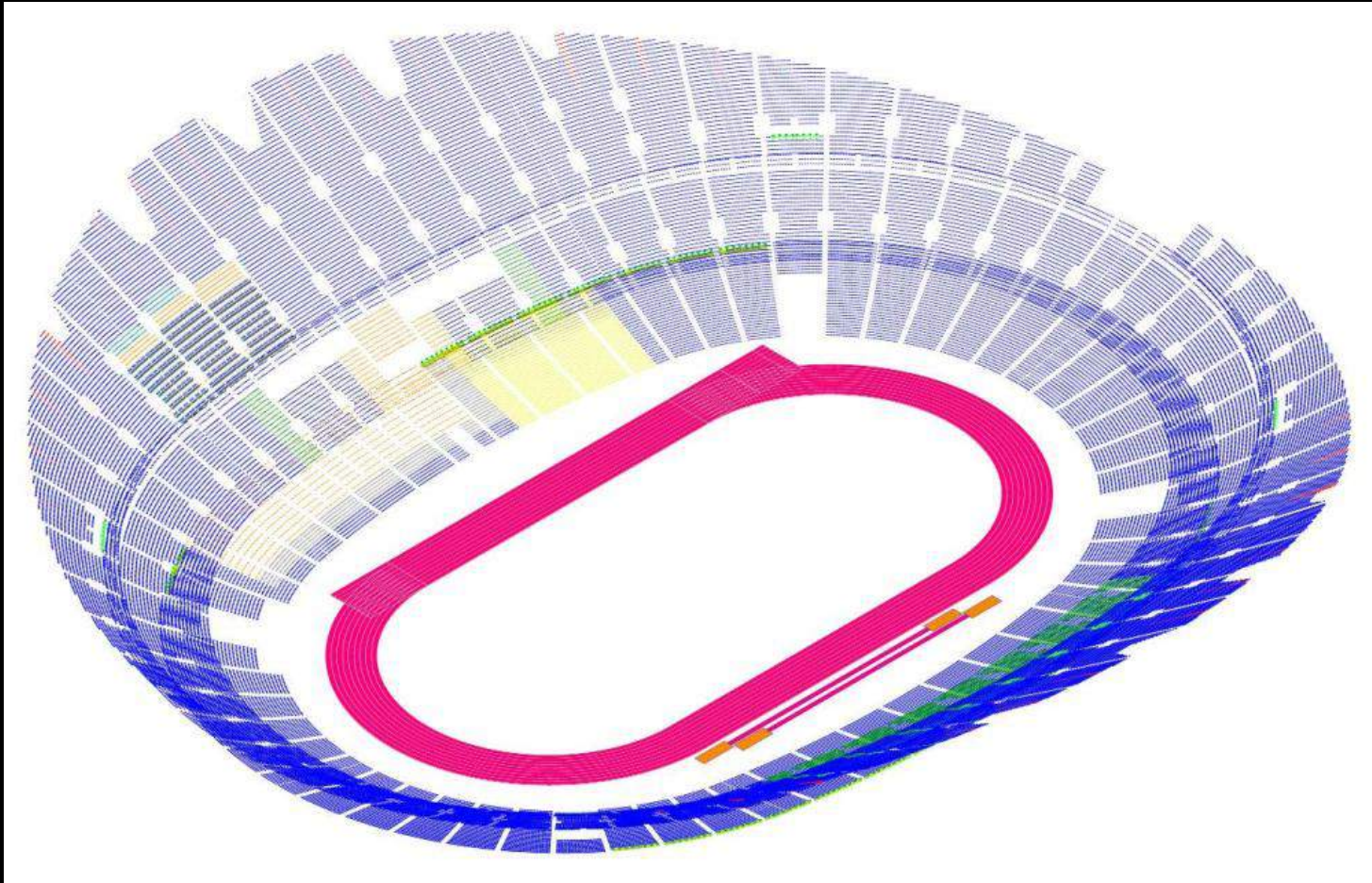


# Beijing National Stadium – Bowl & Enclosure



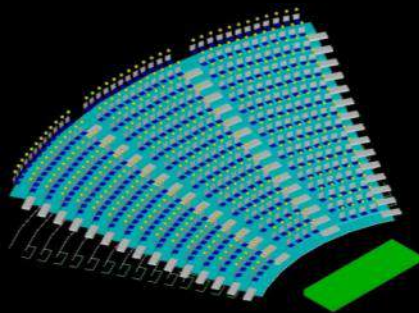
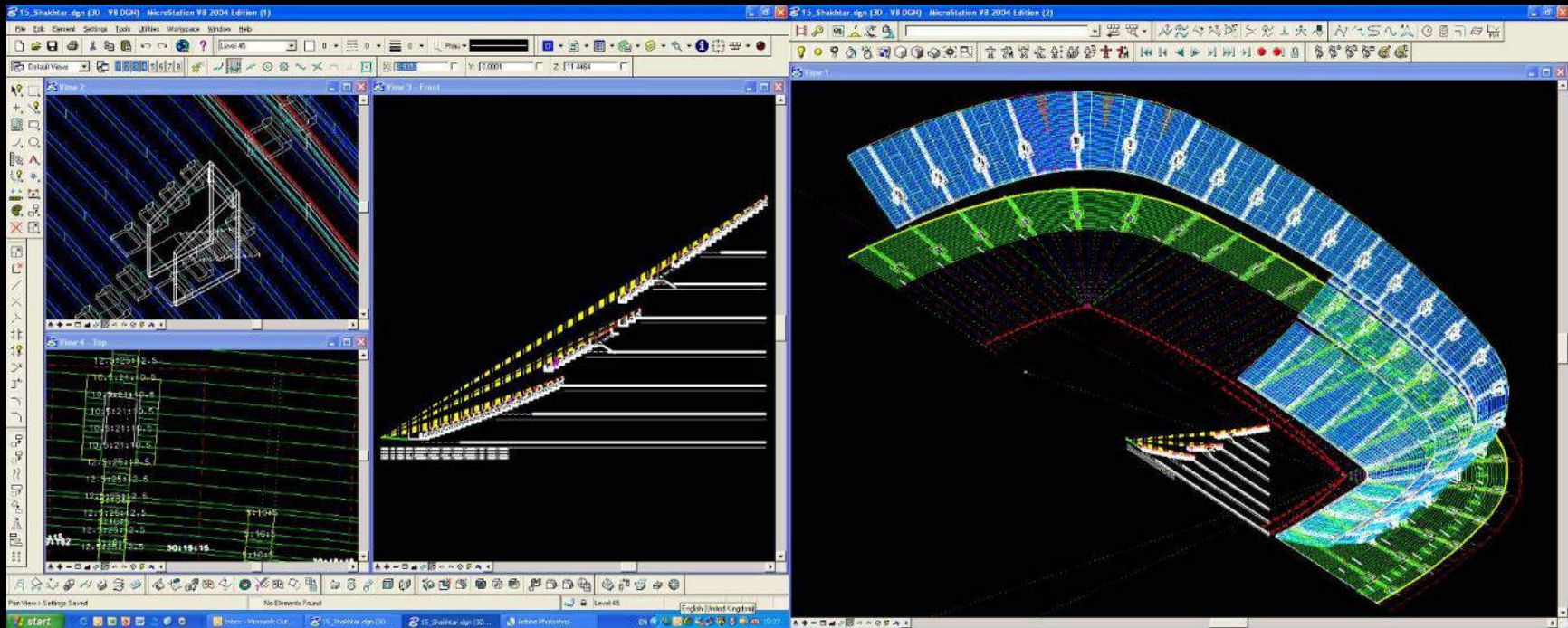


# Beijing National Stadium – Bowl Geometry



- The design of the bowl is the primary design criteria
- Get the bowl right and the rest will follow

# Beijing National Stadium – Bowl Geometry



```

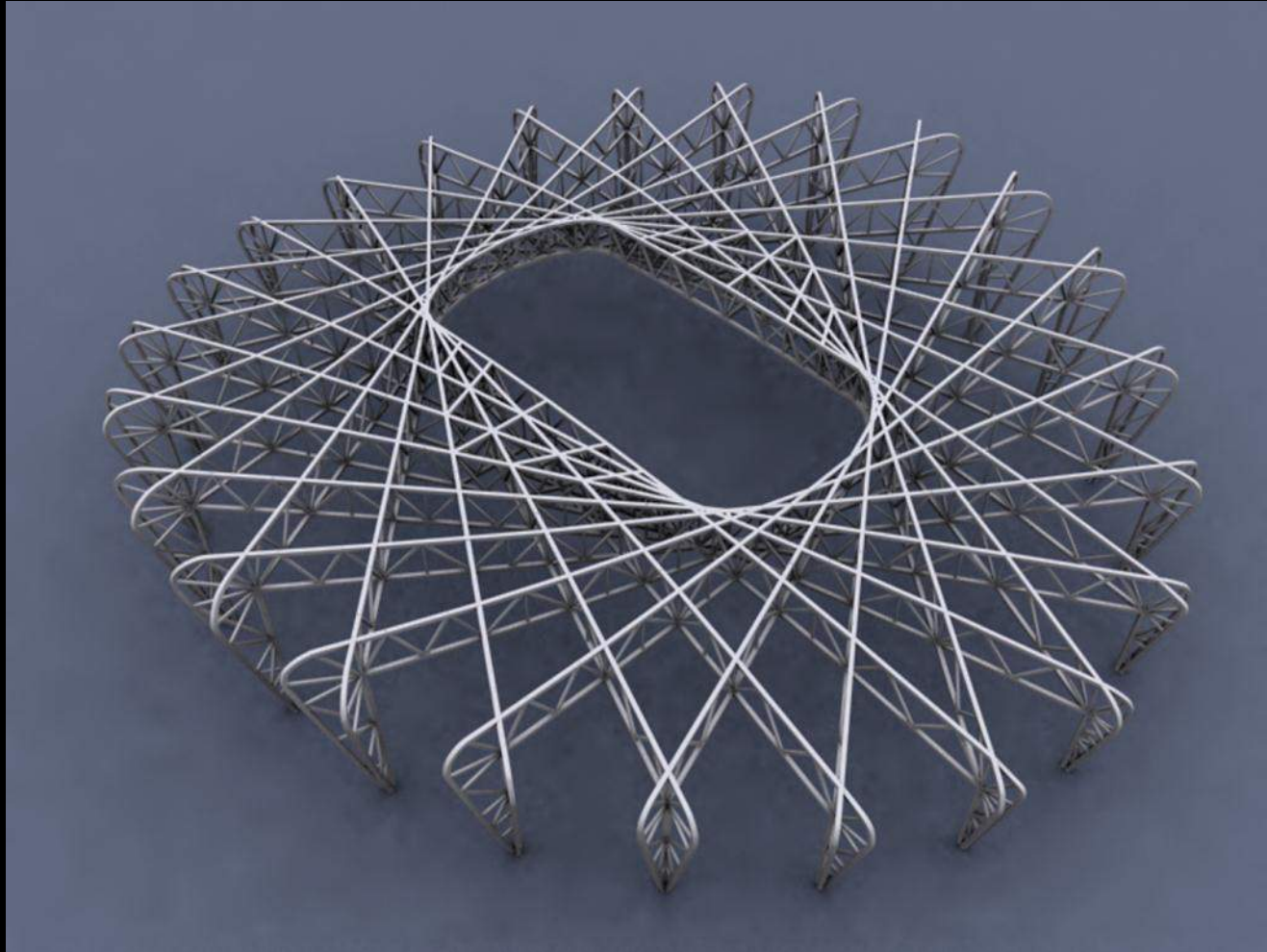
Sub Plot3dRiserAndTread
If TRct > 1 Then
  MbeSendCommand "PLACE SHAPE "
  For ct = 1 to Prev_pB
    pt = Onode(ct)
    pt.z = RowFront(total_rows-TRct + 2).z
    MbeSendDataPoint pt, 1%
  Next ct
  For ct = pBlast to 1 step -1
    pt = node(ct)
    pt.z = RowFront(total_rows-TRct + 2).z
    MbeSendDataPoint pt, 1%
  Next ct
End If
MbeState.locateTolerance=saveTolerance
End Sub 'Plot3dRiserAndTread
    
```

SIGHTLINES CALC	calc up	calc up	calc up
eye X (m) top	29.800	40.340	42.515
eye Z (m) top	7.558	16.229	17.506
eye X (m) bottom	8.933	27.743	41.515
eye Z (m) bottom	0.903	9.903	17.036
locks-links toggle			
rows (no.)	27	16	2
C value (m)	0.100	0.100	0.100
tread depth (m)	0.800	0.840	0.900
1st row adjust (m)	0.150	0.150	0.100
last row adjust (m)	0.000	0.125	0.125
top row angle (deg)	20.737	27.536	27.604
eye height (m)	1.200	1.200	1.200
eye offset (m)	0.150	0.150	0.150
VOMS & GANGWAYS	2 step	3 step	3 step
1st vom: rows / start	0 0	5 4	0 0
2nd vom: rows / start	0 0	5 4	0 0
vom1 - yes / draw	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>



# Beijing National Stadium – Roof Geometry

Generation of Primary Structural Geometry



# Beijing National Stadium – Roof Geometry

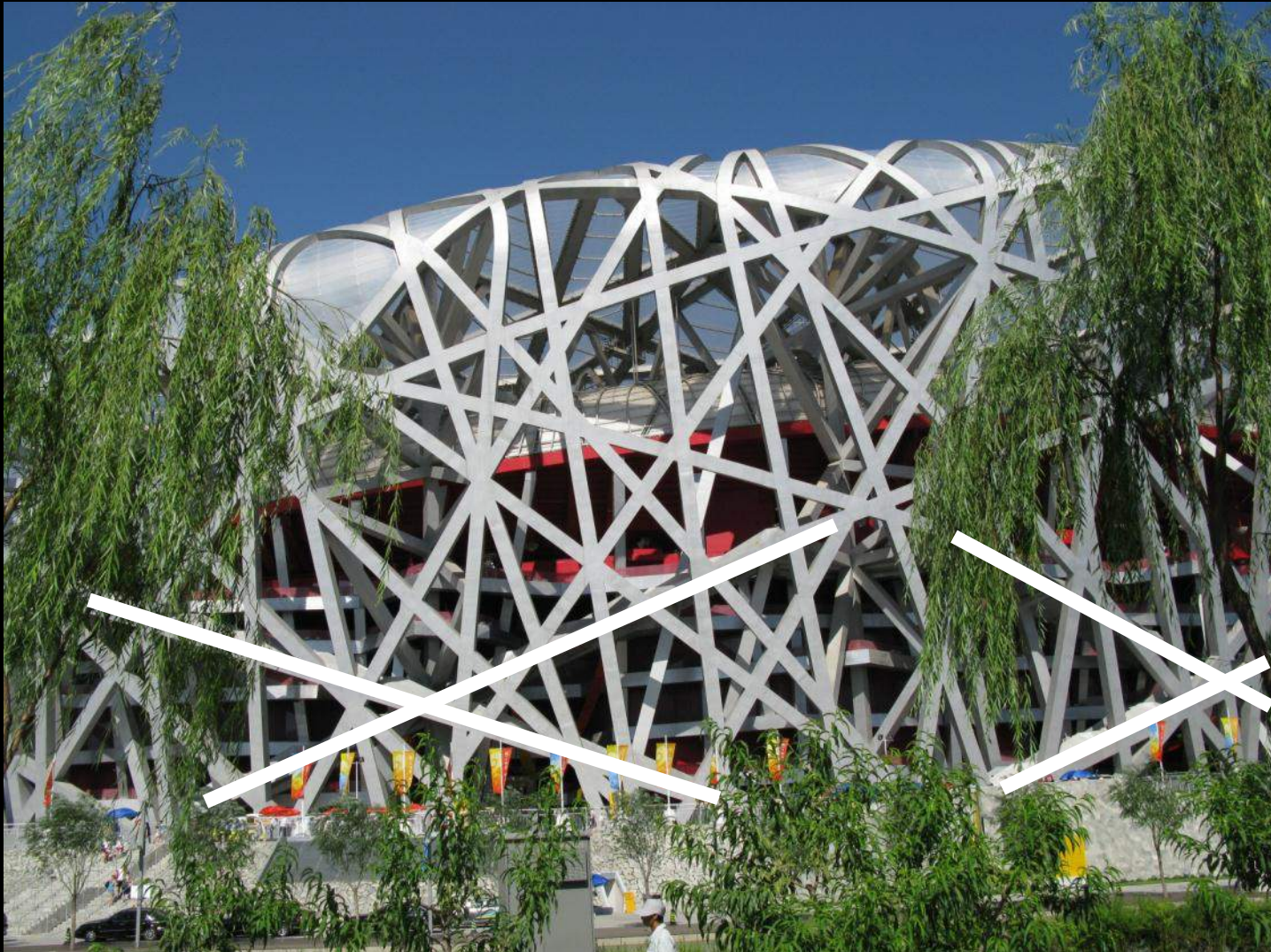
## Cascade Stair Geometry - Final





# Beijing National Stadium – Roof Geometry

Cascade Stair Geometry - Final



# Beijing National Stadium – Roof Geometry

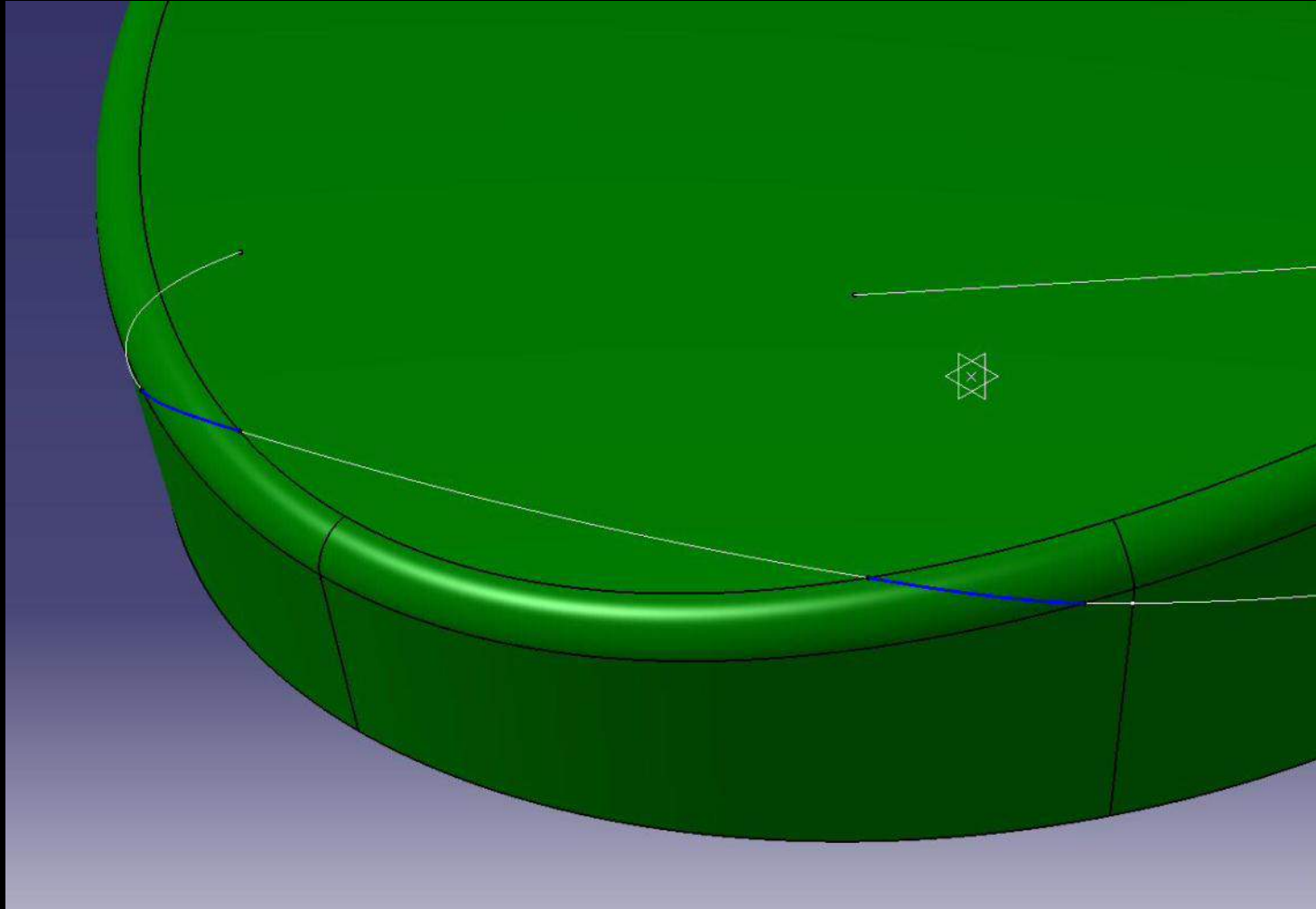
Importance of parametric & associative design





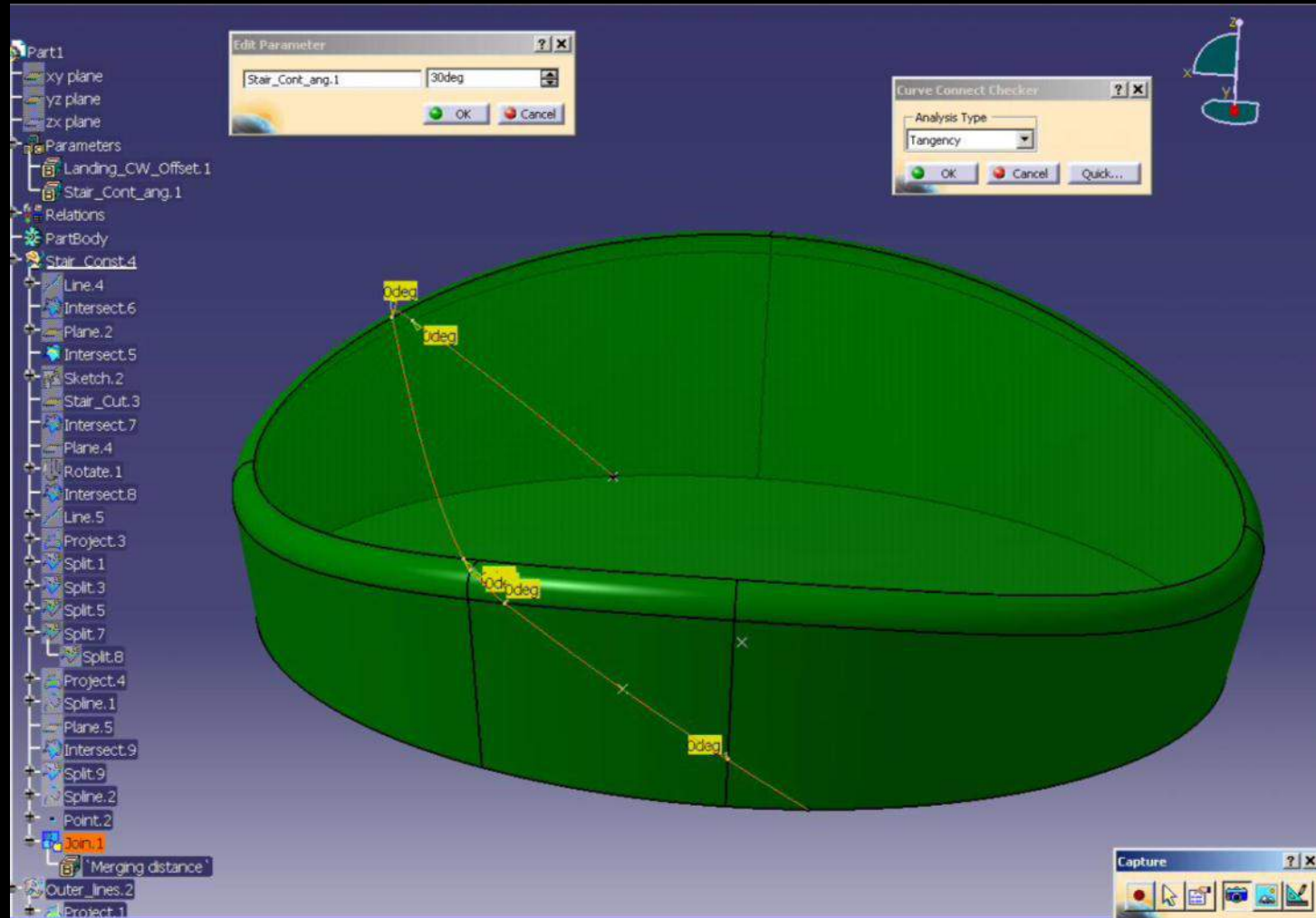
# Beijing National Stadium – Roof Geometry

Importance of parametric & associative design



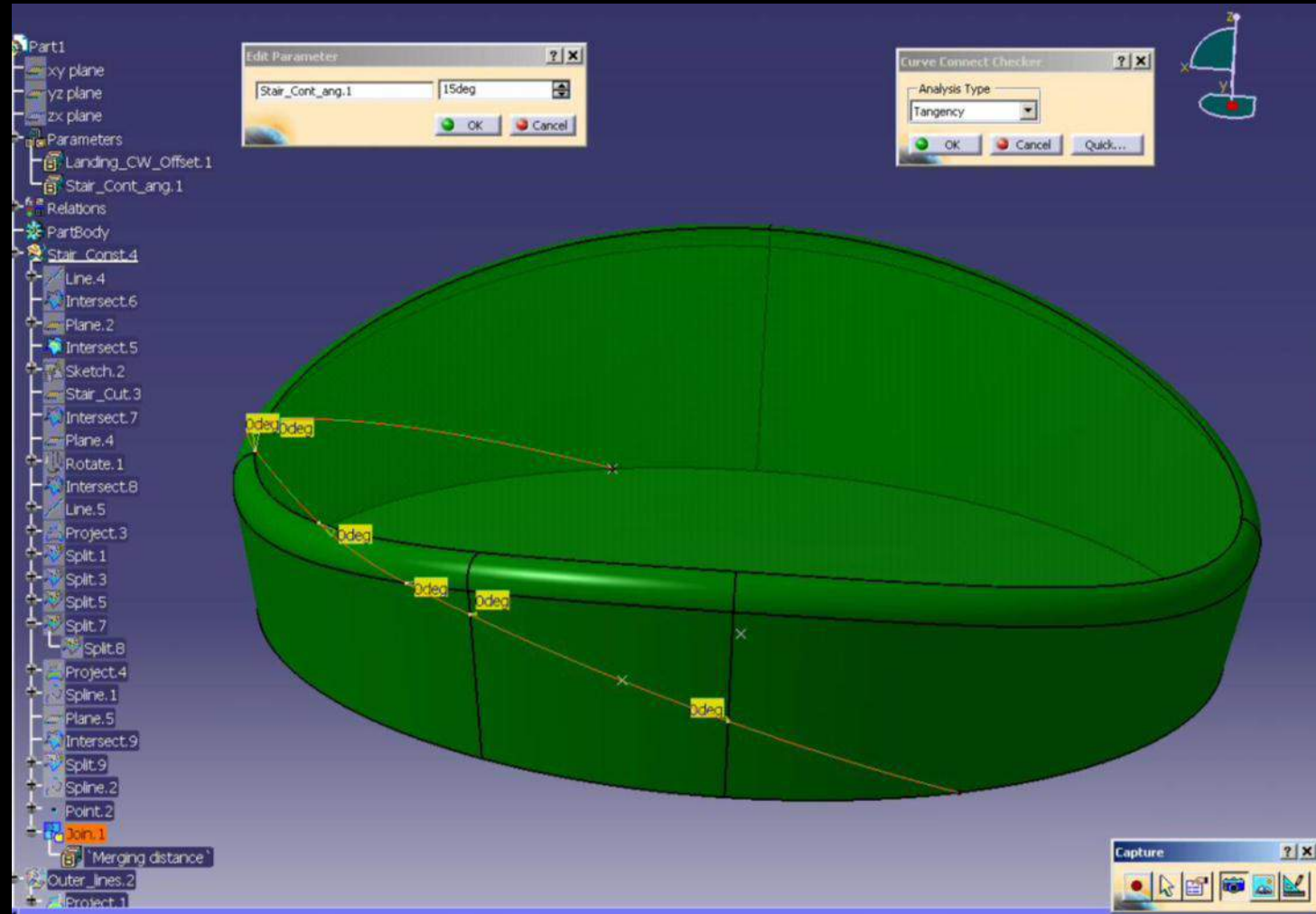
# Beijing National Stadium – Roof Geometry

Importance of parametric & associative design



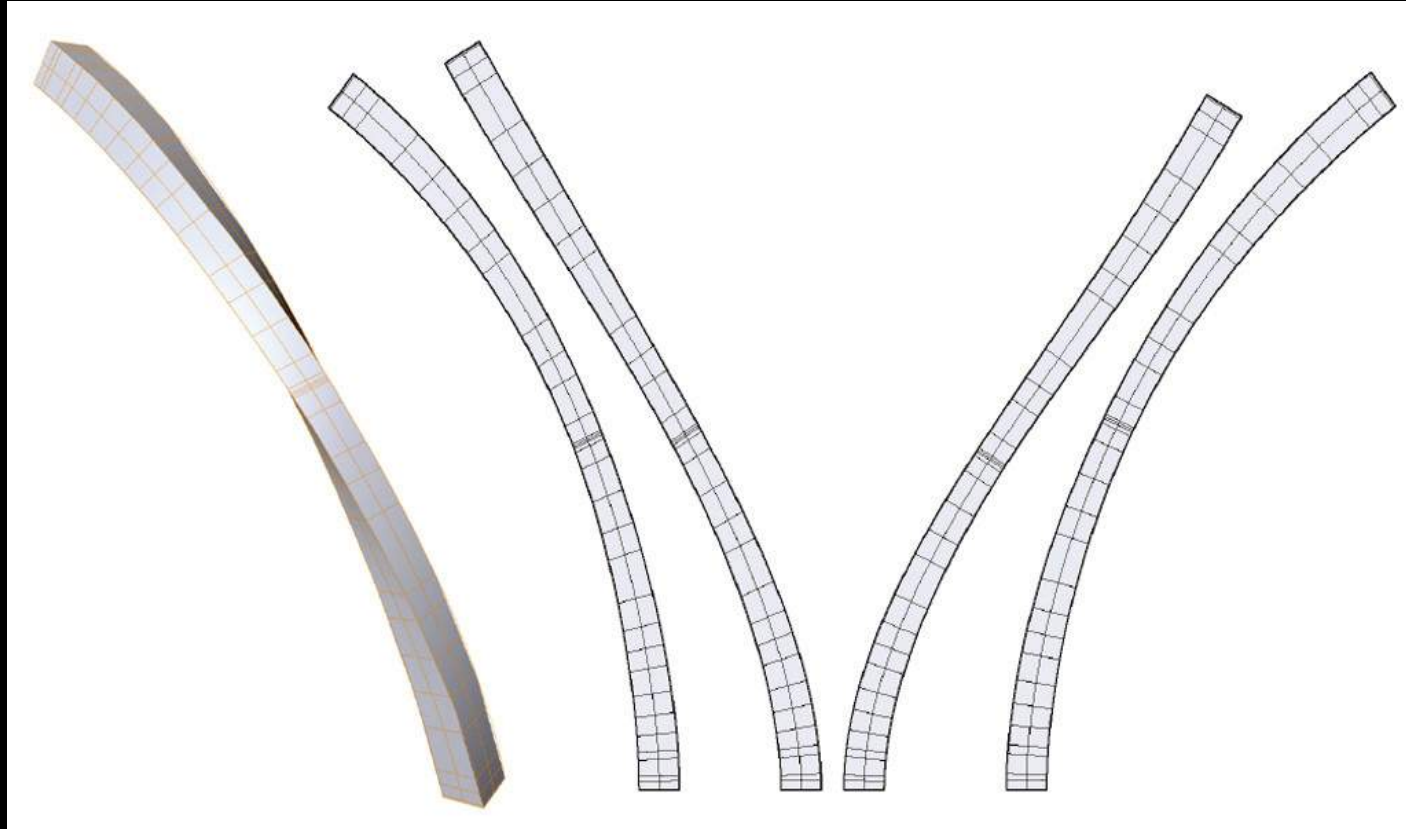
# Beijing National Stadium – Roof Geometry

Importance of parametric & associative design



# Beijing National Stadium – Roof Geometry

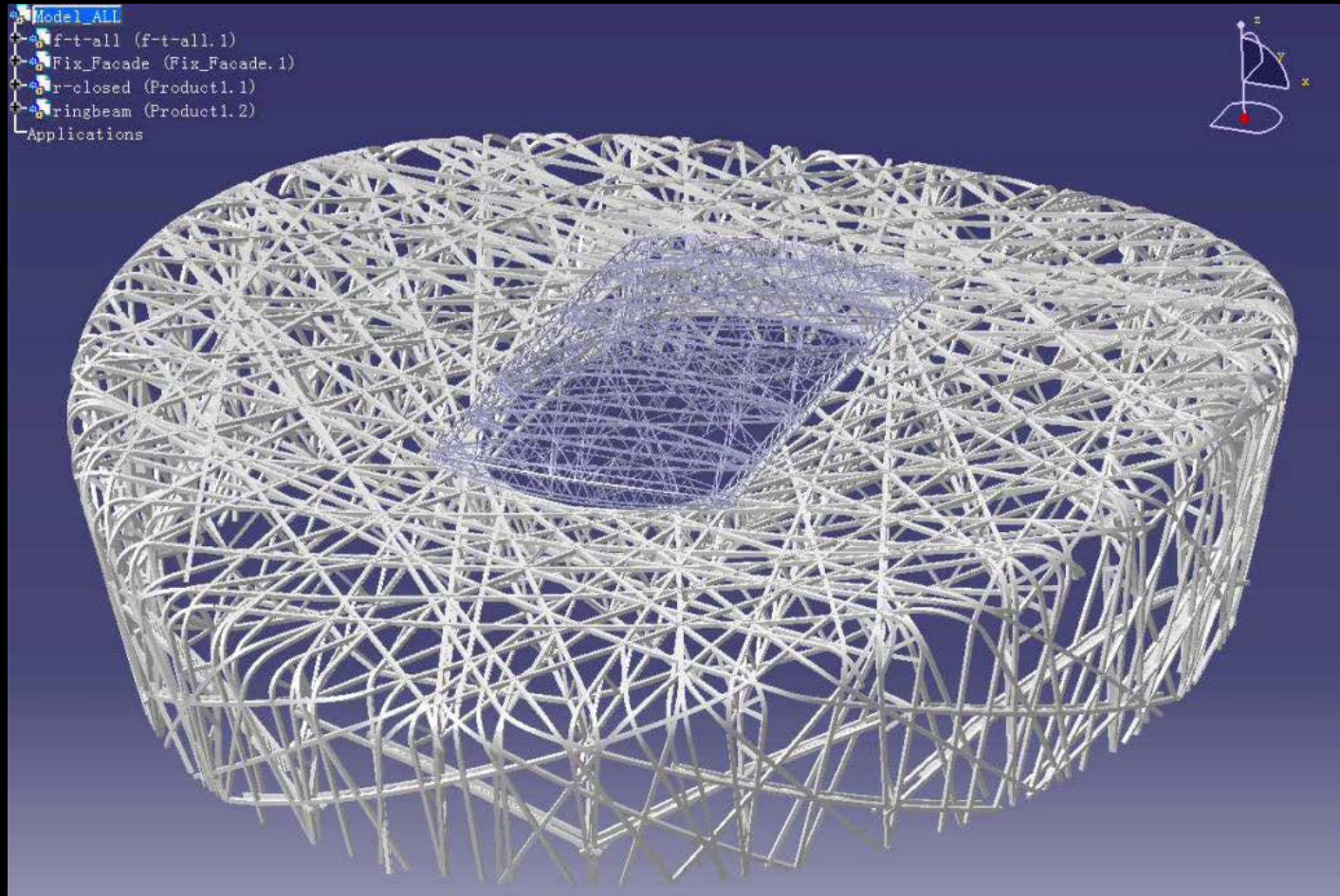
Complex Twisted & Curving Steel Elements





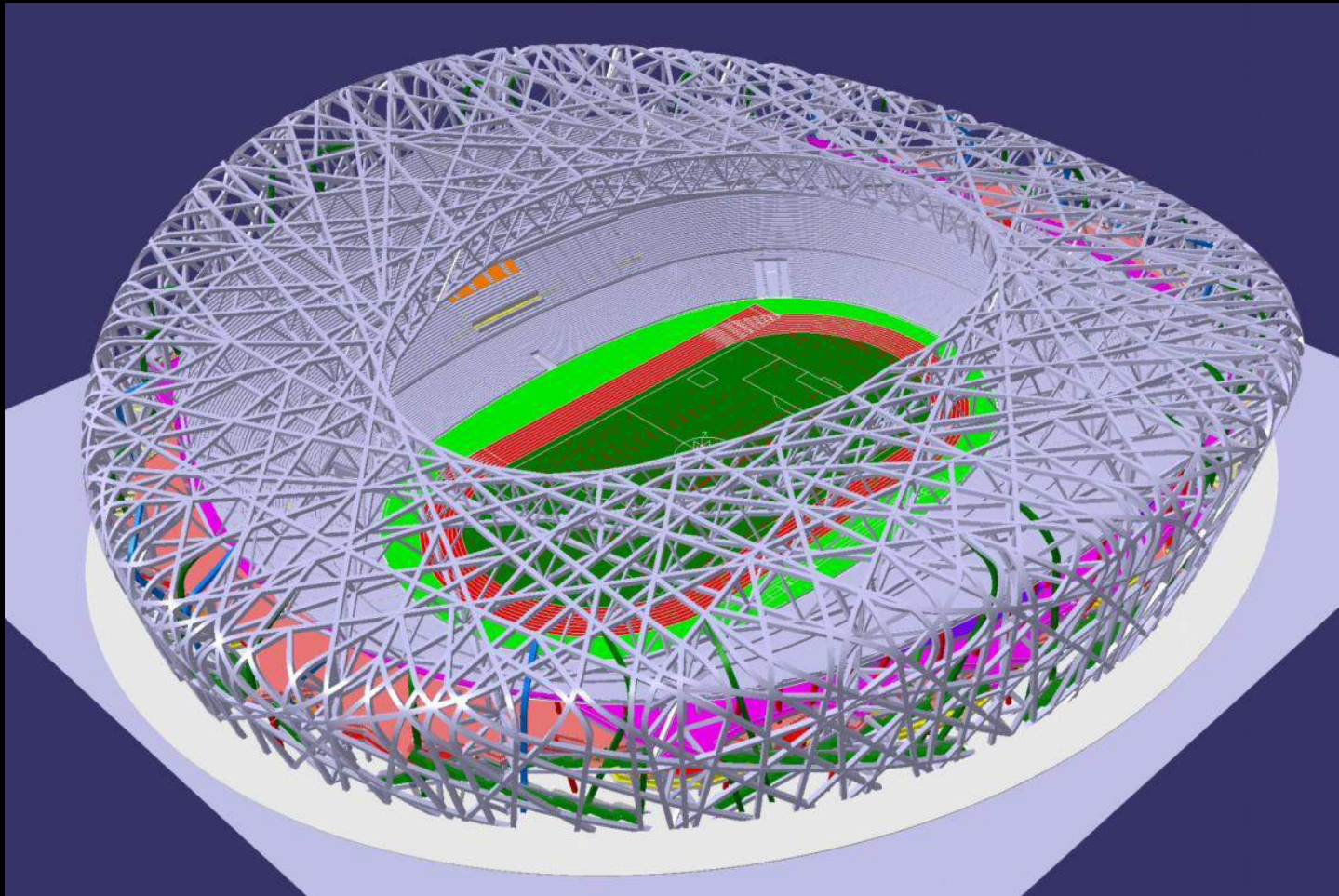
# Beijing National Stadium – Roof Geometry

Realising the concept - Virtual Prototype

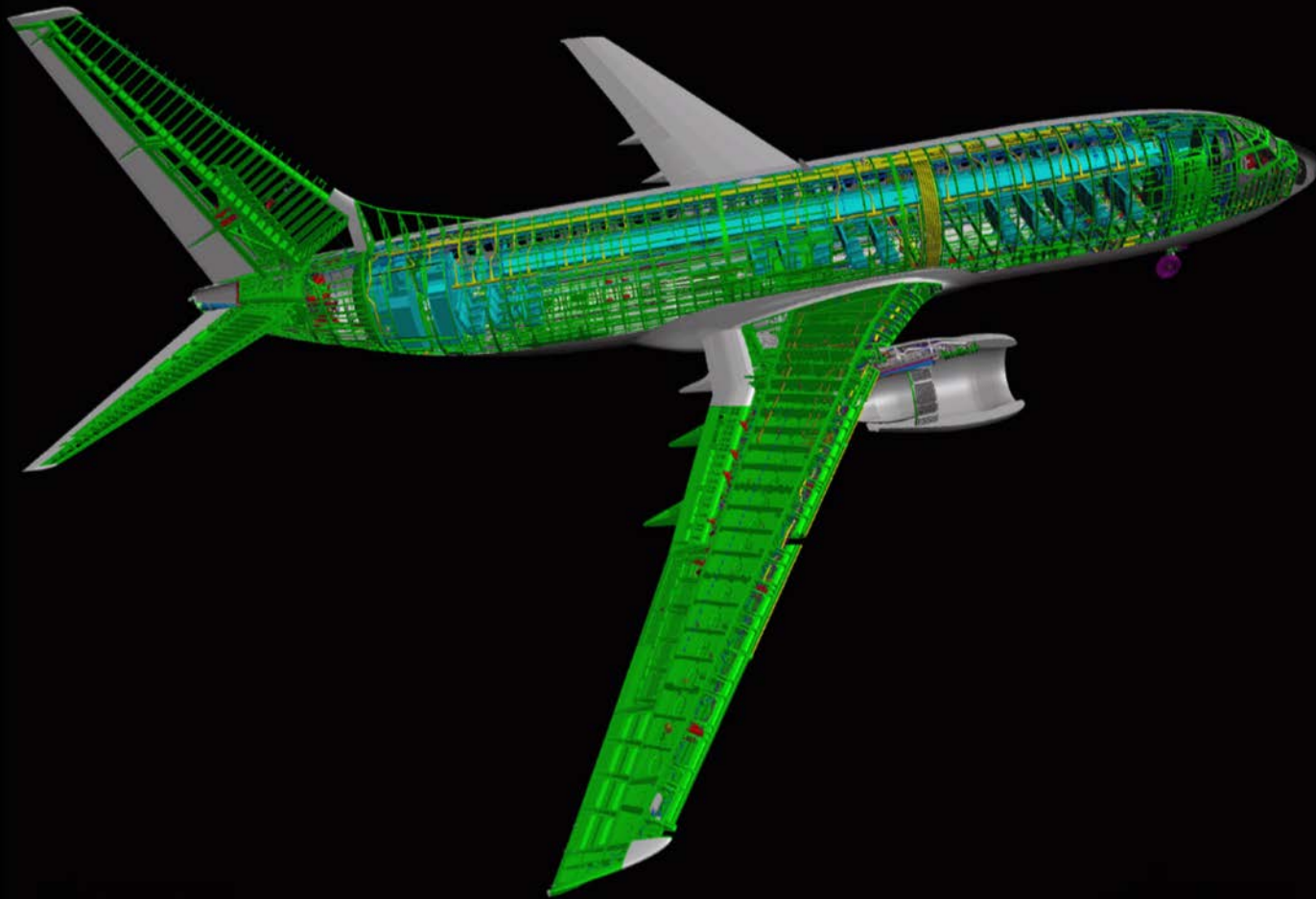


# Beijing National Stadium – Roof Geometry

Final CATIA model







© Boeing/CATIA

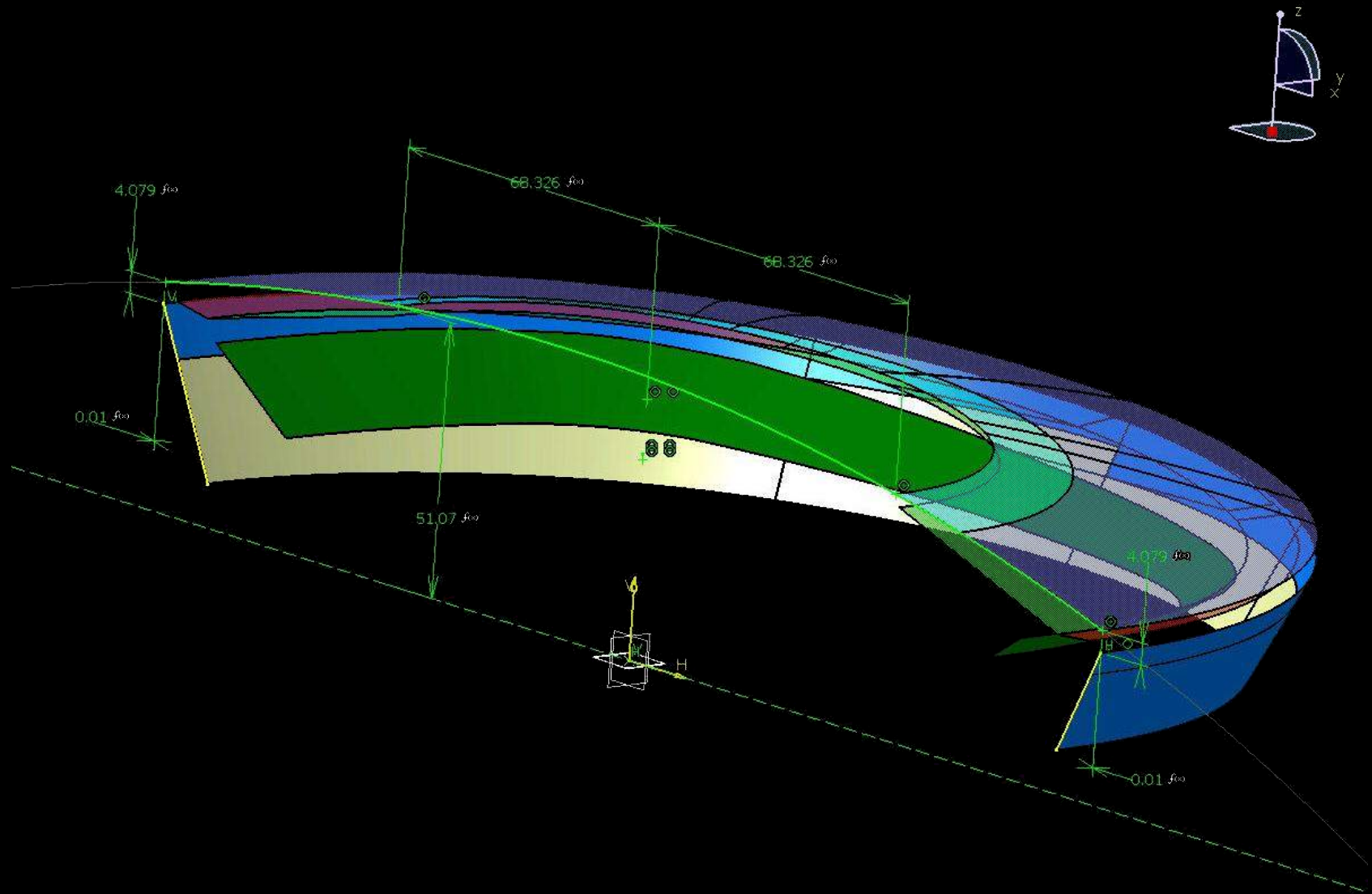
BIM = PLM  
(Product Lifecycle Management)



© ArupSport

# Donbass Arena 2005-2009 Architect: ArupSport

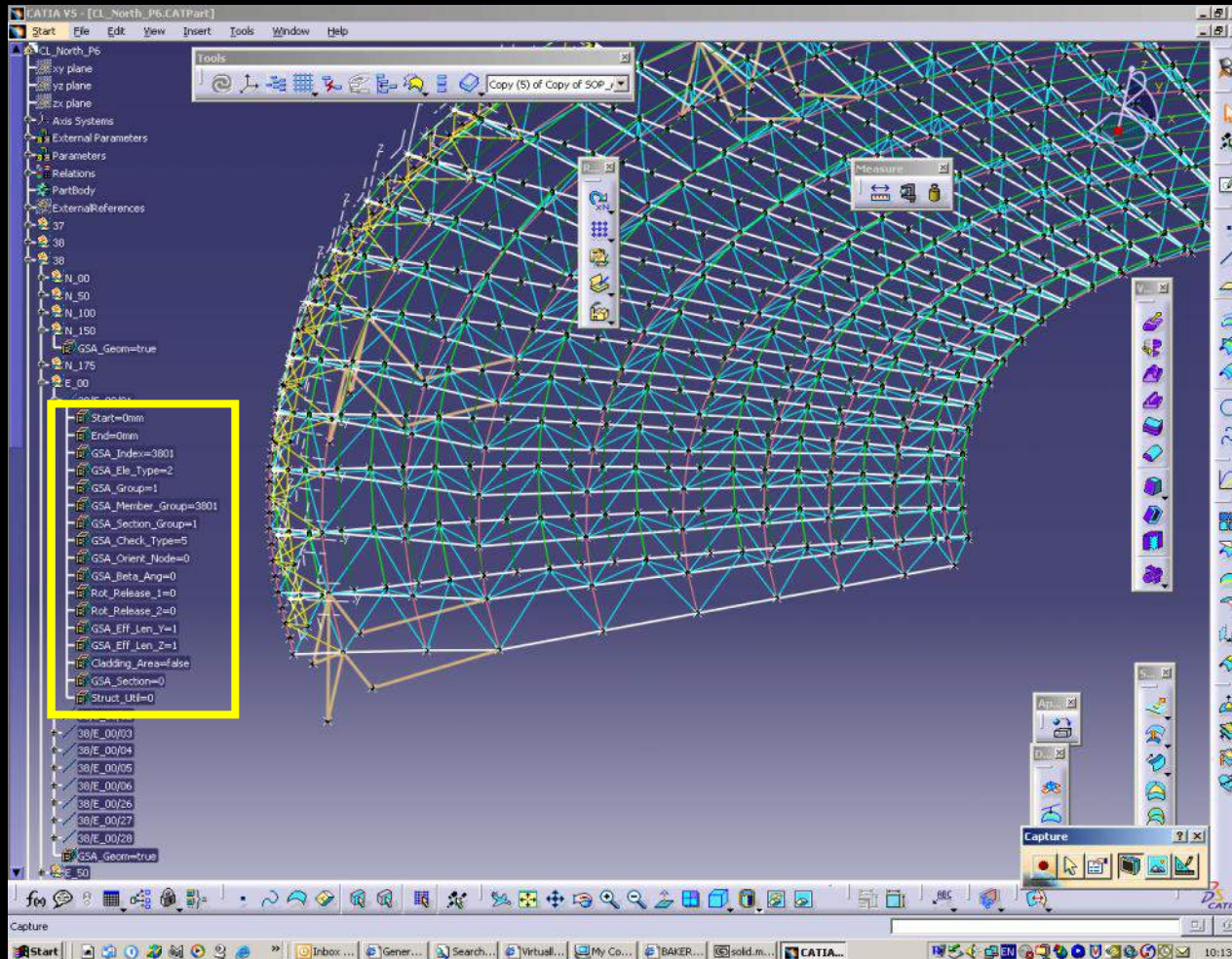
# Donbass Arena – Beyond Geometry





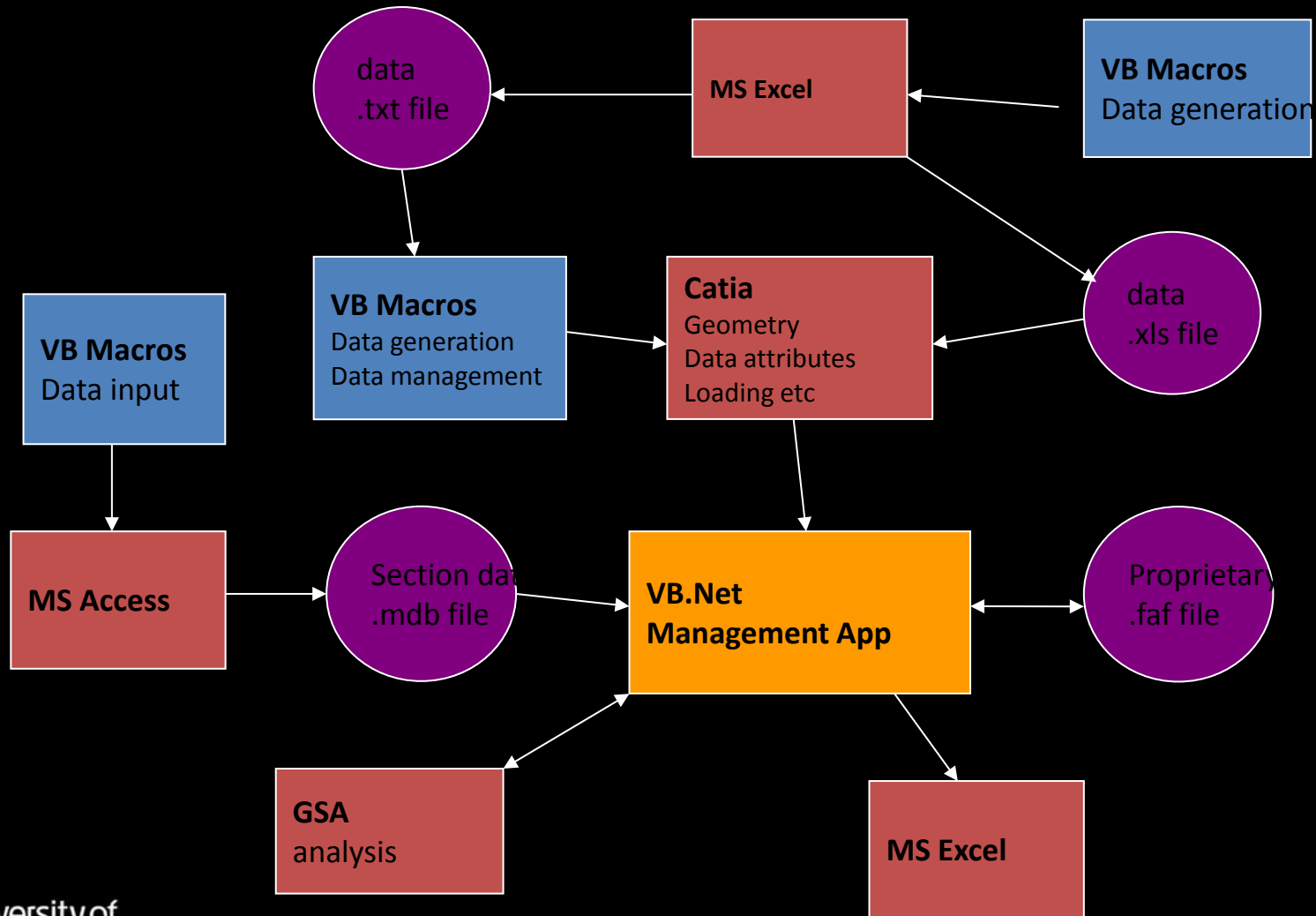
# Donbass Arena – Beyond Geometry

Structural information embedded in CATIA model



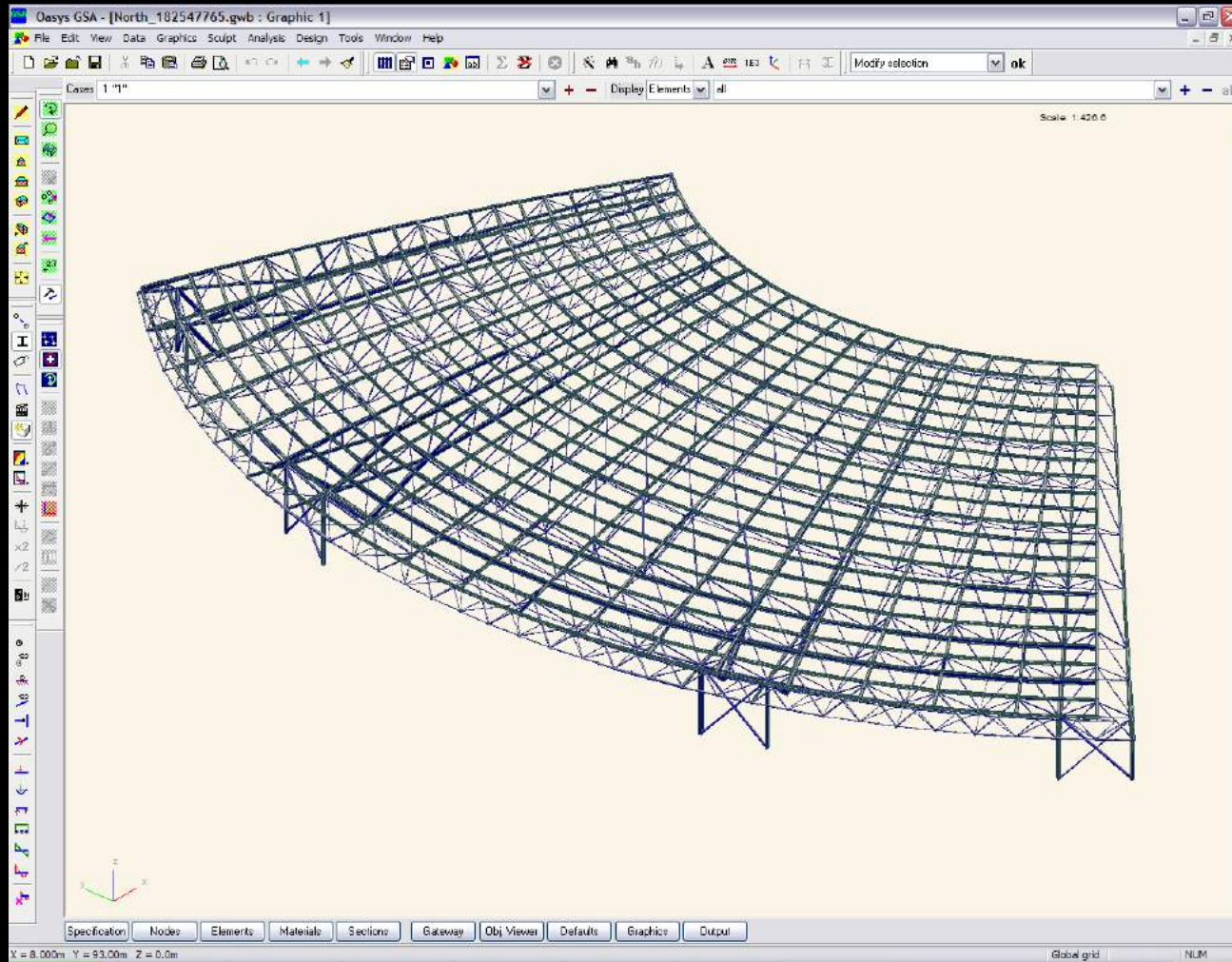
# Donbass Arena – Beyond Geometry

Structural data map



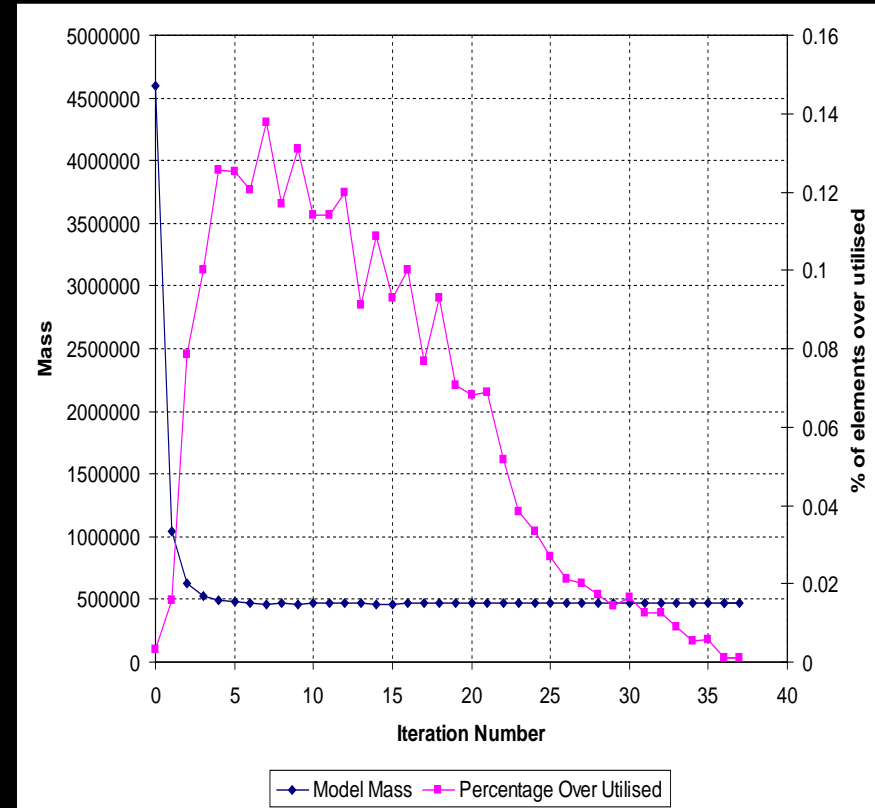
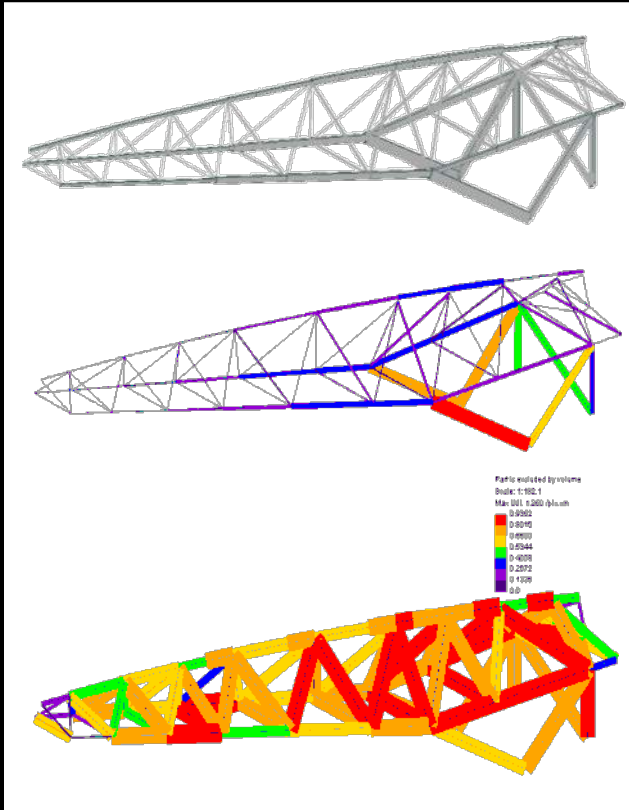
# Donbass Arena – Beyond Geometry

Structural analysis model



# Donbass Arena – Beyond Geometry

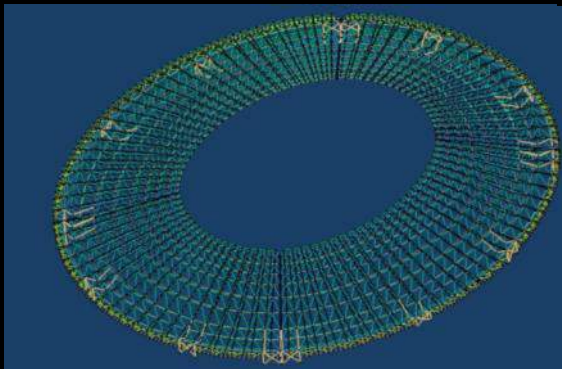
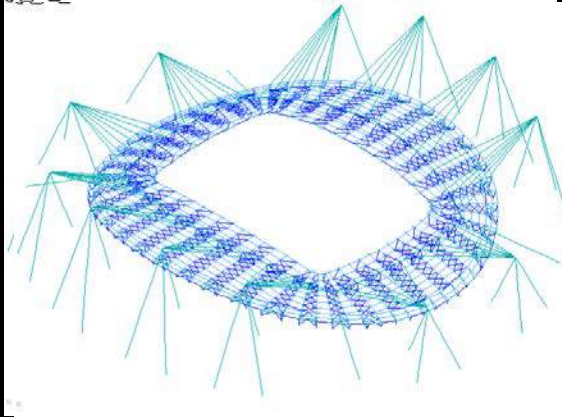
## Optimisation Process



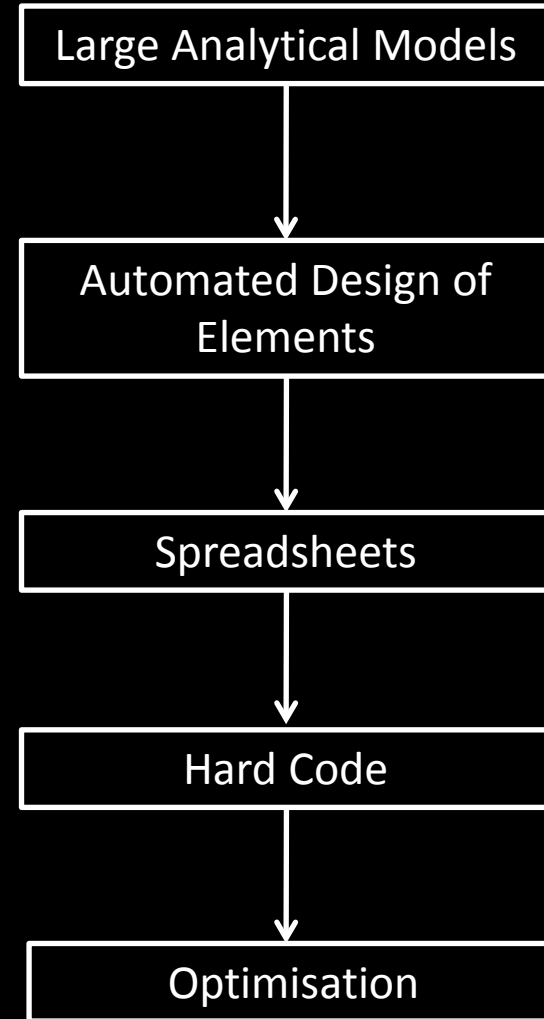


# Evolution of Optimisation

## Structural Optimisation



- Optimisation for Minimum Weight
- Optimisation for No of Elements



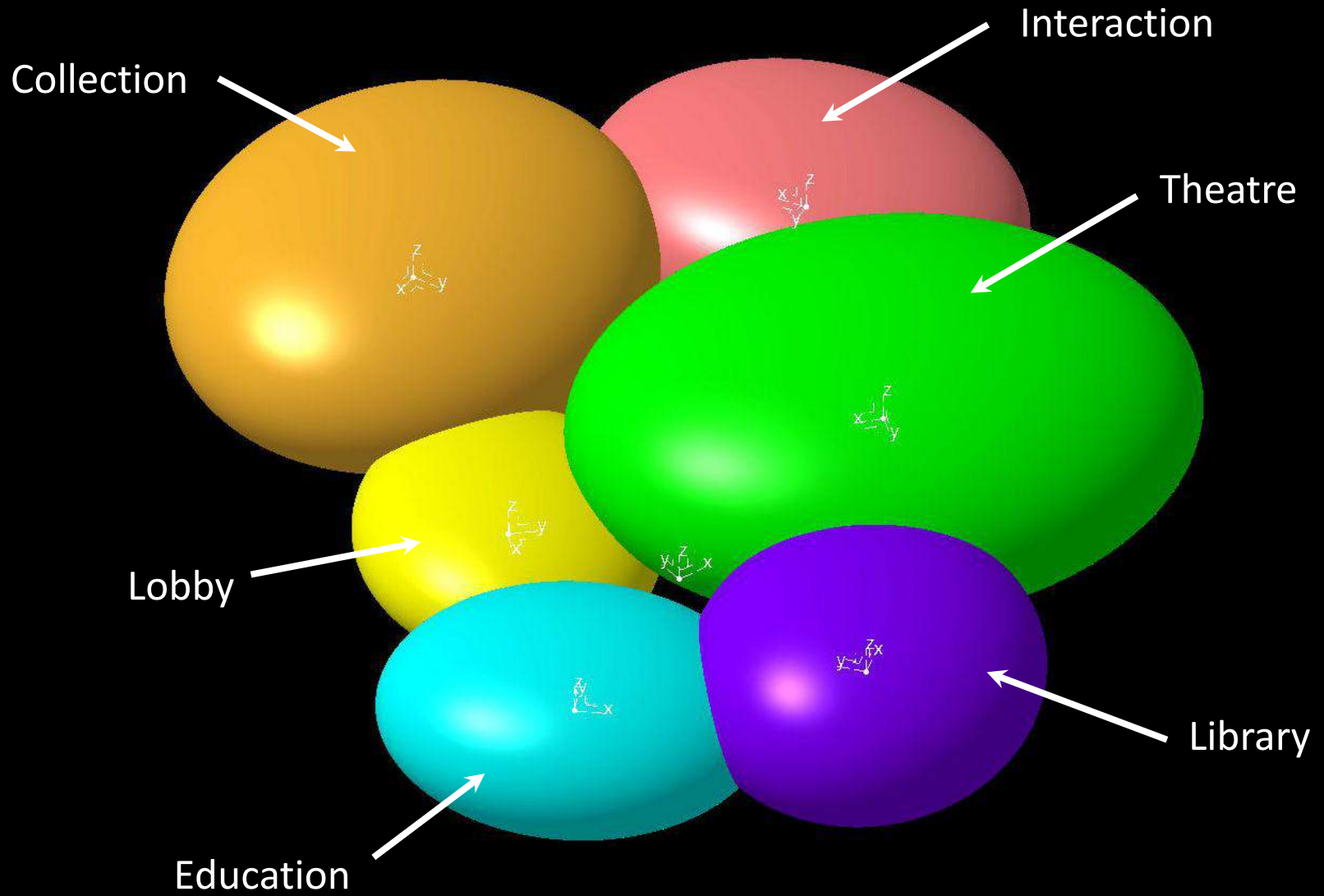


© MVRDV

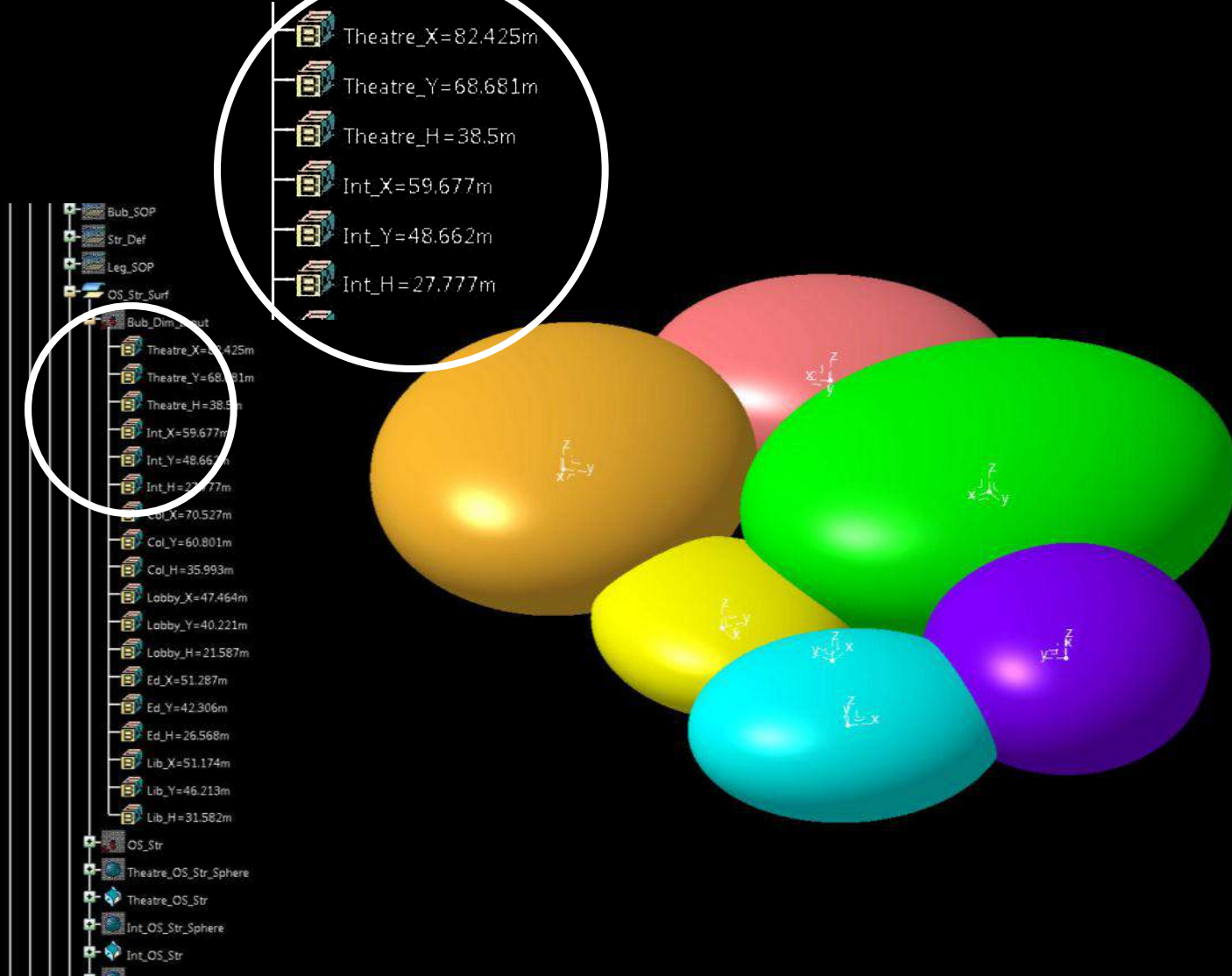
# China Comic and Animation Museum 2011

Architect: MVRDV

# Comic & Animation Museum - Bubbles

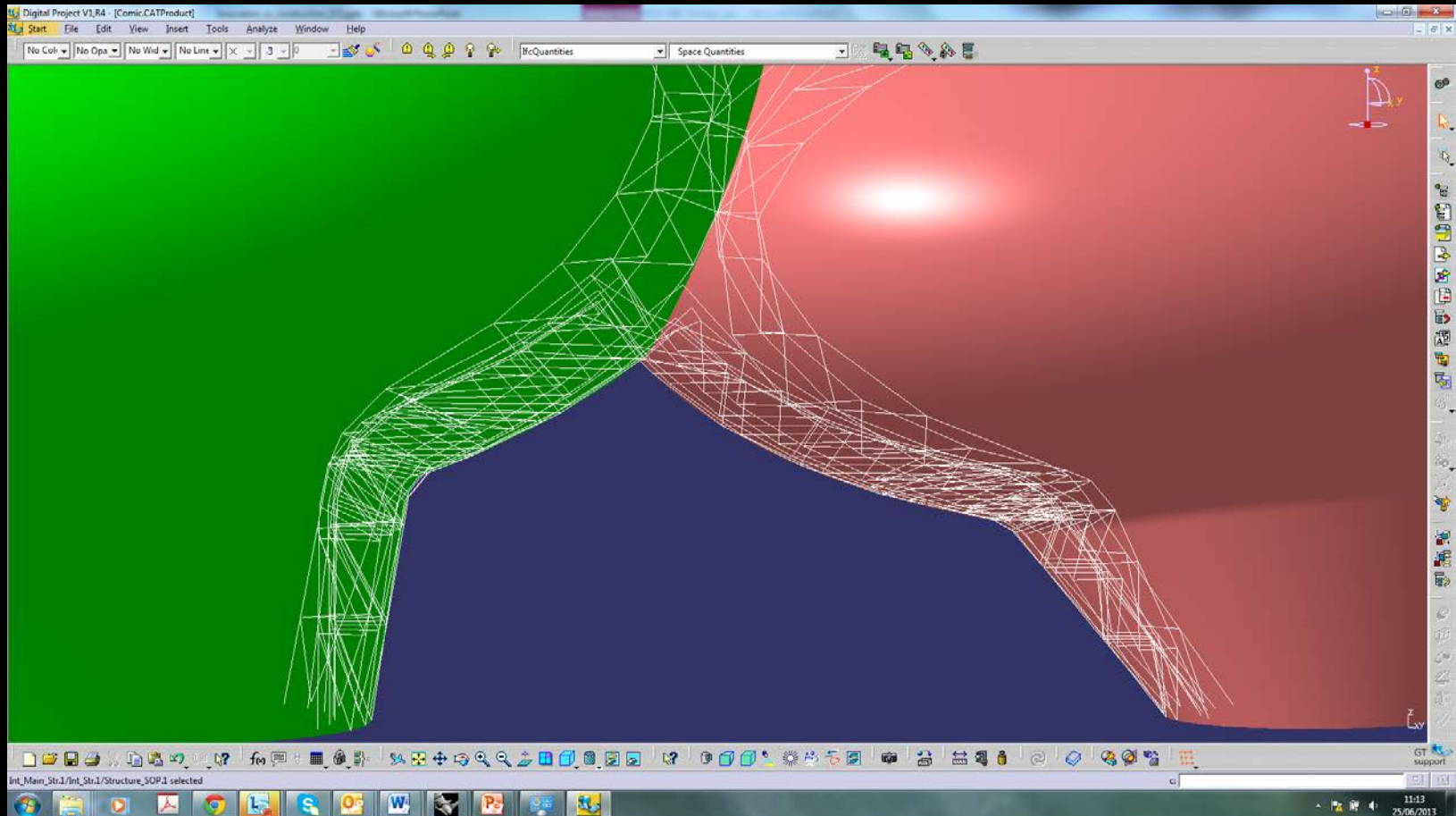


# Comic & Animation Museum Parametric Control

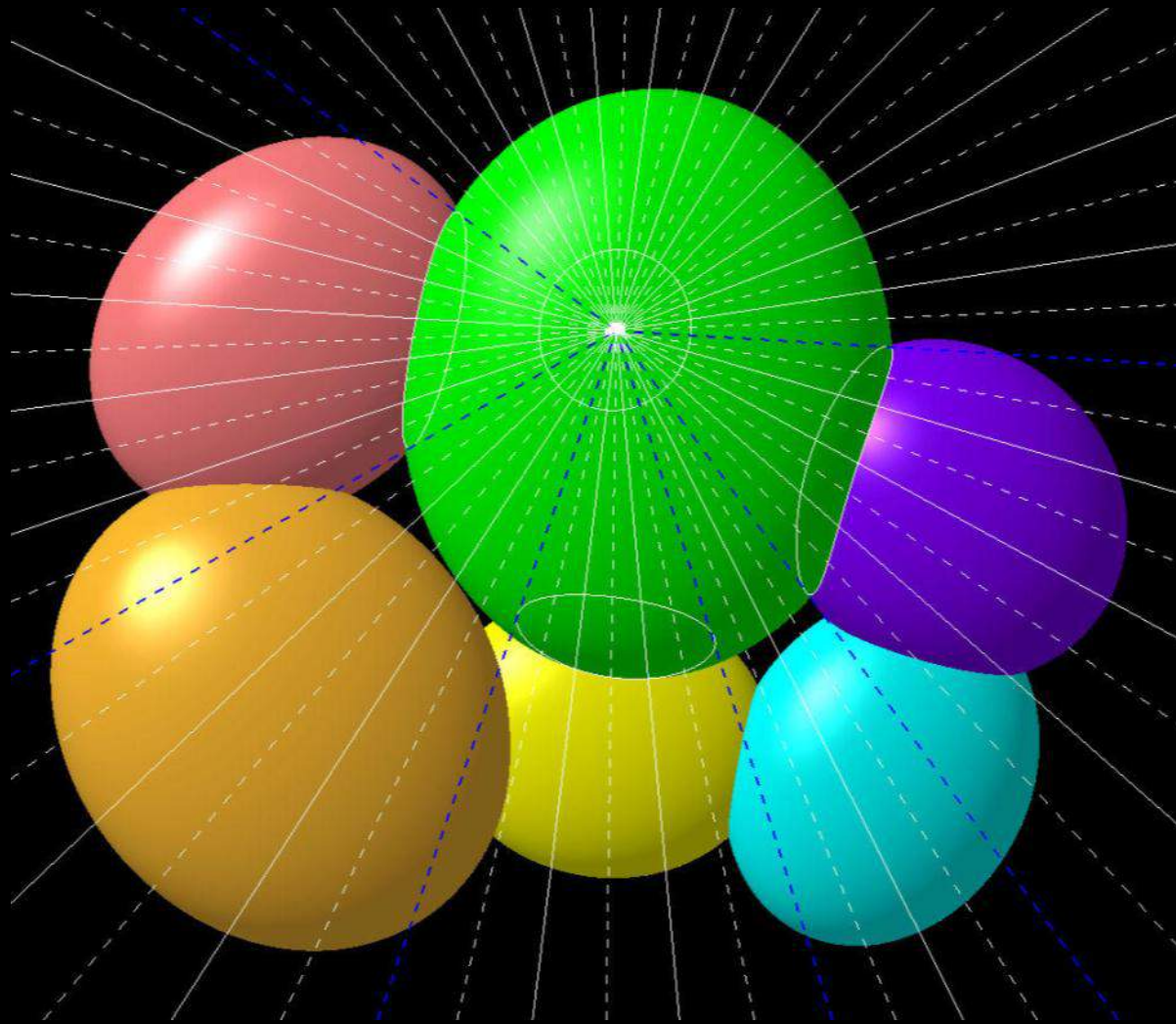




# Comic & Animation Museum Evolution to final concept



# Comic & Animation Museum –Interactions

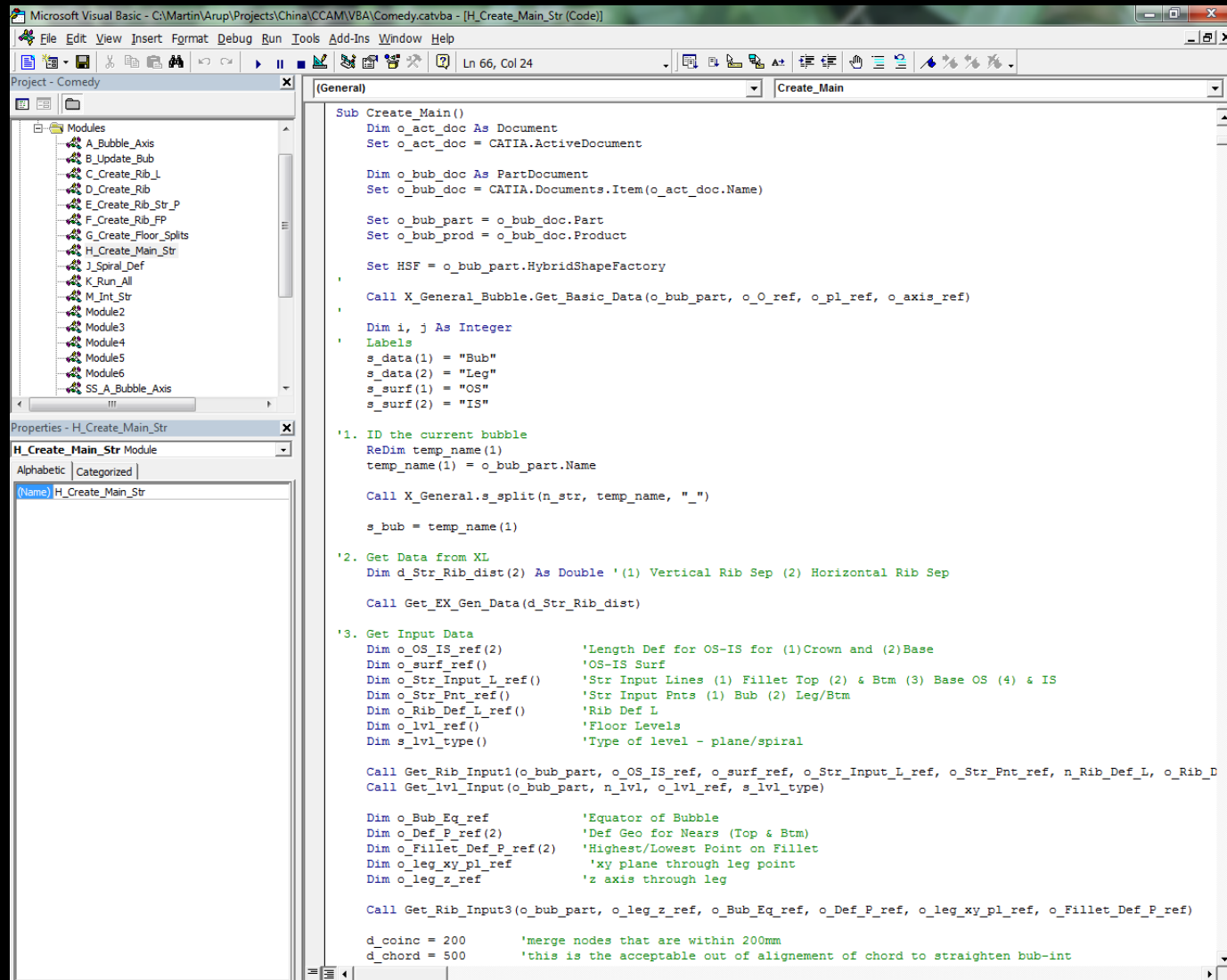


Main

Intermediate



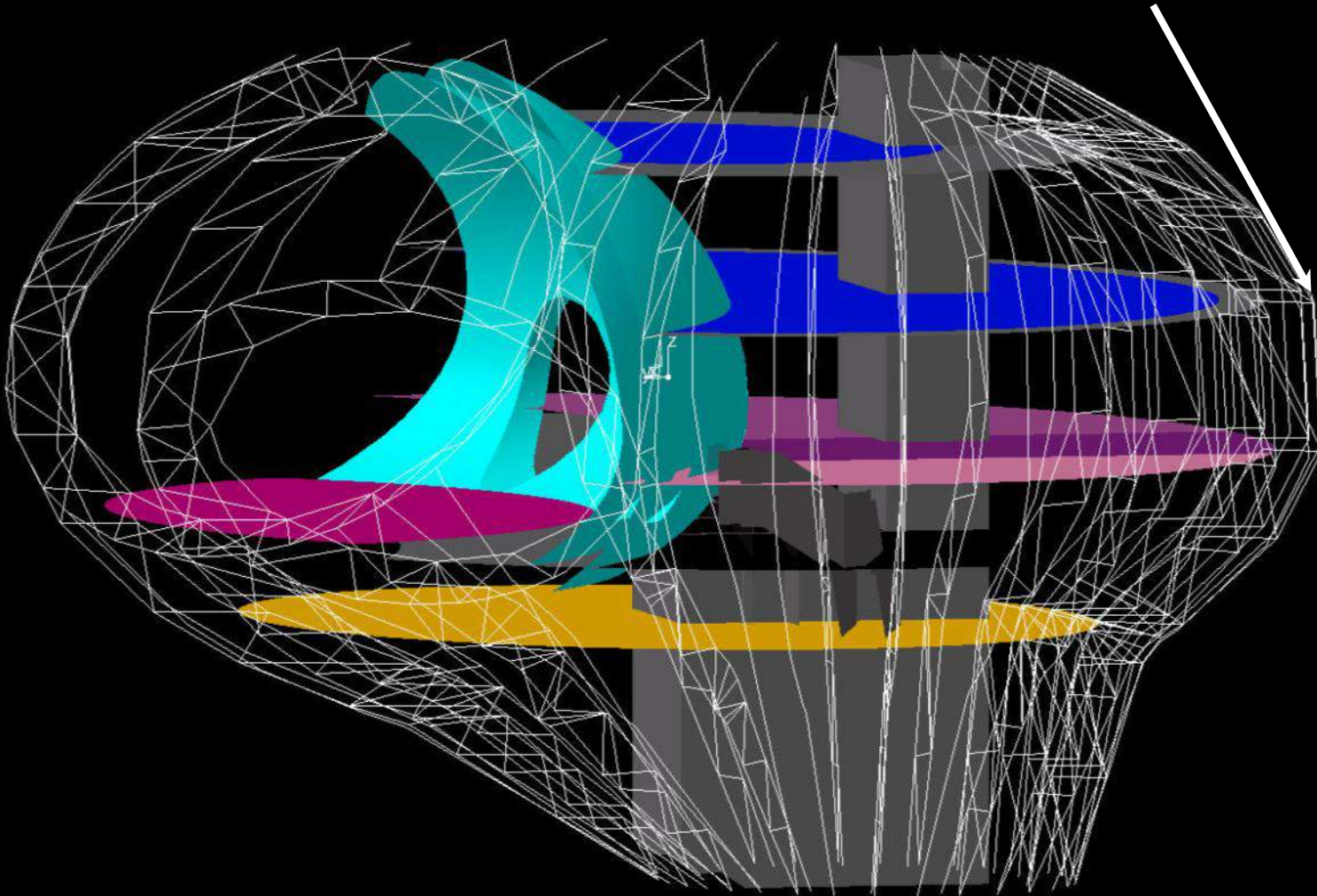
# Comic & Animation Museum – VBA Code



```
Sub Create_Main()  
    Dim o_act_doc As Document  
    Set o_act_doc = CATIA.ActiveDocument  
  
    Dim o_bub_doc As PartDocument  
    Set o_bub_doc = CATIA.Documents.Item(o_act_doc.Name)  
  
    Set o_bub_part = o_bub_doc.Part  
    Set o_bub_prod = o_bub_doc.Product  
  
    Set HSF = o_bub_part.HybridShapeFactory  
  
    Call X_General_Bubble.Get_Basic_Data(o_bub_part, o_O_ref, o_pl_ref, o_axis_ref)  
  
    Dim i, j As Integer  
    'Labels  
    s_data(1) = "Bub"  
    s_data(2) = "Leg"  
    s_surf(1) = "OS"  
    s_surf(2) = "IS"  
  
    '1. ID the current bubble  
    ReDim temp_name(1)  
    temp_name(1) = o_bub_part.Name  
  
    Call X_General.s_split(n_str, temp_name, "_")  
  
    s_bub = temp_name(1)  
  
    '2. Get Data from XL  
    Dim d_Str_Rib_dist(2) As Double ' (1) Vertical Rib Sep (2) Horizontal Rib Sep  
    Call Get_EX_Gen_Data(d_Str_Rib_dist)  
  
    '3. Get Input Data  
    Dim o_OS_IS_ref(2) 'Length Def for OS-IS for (1)Crown and (2)Base  
    Dim o_surf_ref() 'OS-IS Surf  
    Dim o_Str_Input_L_ref() 'Str Input Lines (1) Fillet Top (2) & Btm (3) Base OS (4) & IS  
    Dim o_Str_Pnt_ref() 'Str Input Pnts (1) Bub (2) Leg/Btm  
    Dim o_Rib_Def_L_ref() 'Rib Def L  
    Dim o_lvl_ref() 'Floor Levels  
    Dim s_lvl_type() 'Type of level - plane/spiral  
  
    Call Get_Rib_Input1(o_bub_part, o_OS_IS_ref, o_surf_ref, o_Str_Input_L_ref, o_Str_Pnt_ref, n_Rib_Def_L, o_Rib_D  
    Call Get_lvl_Input(o_bub_part, n_lvl, o_lvl_ref, s_lvl_type)  
  
    Dim o_Bub_Eq_ref 'Equator of Bubble  
    Dim o_Def_P_ref(2) 'Def Geo for Nears (Top & Btm)  
    Dim o_Fillet_Def_P_ref(2) 'Highest/Lowest Point on Fillet  
    Dim o_leg_xy_pl_ref 'xy plane through leg point  
    Dim o_leg_z_ref 'z axis through leg  
  
    Call Get_Rib_Input3(o_bub_part, o_leg_z_ref, o_Bub_Eq_ref, o_Def_P_ref, o_leg_xy_pl_ref, o_Fillet_Def_P_ref)  
  
    d_coinc = 200 'merge nodes that are within 200mm  
    d_chord = 500 'this is the acceptable out of alignment of chord to straighten bub-int
```

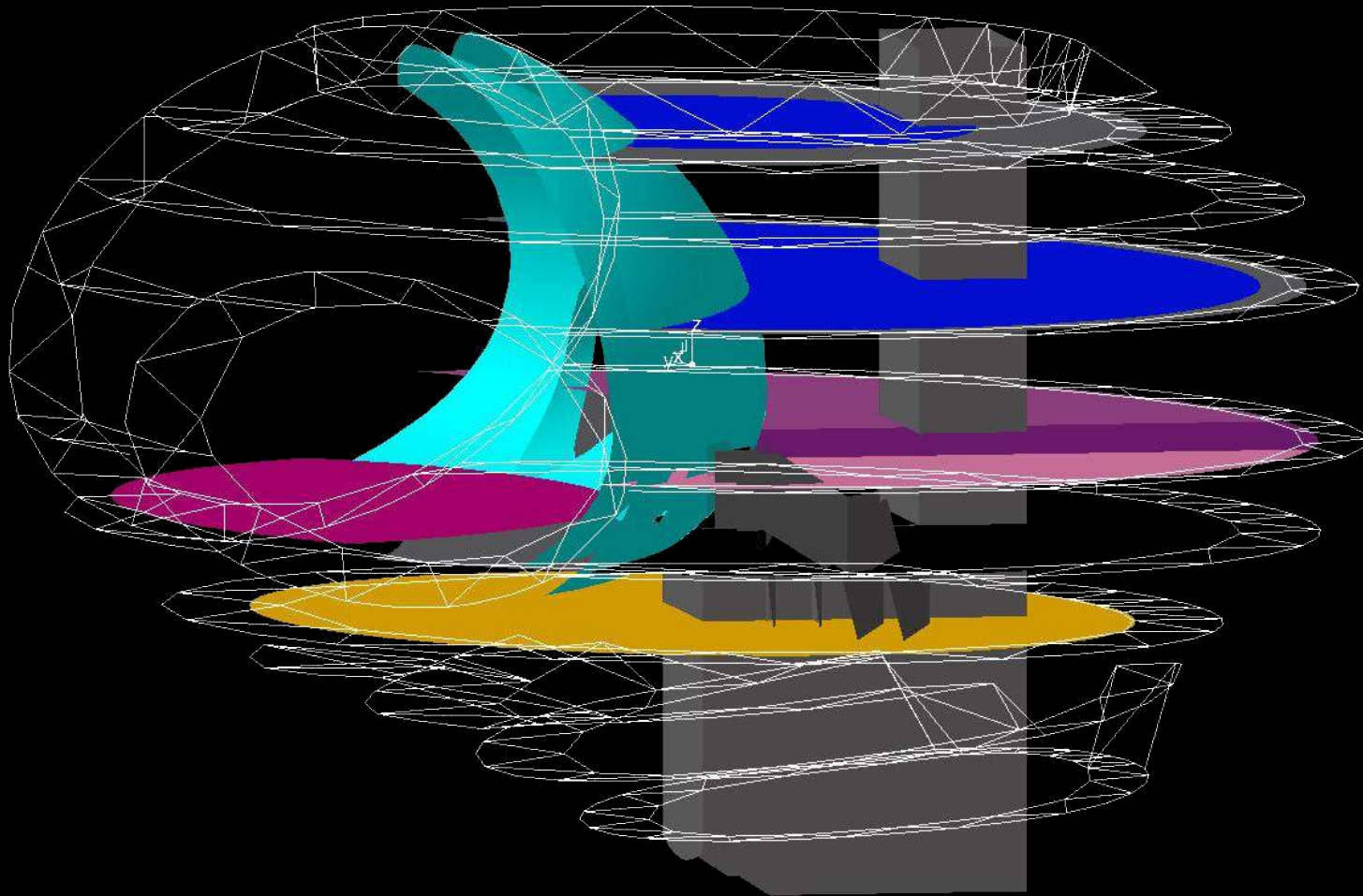
# Comic & Animation Museum : Vertical Frames

Vertical Frames correspond with floor levels



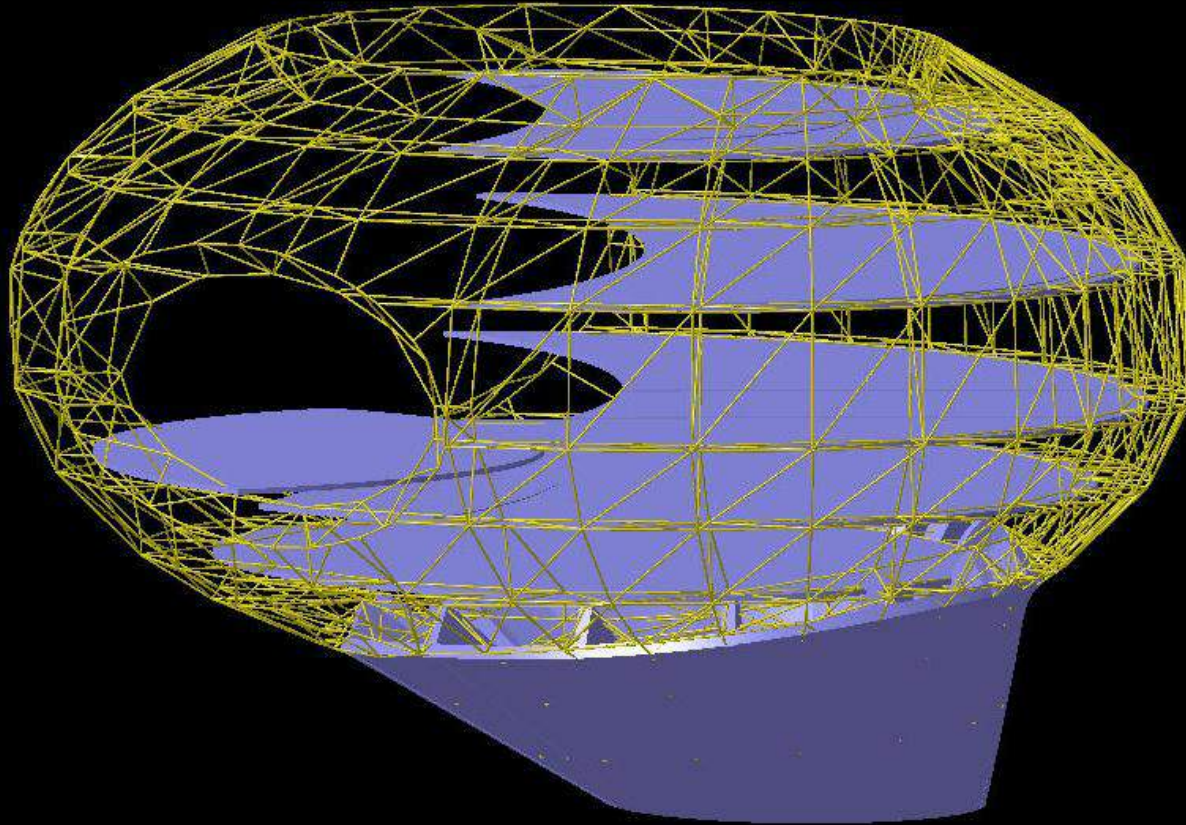
# Comic & Animation Museum : Horizontal Frames

Horizontal Frames at floor levels and share  
load between vertical frame

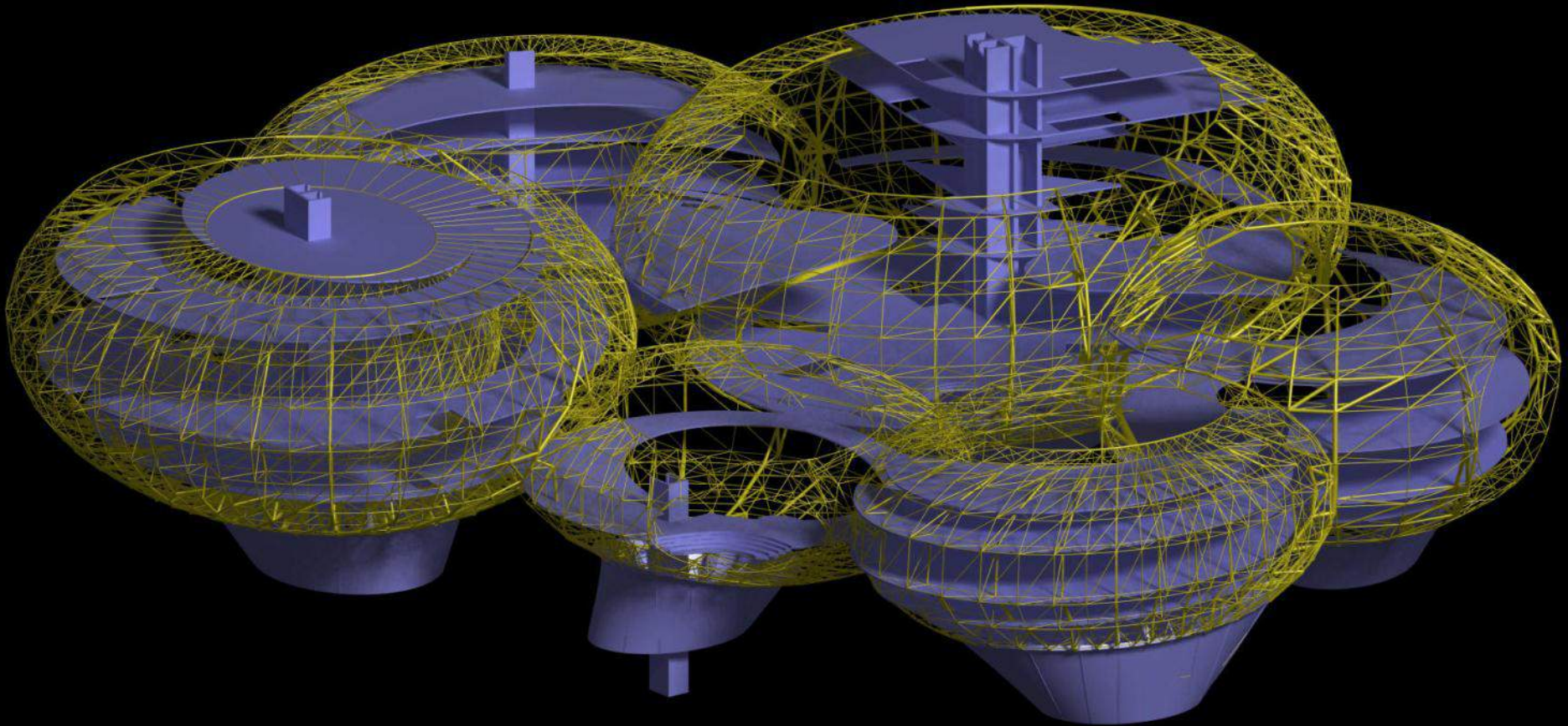




# Comic & Animation Museum - Complete Bubble

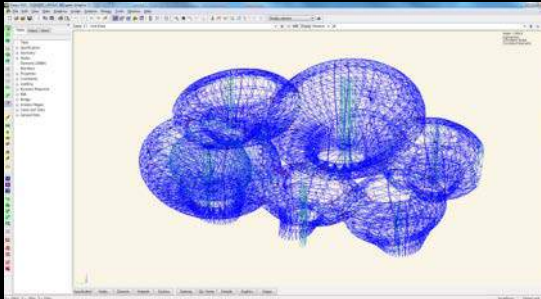
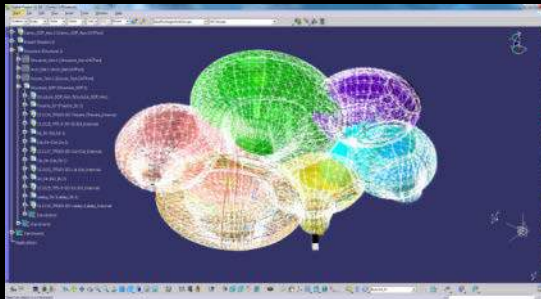
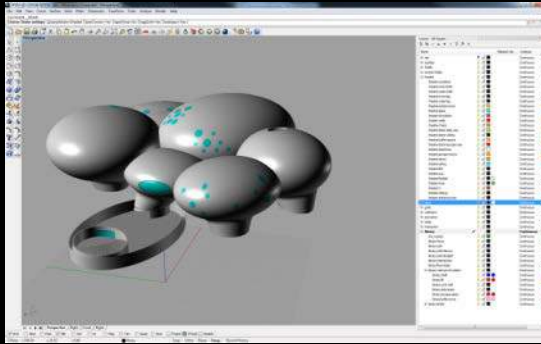


# Comic & Animation Museum - Complete Model

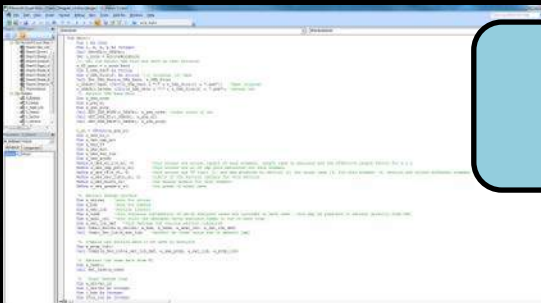




# Comic & Animation Museum - Process



University of  
**Salford**  
MANCHESTER



Architectural  
Requirements

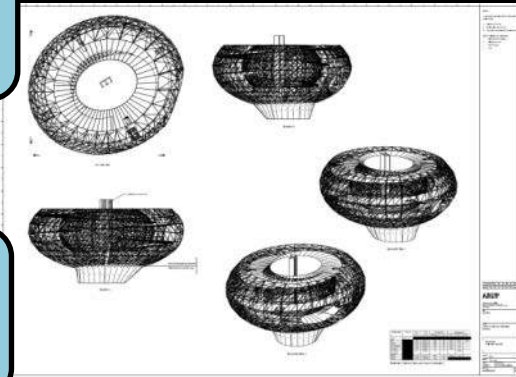
2D Drawing

3D Parametric  
Model

Structural  
Analysis Model

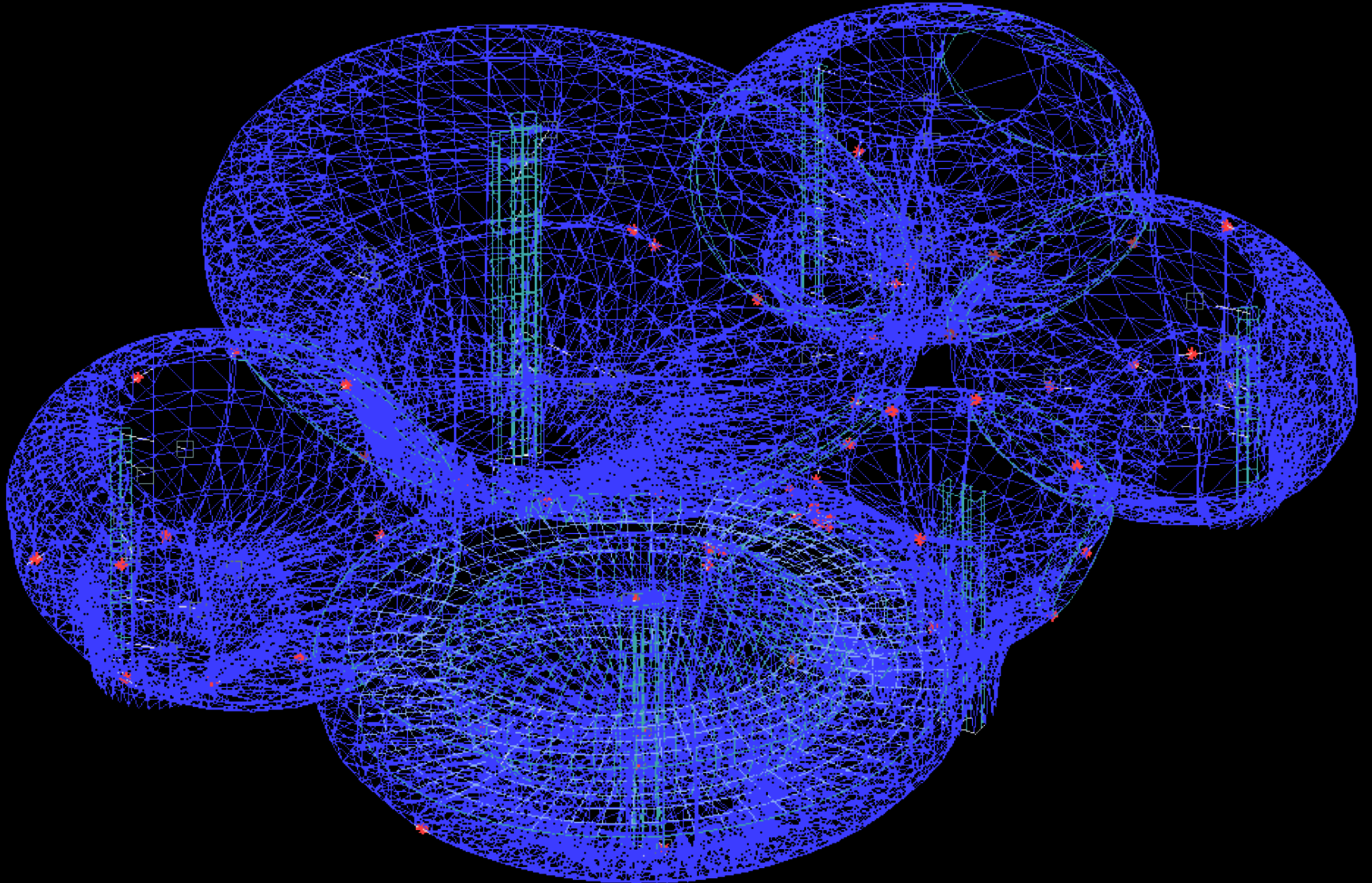
Member  
Design

Analysis



ARUP

# Comic & Animation Museum - Analysis Model



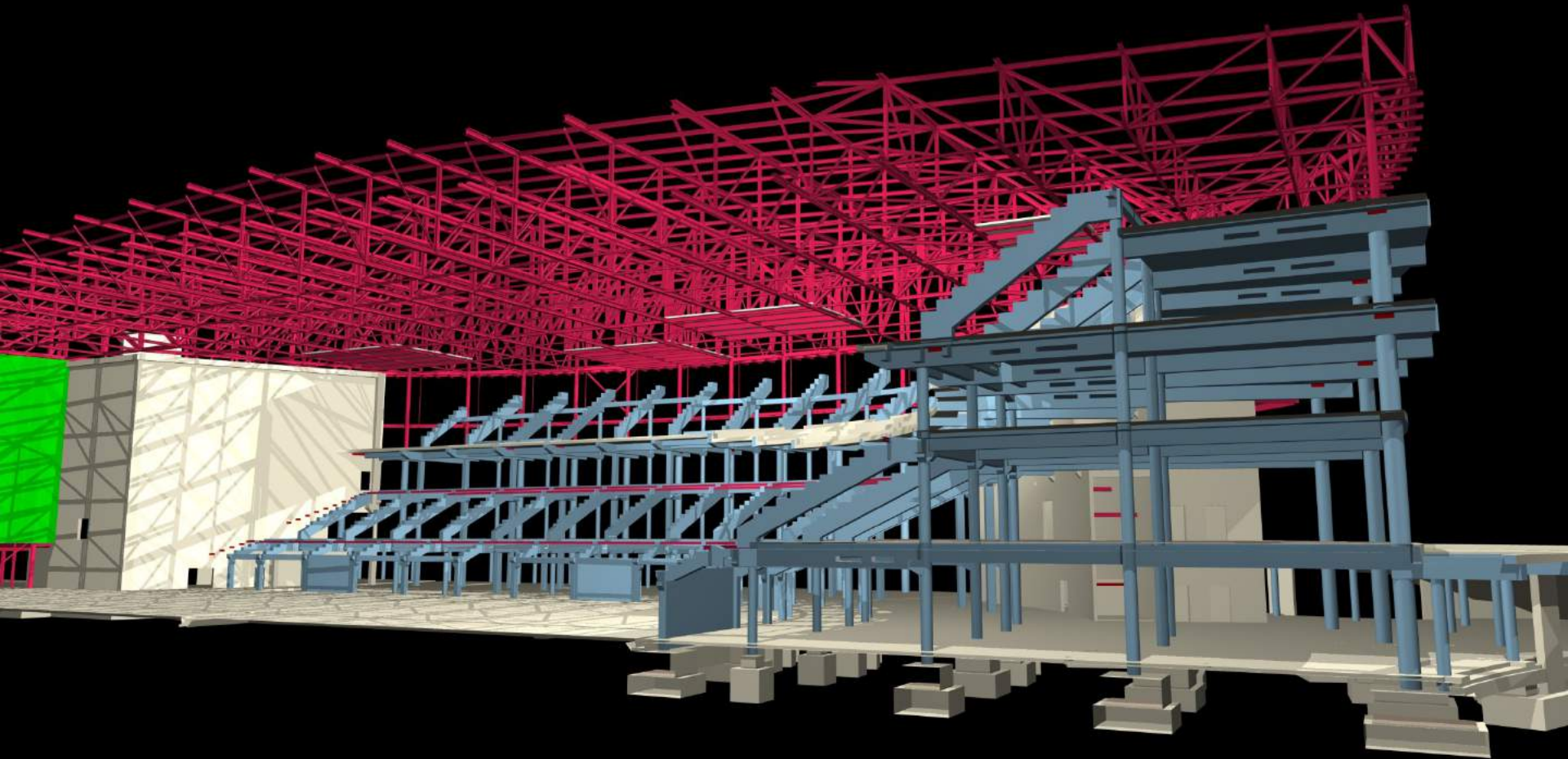




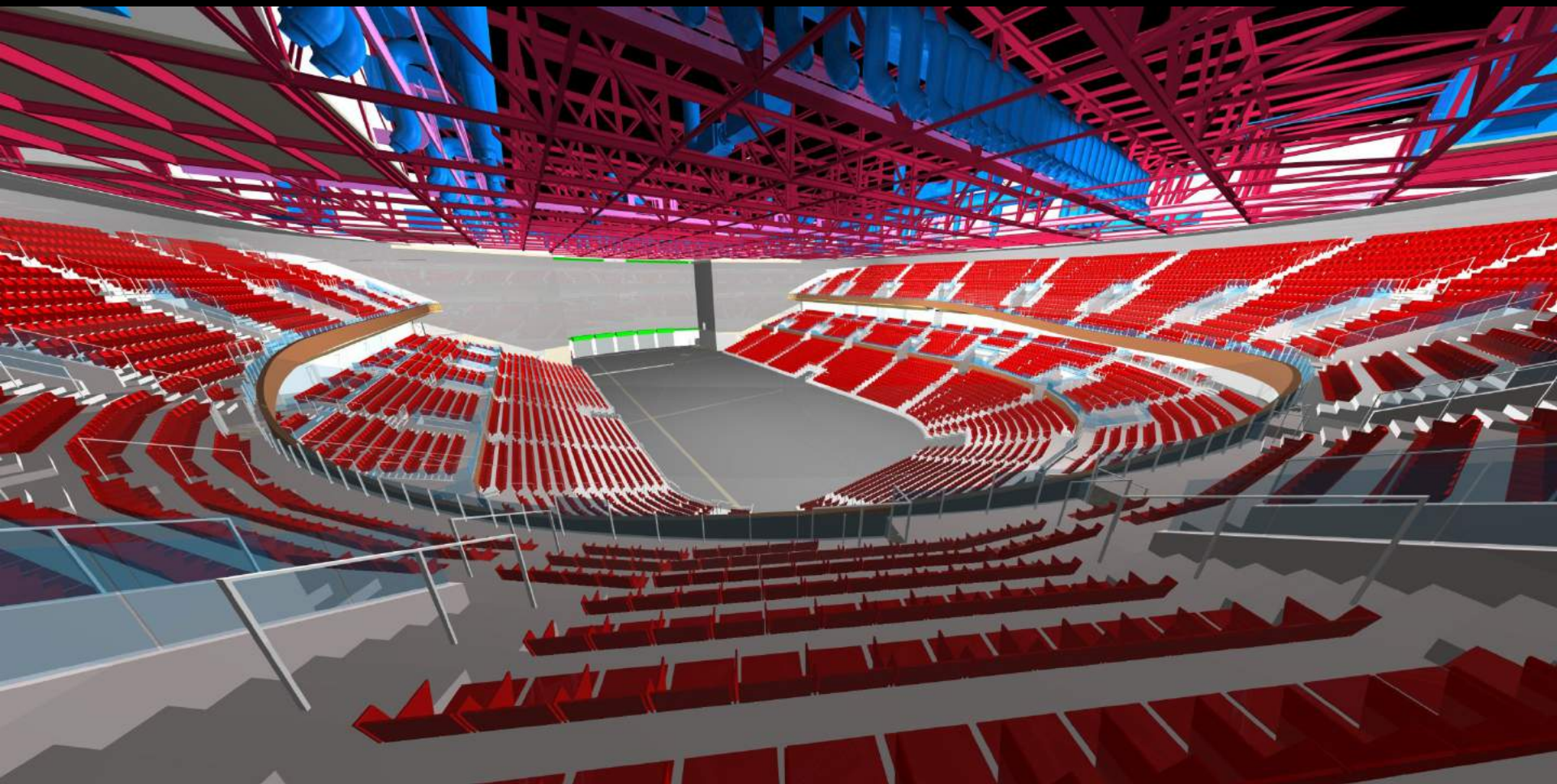
Copenhagen Arena  
2012→  
Architect: 3XN



# Copenhagen Arena



# Copenhagen Arena





BIM is not a software platform

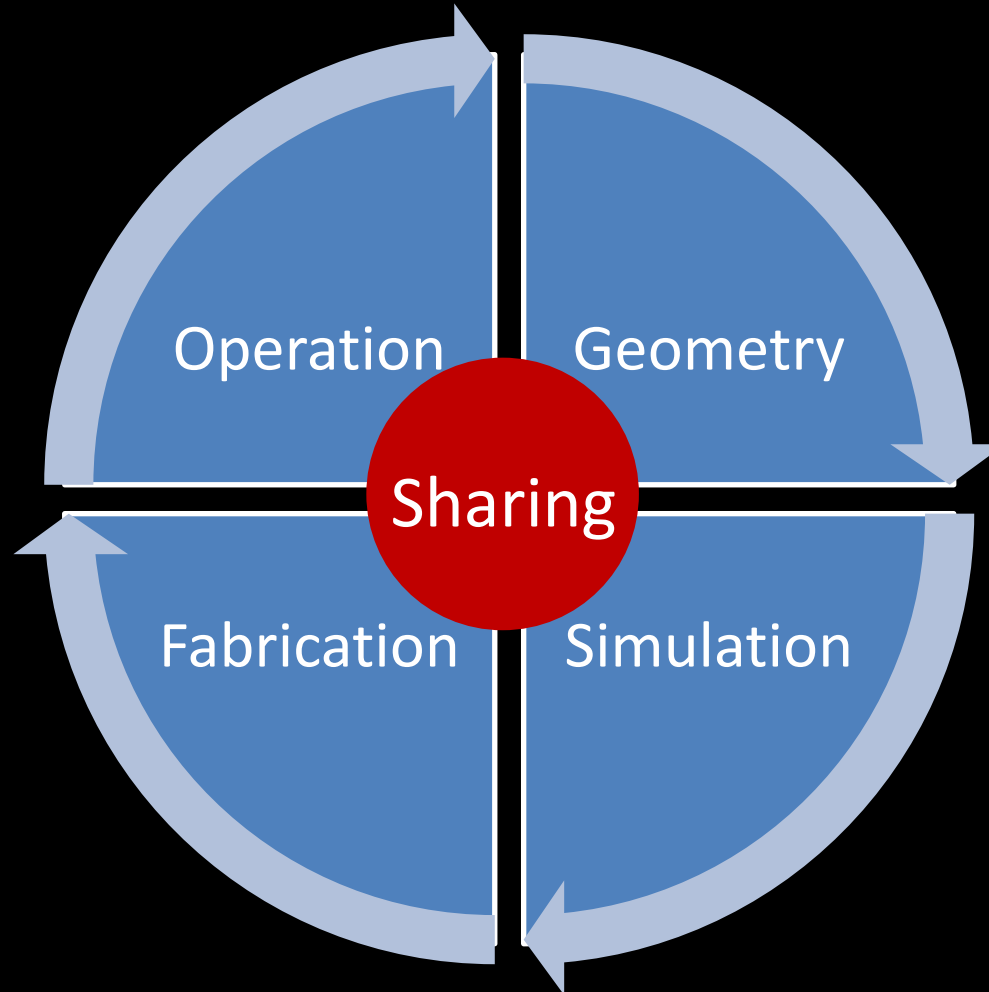
## Should BIM be:

A) A process that conforms, enhances and strengthens your current business by facilitating greater efficiency and providing new opportunity?

B) A software that you choose to impose on your current business because “everyone else is using it” and you are therefore willing to conform your business processes to the limitations of the software?

# BIM Enabled Tools

# Classification of BIM Tools



# IFC Enabled Software A → B



Name	Vendor	Type
3D PDF Converter (for Adobe Acrobat X)	Tetra 4D	modelviewer
4M FineELEC	4M SA	buildingservices
4M FineHVAC	4M SA	buildingservices
4M FineSANI	4M SA	buildingservices
4M IDEA Architecture	4M SA	architectural
4M STRAD	4M SA	structural
ACTIVE3D Build Server	GROUPE ARCHIMEN	dataserver
ACTIVE3D Facility Server	GROUPE ARCHIMEN	facilitymanagement
AEC3 BimServices	AEC3	other
ActiveFacility	ActiveFacility	dataserver
Advance Concrete	GRAITEC SA	structural
Advance Design	GRAITEC SA	structural
Advance Steel	GRAITEC SA	structural
Allplan Architecture	Nemetschek Deutschland GmbH	architectural
Allplan Engineering	Nemetschek Deutschland GmbH	structural
ArcGIS Desktop	Esri	geographicinformationsystem
ArchiCAD	GRAPHISOFT	architectural
Artra Field BIM & Life Cycle Management	ARTRA BIMProducts Ltd	facilitymanagement
AutoBid SheetMetal	QuickPen	constructionmanagement
AutoCAD Architecture	Autodesk, Inc.	architectural
AutoCAD MEP	Autodesk, Inc.	buildingservices
AutoVue 3D Professional Advanced	Oracle	modelviewer
AxisVM	InterCAD Kft.	structural
BIM Collaboration Hub	Eurostep Group AS	dataserver
BIMProject evolution	AceCad Software Ltd.	constructionmanagement
BIMReview evolution	AceCad Software Ltd.	modelviewer
BIMserver	BIMserver.org	dataserver
BIMsurfer WebGL viewer	BIMsurfer.org	other
BSPPro	Granlund	developmenttools
Benchmark	ITI International Training Institute	buildingservices
Bentley Architecture V8i	Bentley Systems, Inc.	architectural
Bentley Building Electrical Systems V8i	Bentley Systems, Inc.	buildingservices
Bentley Building Mechanical Systems V8i	Bentley Systems, Inc.	buildingservices
Bentley Structural Modeler v8i	Bentley Systems, Inc.	structural
Bentley speedikon V8i (SELECTseries4)	Bentley Systems, Inc.	architectural
Bimshare	Perfect Blue B.V.	modelviewer



# IFC Enabled Software C → H



Name	Vendor	Type
CAD/QST	TQS Informática Ltda.	structural
CADS Planner Electric	Kymdata Oy	buildingservices
CADduct	MAP Software	buildingservices
CADiE Sähköä	Cad-Quality Oy	buildingservices
CADmep+	MAP Software	buildingservices
CSiBridge	Computers and Structures, Inc. (CSI)	structural
CYPECAD	CYPE Ingenieros, S.A.	structural
Constructivity Model Editor	Constructivity.com, LLC	generalmodeling
Constructivity Model Server	Constructivity.com, LLC	dataserver
Constructivity Model Viewer	Constructivity.com, LLC	modelviewer
CostOS BIM Estimating	Nomitech	constructionmanagement
CostX	Exactal Technologies Pty Ltd	constructionmanagement
DDS-CAD Architect	Data Design System ASA	architectural
DDS-CAD BIM-Enhancer	Data Design System ASA	modelviewer
DDS-CAD Construction	Data Design System ASA	constructionmanagement
DDS-CAD MEP	Data Design System ASA	buildingservices
DDS-CAD Viewer	Data Design System ASA	modelviewer
DProfiler	The Beck Group / Beck Technology	constructionmanagement
Dalux BIM Checker	Dalux	modelviewer
Dalux Building View	Dalux	modelviewer
DaluxFM	Dalux	facilitymanagement
Design Master Electrical	Design Master Software, Inc.	buildingservices
Design Master HVAC	Design Master Software, Inc.	buildingservices
Design Master Plumbing	Design Master Software, Inc.	buildingservices
Digital Project	Gehry Technologies	architectural
DuctDesigner 3D	QuickPen	buildingservices
ECCO Toolkit	PD Tec GmbH	developmenttools
EDMserver	Jotne EPM Technology AS	dataserver
ETABS	Computers and Structures, Inc. (CSI)	structural
EcoDomus FM	EcoDomus	facilitymanagement
EcoDomus PM	EcoDomus	constructionmanagement
EliteCAD AR	Roland Messerli AG Informatik	architectural
FEM-Design	Structural Design Software in Europe AB / StruSoft	structural
FME	Safe Software Inc.	geographicinformationsystem
FZK Viewer	Karlsruhe Institute of Technology	modelviewer
FaMe	Facilities Management Software GmbH	facilitymanagement
GALA Construction Software	GALA Construction software	constructionmanagement
GTX	Gehry Technologies	architectural
HOOPS Exchange	Tech Soft 3D	developmenttools
Horizontal Glue	Horizontal Systems, Inc.	dataserver

<http://www.buildingsmart-tech.org/implementation/implementations/plominoview.allapplications?widget=BASIC&start=101&limit=100>

# IFC Enabled Software I → R



Name	Vendor	Type
IDA ICE	Equa Simulation AB	buildingperformance
IFC BIM Validation Service	Digital Alchemy	other
IFC Engine DLL	TNO	developmenttools
IFC Engine Viewer	TNO	modelviewer
IFC File Analyzer	National Institute of Standards and Technology (NIST)	modelviewer
IFC Model Exchange for Microsoft Visio	Digital Alchemy	other
IFC Quick Browser	GEM Team Solutions GbR	modelviewer
IFC SDK	Centre Scientifique et Technique du Batiment (CSTB)	developmenttools
IFC Takeoff for Microsoft Excell	Digital Alchemy	constructionmanagement
IFC Toolbox	Eurostep Group AS	developmenttools
IFC-to-RDF Web Service	UGent SMARTLAB	architectural
IFC2SKP plugin	SECOM CO., LTD. / Secom IS Lab	modelviewer
IFCsvg ActiveX Component	SECOM CO., LTD. / Secom IS Lab	developmenttools
ISY Calcus	Norconsult Informasjonssystemer AS	constructionmanagement
IfcGears	Bauhaus Universität Weimar	developmenttools
IfcOpenShell	Krijnen, Thomas	developmenttools
IfcWebServer	Ismail, Ali	dataserver
InfoCAD	InfoGraph GmbH	structural
MORADA	SMB AG	facilitymanagement
MagiCAD	Progman Oy	buildingservices
NTItools Arkitekt (Revit plug-ins)	NTI Nestor AS	architectural
NTItools Konstruksjon (Revit plug-ins)	NTI Nestor AS	structural
Navisworks	Autodesk, Inc.	constructionmanagement
Nemetschek IFC Viewer	Nemetschek Deutschland GmbH	modelviewer
Onuma System	Onuma, Inc.	other
Open IFC Tools	Bauhaus Universität Weimar / HOCHTIEF AG	developmenttools
PipeDesigner 3D	QuickPen	buildingservices
RFEM	Ing.-Software Dlubal GmbH	structural
RIUSKA	Granlund	buildingperformance
ROOMEX	Granlund	other
RSTAB	Ing.-Software Dlubal GmbH	structural
Raumtool 3D	SOLAR-COMPUTER GmbH	buildingservices
Real Estate	Vizelia	facilitymanagement
Revit Architecture	Autodesk, Inc.	architectural
Revit MEP	Autodesk, Inc.	buildingservices
Revit Structure	Autodesk, Inc.	structural

<http://www.buildingsmart-tech.org/implementation/implementations/plominoview.allapplications?widget=BASIC&start=101&limit=100>

# IFC Enabled Software S → Z



Name	Vendor	Type
SAP2000	Computers and Structures, Inc. (CSI)	structural
SDS/2	Design Data	structural
SOFISTIK Structural Desktop (SSD)	SOFISTIK AG	structural
SPACE GASS	SPACE GASS	structural
SPIRIT	STI / SOFTTECH	architectural
ST-Developer	STEP Tools, Inc.	developmenttools
SUPerPlan	Deliver Simulation Ltd	constructionmanagement
ScaleCAD	Jidea Ltd.	structural
Scia Engineer	Nemetschek Scia	structural
SmartKalk	Holte Byggsafe AS	constructionmanagement
Solibri Model Checker	Solibri, Inc.	modelviewer
Solibri Model Optimizer	Solibri, Inc.	other
Solibri Model Viewer	Solibri, Inc.	modelviewer
SolidWorks Premium	Dassault Systèmes SolidWorks Corp	generalmodeling
Space Layout Editor for Microsoft Visio	Digital Alchemy	other
SteelVis	National Institute of Standards and Technology (NIST)	structural
StruCad	AceCad Software Ltd.	structural
StruWalker	AceCad Software Ltd.	modelviewer
Structural Modeler V8i	Bentley Systems, Inc.	structural
Synchro Professional	Synchro Ltd.	facilitymanagement
TRIRIGA Facilities	TRIRIGA Inc.	facilitymanagement
Tekla BIMsight	Tekla Corporation	constructionmanagement
Tekla Structures	Tekla Corporation	structural
Tilt-Werks	Tilt-Up Design Systems, LLC	structural
Tricalcar	Arktec, S.A.	structural
Trimble Design Link	QuickPen	buildingservices
Vectorworks Architect	Nemetschek Vectorworks, Inc.	architectural
Vico Office Suite	Vico Software, Inc.	constructionmanagement
VisualARQ	Asuni CAD, S.A.	architectural
Ziggurat	Ziggurat Systems Ltd.	generalmodeling

<http://www.buildingsmart-tech.org/implementation/implementations/plominoview.allapplications?widget=BASIC&start=101&limit=100>



BIM Good

2D Bad



# 2D Drawings are Kryptonite for BIM

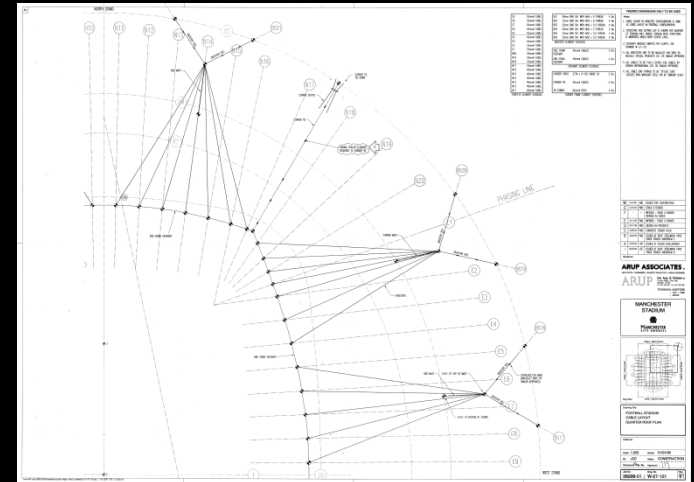


# Have we actually improved things?

Over 15 years ago engineers would provide technicians with sketches that they reproduced using drawing boards.

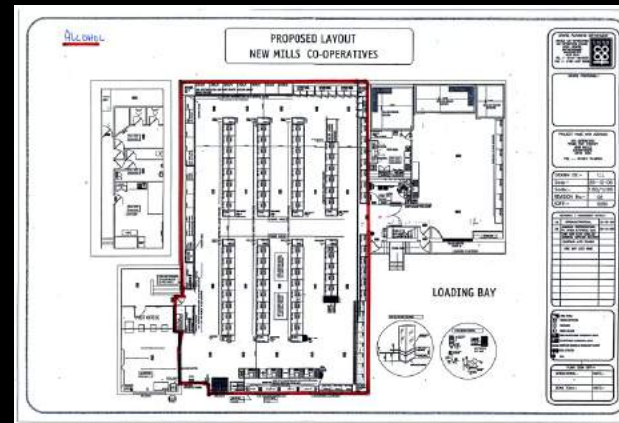
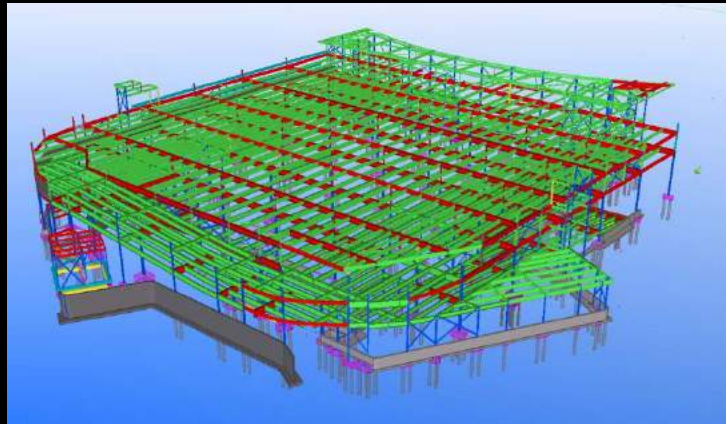


Until recently engineering would provide technicians with sketches that they would reproduce in CAD



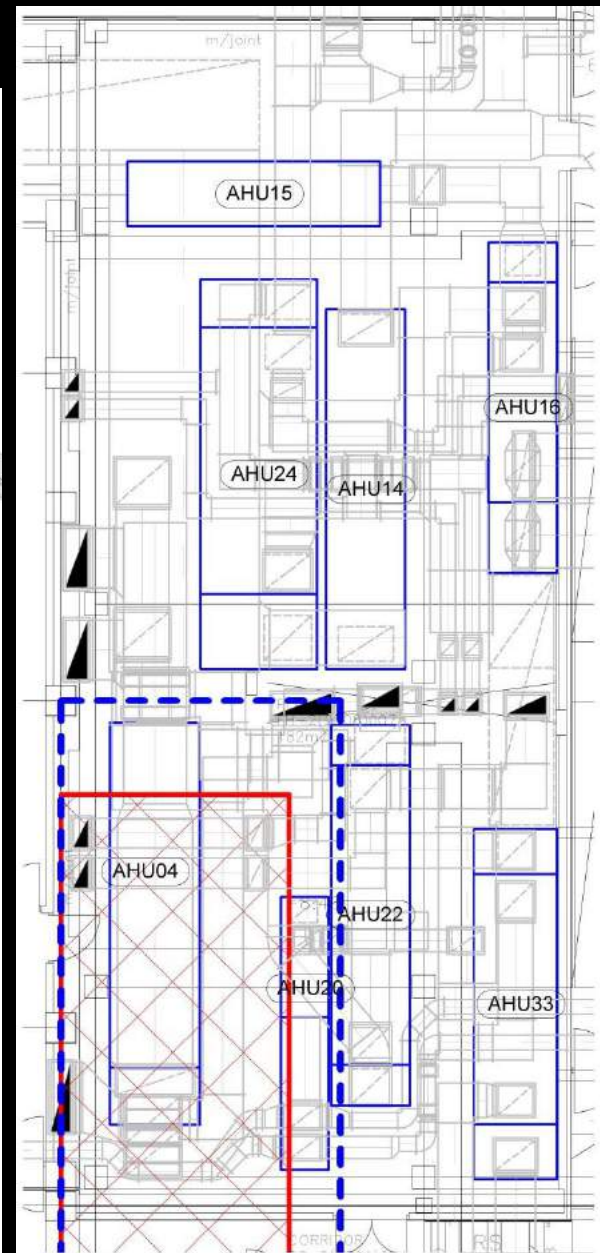
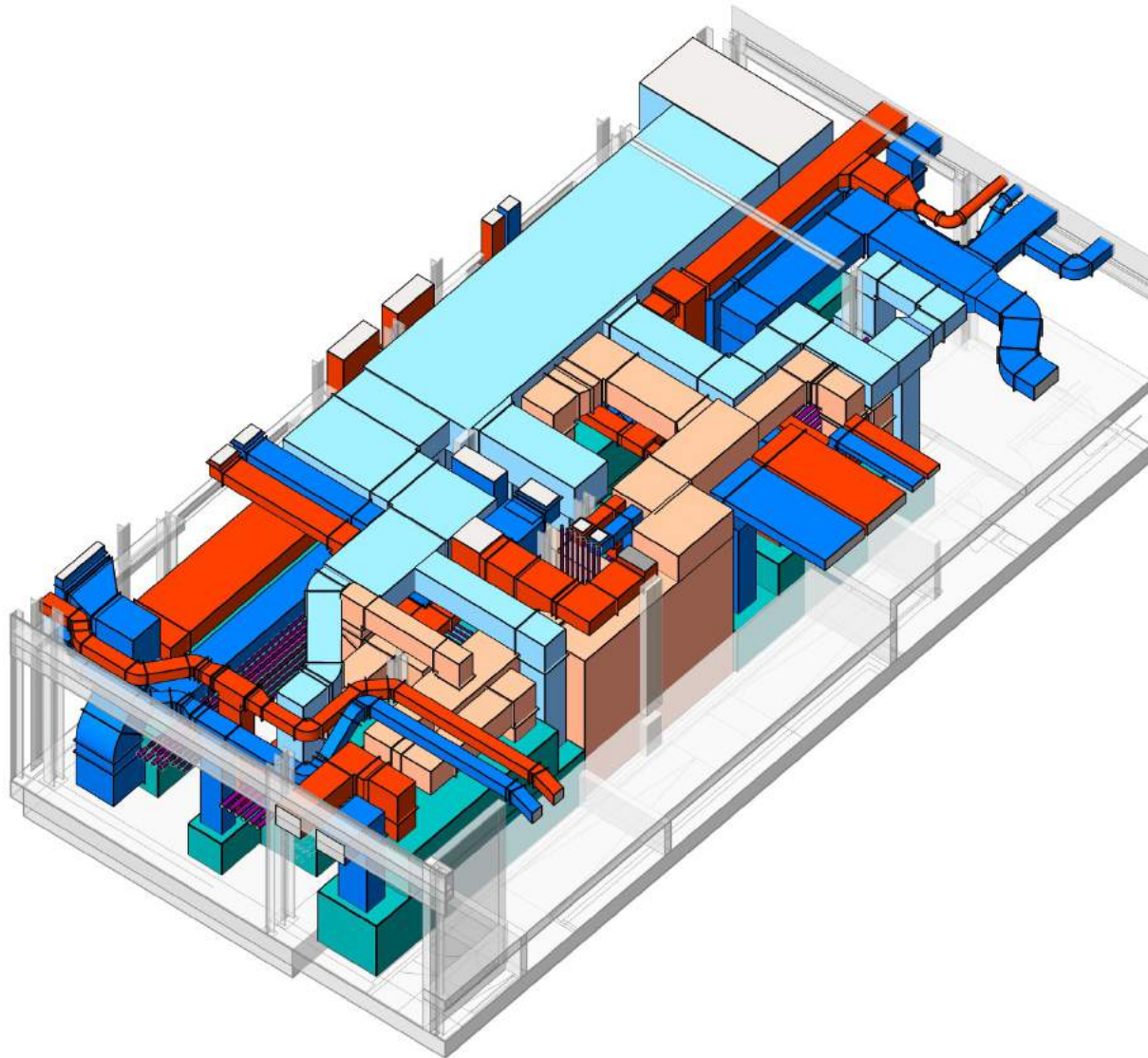
# Have we actually improved things?

Now engineers have started to provide technicians with sketches so that they can build a 3D model and then extract sections, elevations. (These often require extensive dressing up). So that we can issue 2D drawings.



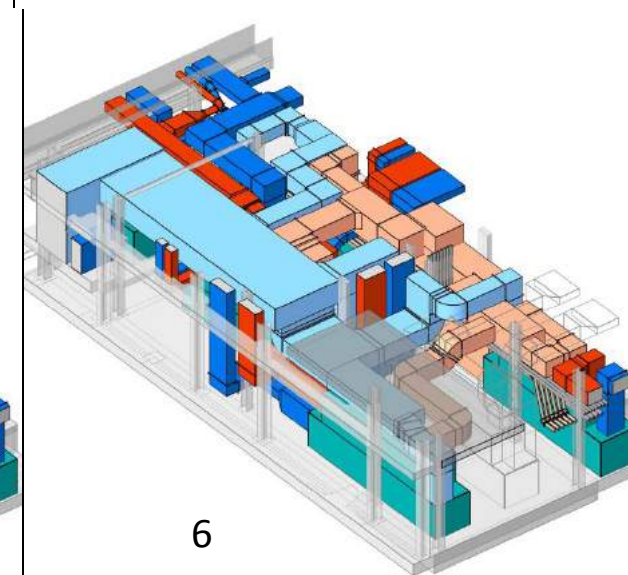
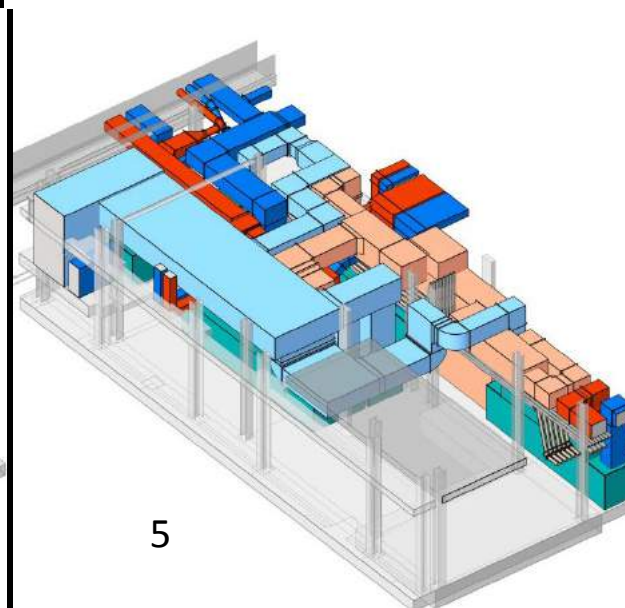
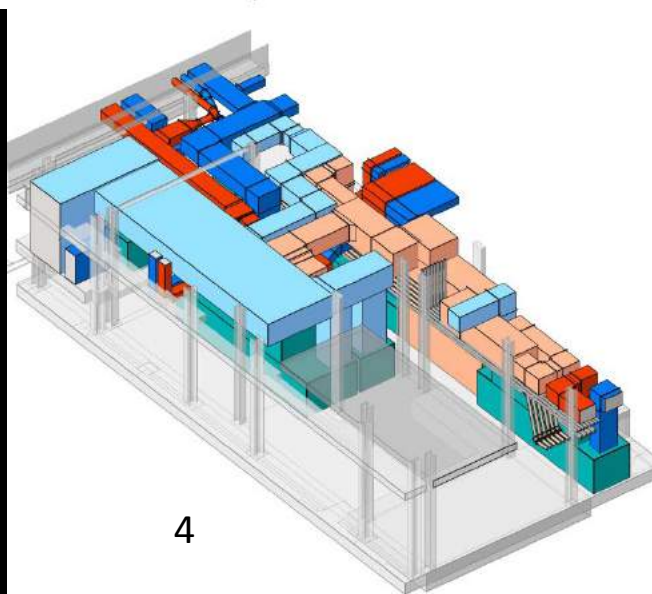
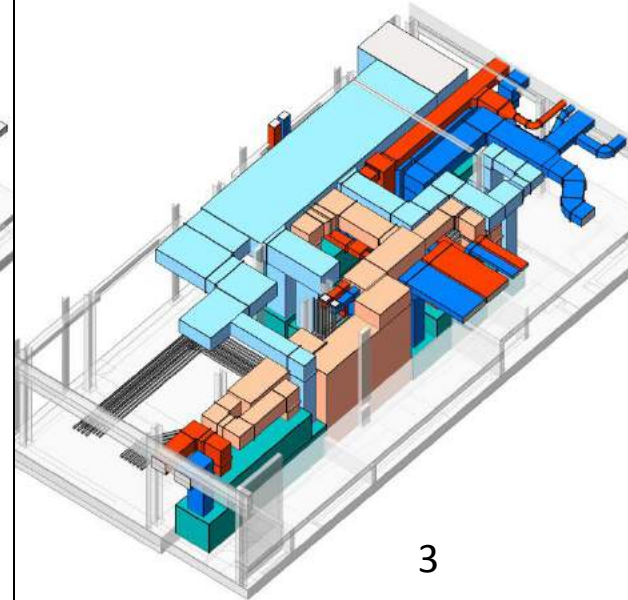
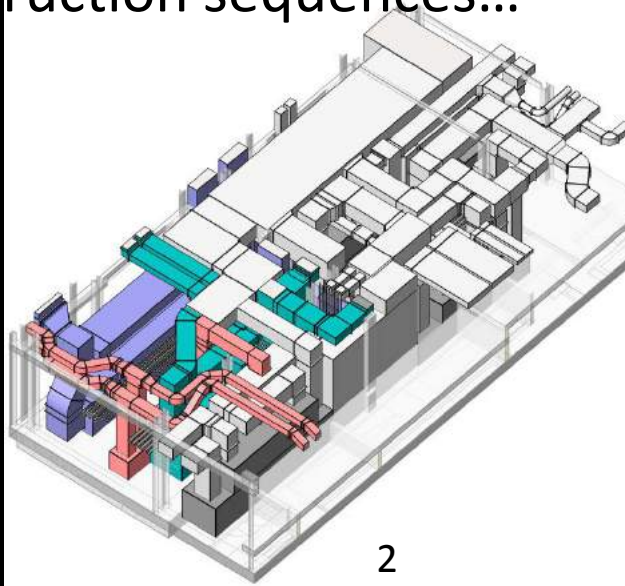
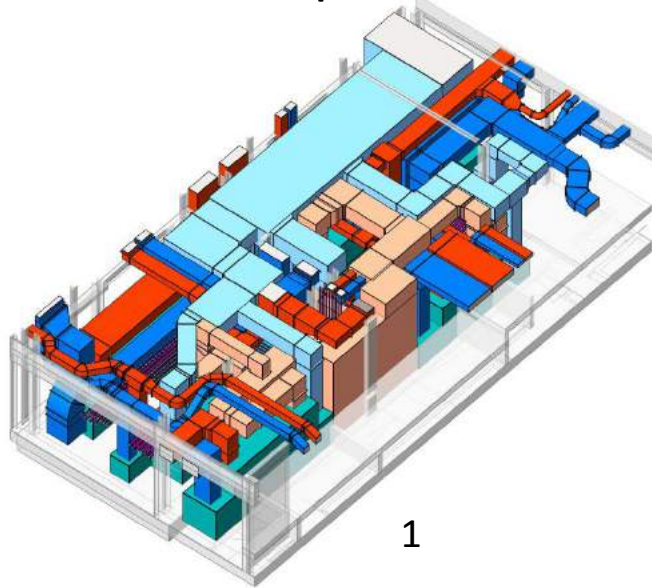


# AHU plantroom in Revit to understand distribution implications...

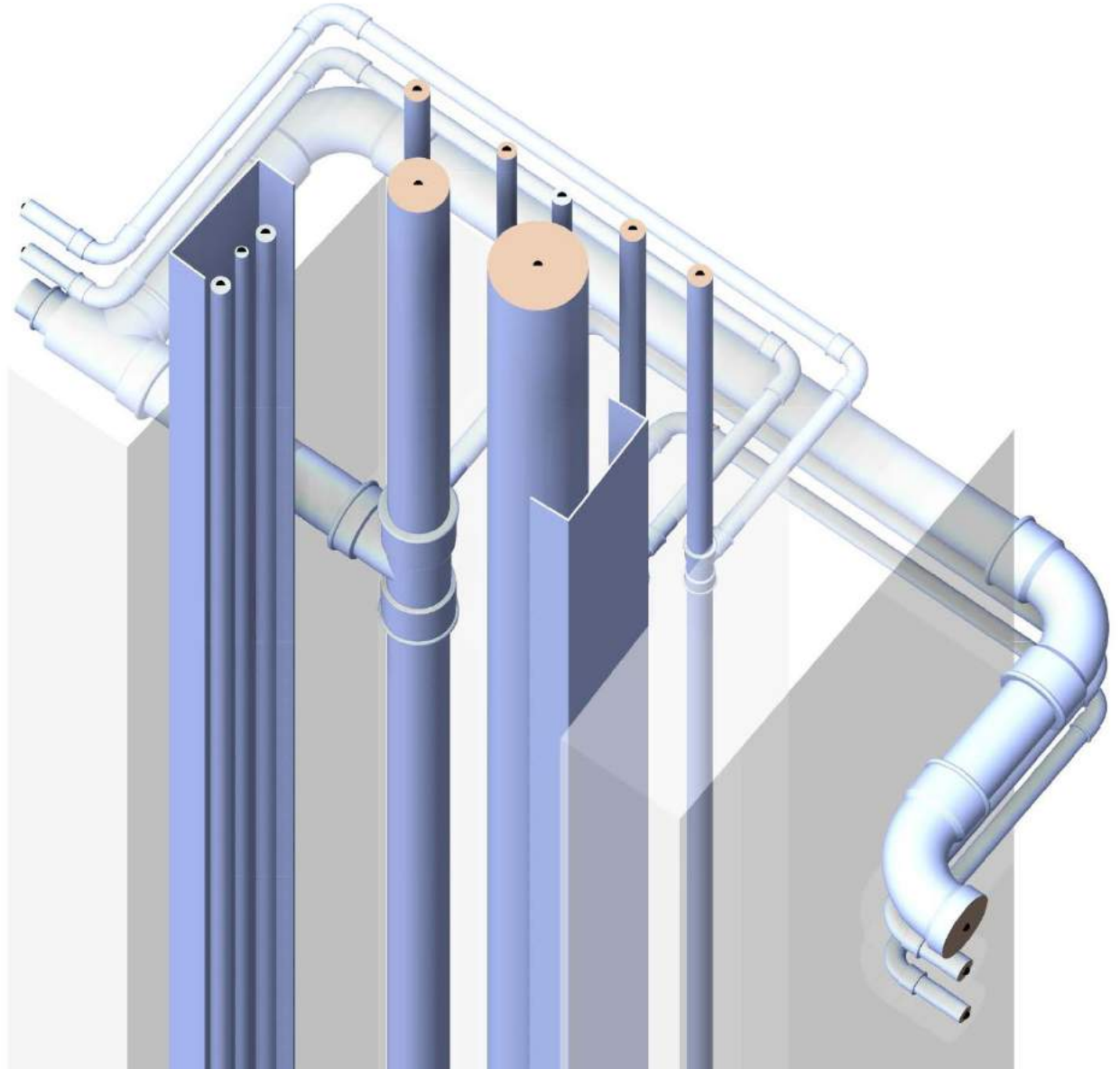
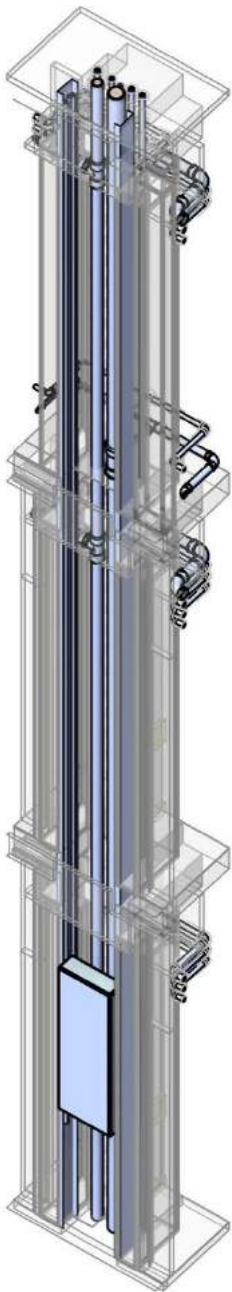




# Review impact on construction sequences...

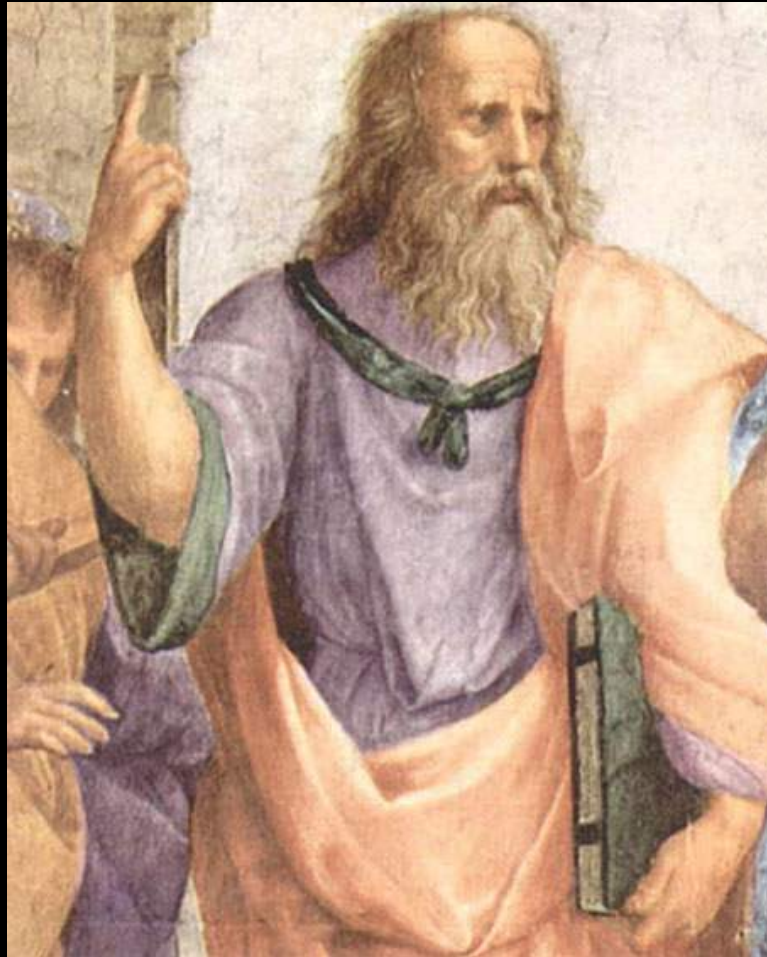


- Coordinated services and structural column....



# "Let no man ignorant of geometry enter here."

Inscribed over the entrance to Plato's academy in ancient Greece.



# Advanced Geometry Techniques

- Parametric Modelling
- Associative / Constraint Based Modelling
- Algorithmic/Generative Modelling
- Component Modelling

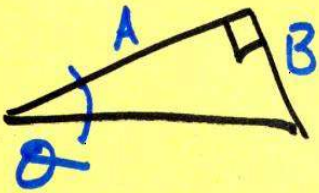


# Parametric Modelling

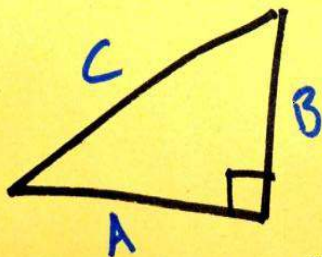
## Parameter

– noun

*“a constant or variable term in a function that determines the specific form of the function but not its general nature”*

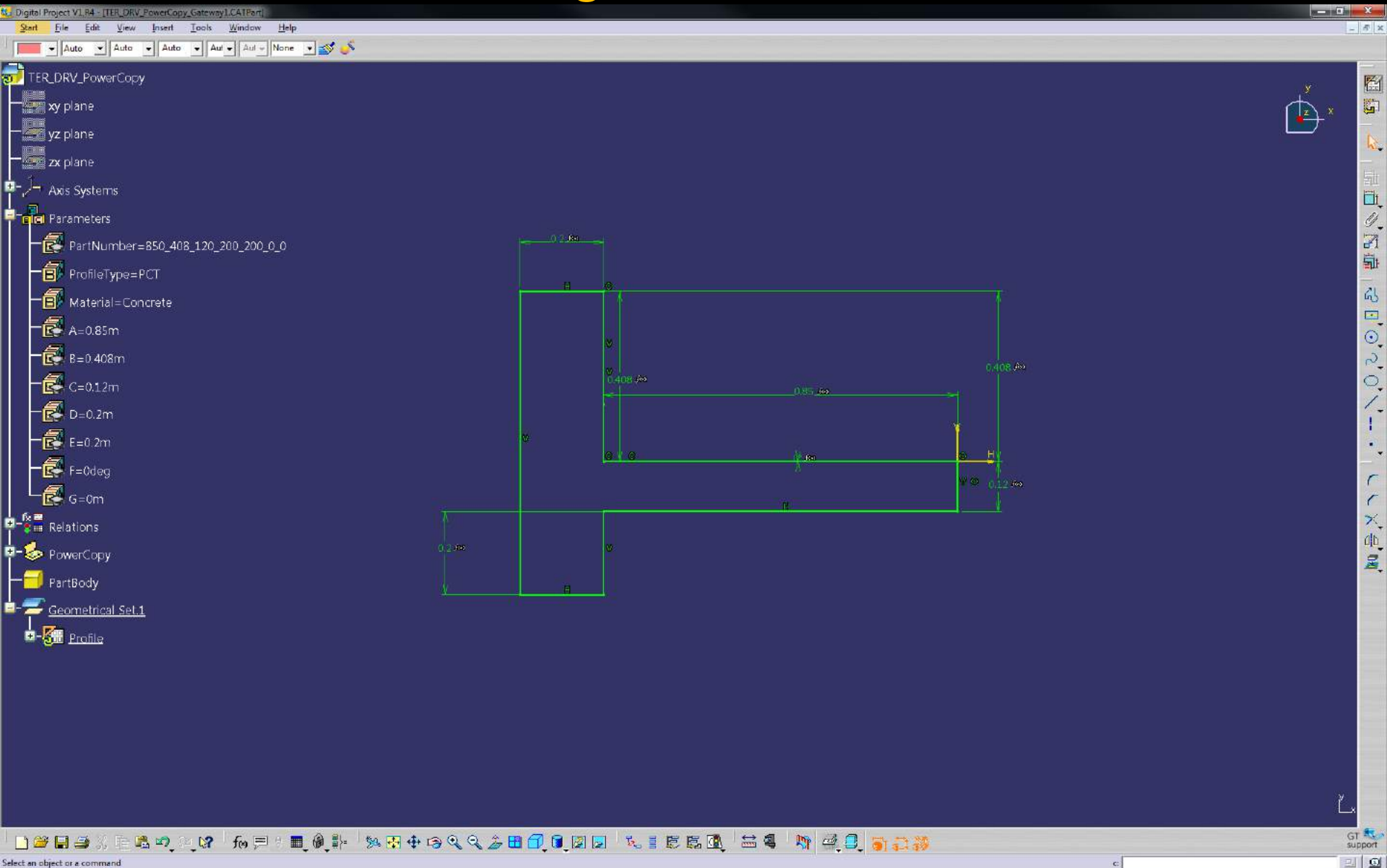


$$\tan \theta \times A = B$$



$$A^2 + B^2 = C^2$$

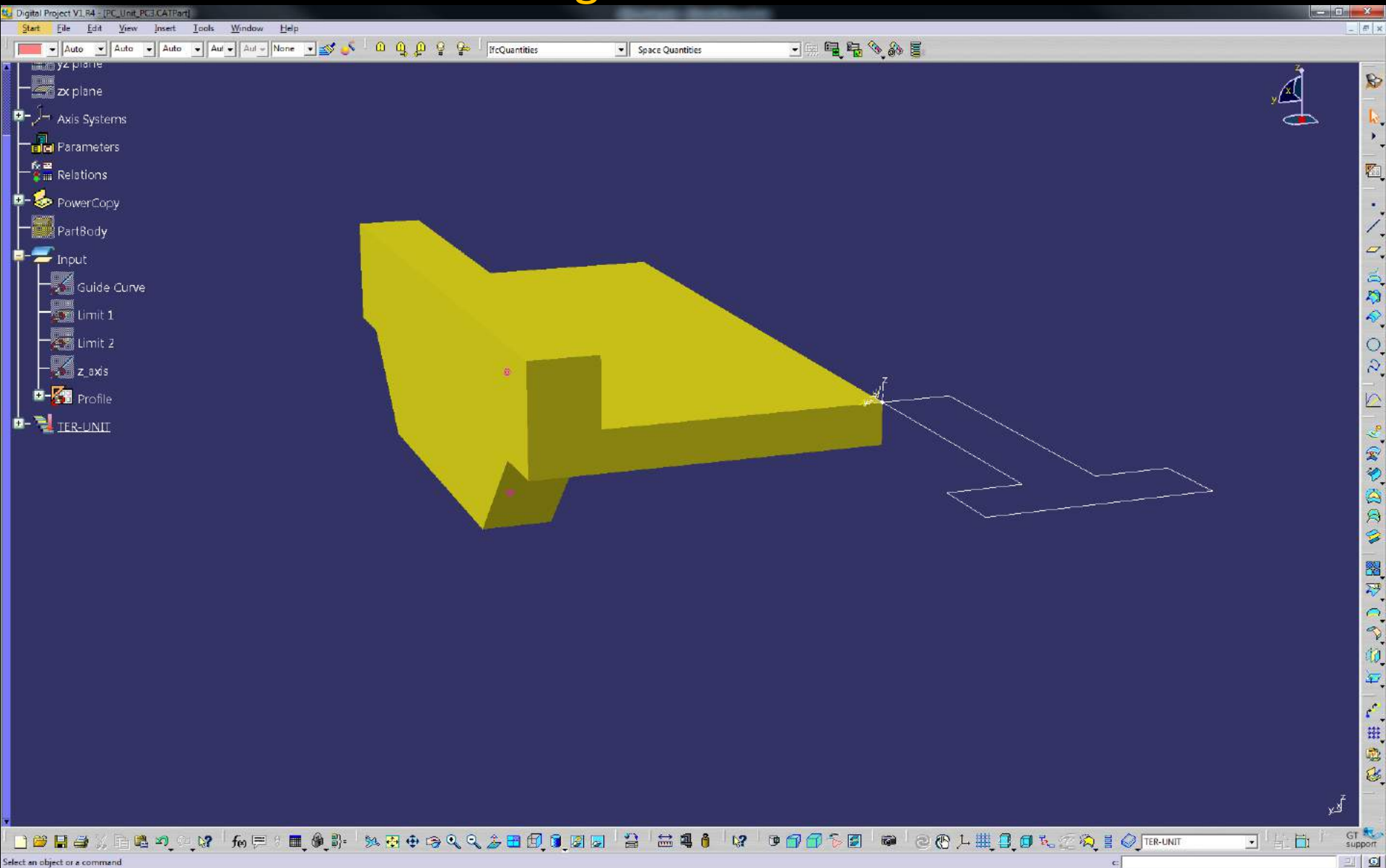
# Parametric Modelling



# Parametric Modelling

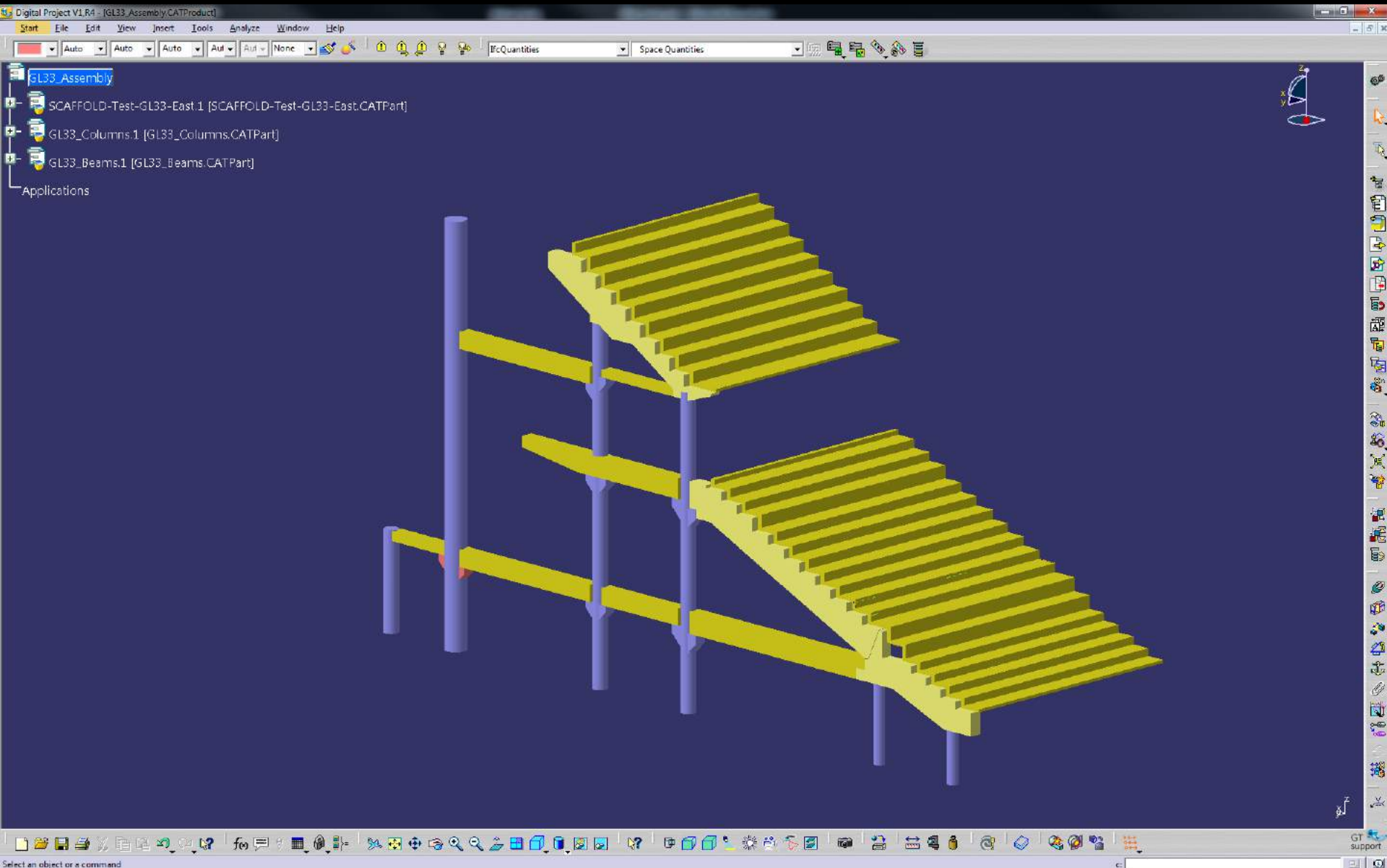
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A1170		PL-40_39																										
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2	Line Name	Line Origin	X Coord	Y Coord	Z Coord	Line Extremity	X Coord	Y Coord	Z Coord	Line Length	Geog X	Geog Y	A	B	C	D	E	F	G	Profile Name								
3	01_00_09	01	-22467.4	39148.54	2945 00	-22467.4	46148.54	2945	7000	640000	5.296-2	800	300	180	180	120	200	200	0	0	800_180_120_200_200_0_0							
4	01_00_10	01	-23267.4	39148.54	3245 00	-23267.4	46148.54	3245	7000	640000	5.296-2	800	300	180	180	120	200	200	0	0	800_180_120_200_200_0_0							
5	01_00_11	01	-24067.4	39148.54	3545 00	-24067.4	46148.54	3545	7000	640000	5.296-2	800	313	195	195	120	200	200	0	0	800_195_120_200_200_0_0							
6	01_00_12	01	-24867.4	39148.54	3860 01	-24867.4	46148.54	3860	7000	640000	5.296-2	800	313	195	195	120	200	200	0	0	800_195_120_200_200_0_0							
7	01_00_14	01	-25667.4	39148.54	4175 00	-25667.4	46148.54	4175	7000	640000	5.296-2	800	313	195	195	120	200	200	0	0	800_195_120_200_200_0_0							
8	01_00_15	01	-26467.4	39148.54	4490 00	-26467.4	46148.54	4490	7000	640000	5.296-2	800	350	430	430	120	200	200	0	0	800_430_120_200_200_0_0							
9	01_00_16	01	-27267.4	39148.54	5040 00	-27267.4	46148.54	5040	7000	640000	5.296-2	800	350	430	430	120	200	200	0	0	800_430_120_200_200_0_0							
10	01_00_17	01	-28067.4	39148.54	5590 00	-28067.4	46148.54	5590	7000	1134323	5.296-2	1065	360	240	240	120	200	200	0	0	1065_240_120_200_200_0_0							
11	01_00_18	01	-29132.4	39148.54	5950 00	-29132.4	46148.54	5950	7000	722500	5.296-2	850	360	240	240	120	200	200	0	0	850_240_120_200_200_0_0							
12	01_00_19	01	-29982.4	39148.54	6310 00	-29982.4	46148.54	6310	7000	722500	5.296-2	850	360	240	240	120	200	200	0	0	850_240_120_200_200_0_0							
13	01_00_20	01	-30832.4	39148.54	6670 00	-30832.4	46148.54	6670	7000	722500	5.296-2	850	360	240	240	120	200	200	0	0	850_240_120_200_200_0_0							
14	01_00_21	01	-31682.4	39148.54	7030 00	-31682.4	46148.54	7030	7000	722500	5.296-2	850	375	255	255	120	200	200	0	0	850_255_120_200_200_0_0							
15	01_00_22	01	-32532.4	39148.54	7405 00	-32532.4	46148.54	7405	7000	722500	5.296-2	850	375	255	255	120	200	200	0	0	850_255_120_200_200_0_0							
16	01_00_23	01	-33382.4	39148.54	7780 00	-33382.4	46148.54	7780	7000	722500	5.296-2	850	375	255	255	120	200	200	0	0	850_255_120_200_200_0_0							
17	01_00_24	01	-34232.4	39148.54	8155 00	-34232.4	46148.54	8155	7000	722500	5.296-2	850	375	255	255	120	200	200	0	0	850_255_120_200_200_0_0							
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19	01_00_26	01	-35932.4	39148.54	9033.375 00	-35932.4	46148.54	9033.375	7000	722500	5.296-2	850	350	230	230	120	200	200	0	0	850_230_120_200_200_0_0							
20	01_00_28	01	-36782.4	39148.54	9383.375 00	-36782.4	46148.54	9383.375	7000	640000	5.296-2	800	311	197	197	120	200	200	0	0	800_197_120_200_200_0_0							
21	01_00_29	01	-37582.4	39148.54	9700 00	-37582.4	46148.54	9700	7000	14465.13	5.296-2	0	350	230	230	120	200	200	0	0	800_197_120_200_200_0_0							
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30	01_00_42	01	-44382.4	39148.54	17145 00	-44382.4	46148.54	17145	7000	640000	5.296-2	800	495	375	375	120	200	200	0	0	800_375_120_200_200_0_0							
31	01_00_43	01	-45182.4	39148.54	17640 00	-45182.4	46148.54	17640	7000	5.181440	13405450	23524	-14695	-14695	120	200	200	0	0	800_375_120_200_200_0_0								
32	02_01_09	02	-22467.4	33032.54	2945 01	-22467.4	39148.54	2945	6120	640000	5.296-2	800	300	180	180	120	200	200	0	0	800_180_120_200_200_0_0							
33	02_01_10	02	-23267.4	33032.54	3245 01	-23267.4	39148.54	3245	6120	640000	5.296-2	800	300	180	180	120	200	200	0	0	800_180_120_200_200_0_0							
34	02_01_11	02	-24067.4	33032.54	3545 01	-24067.4	39148.54	3545	6120	640000	5.296-2	800	313	195	195	120	200	200	0	0	800_195_120_200_200_0_0							
35	02_01_12	02	-24867.4	33032.54	3860 01	-24867.4	39148.54	3860	6120	640000	5.296-2	800	313	195	195	120	200	200	0	0	800_195_120_200_200_0_0							
36	02_01_14	02	-25667.4	33032.54	4175 01	-25667.4	39148.54	4175	6120	640000	5.296-2	800	313	195	195	120	200	200	0	0	800_195_120_200_200_0_0							
37	02_01_15	02	-26467.4	33032.54	4490 01	-26467.4	39148.54	4490	6120	640000	5.296-2	800	350	430	430	120	200	200	0	0	800_430_120_200_200_0_0							
38	02_01_16	02	-27267.4	33032.54	5040 01	-27267.4	39148.54	5040	6120	640000	5.296-2	800	350	430	430	120	200	200	0	0	800_430_120_200_200_0_0							
39	02_01_17	02	-28067.4	33032.54	5590 01	-28067.4	39148.54	5590	6120	1134323	5.296-2	1065	360	240	240	120	200	200	0	0	1065_240_120_200_200_0_0							
40	02_01_18	02	-29132.4	33032.54	5950 01	-29132.4	39148.54	5950	6120	722500	5.296-2	850	360	240	240	120	200	200	0	0	850_240_120_200_200_0_0							
41	02_01_19	02	-29982.4	33032.54	6310 01	-29982.4	39148.54	6310	6120	722500	5.296-2	850	360	240	240	120	200	200	0	0	850_240_120_200_200_0_0							

# Parametric Modelling





# Parametric Modelling



# Algorithmic / Generative Design

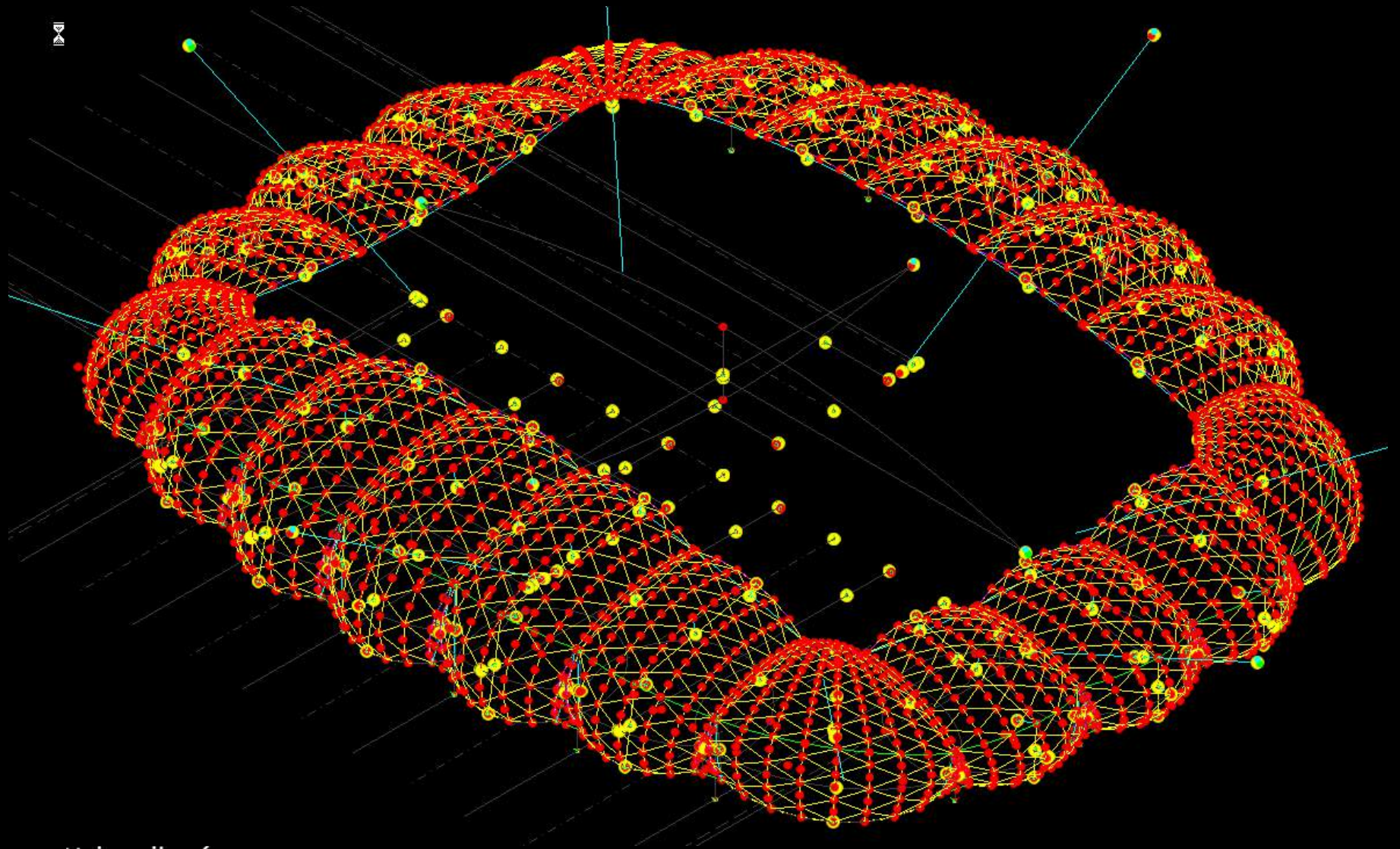
- Algorithm is defined as an effective method expressed as a finite list of well-defined instructions
- Examples:
  - Generative Components by Bentley Systems
  - Grasshopper (a plug-in for Rhinoceros by McNeel)
  - Knowledgeware (a plug-in for CATIA)
- Other packages can be made to act in a algorithmic manner using scripting languages.
- Most of my personal work is using VBA with CATIA (Digital Projects)

# Melbourne Rectangular Stadium





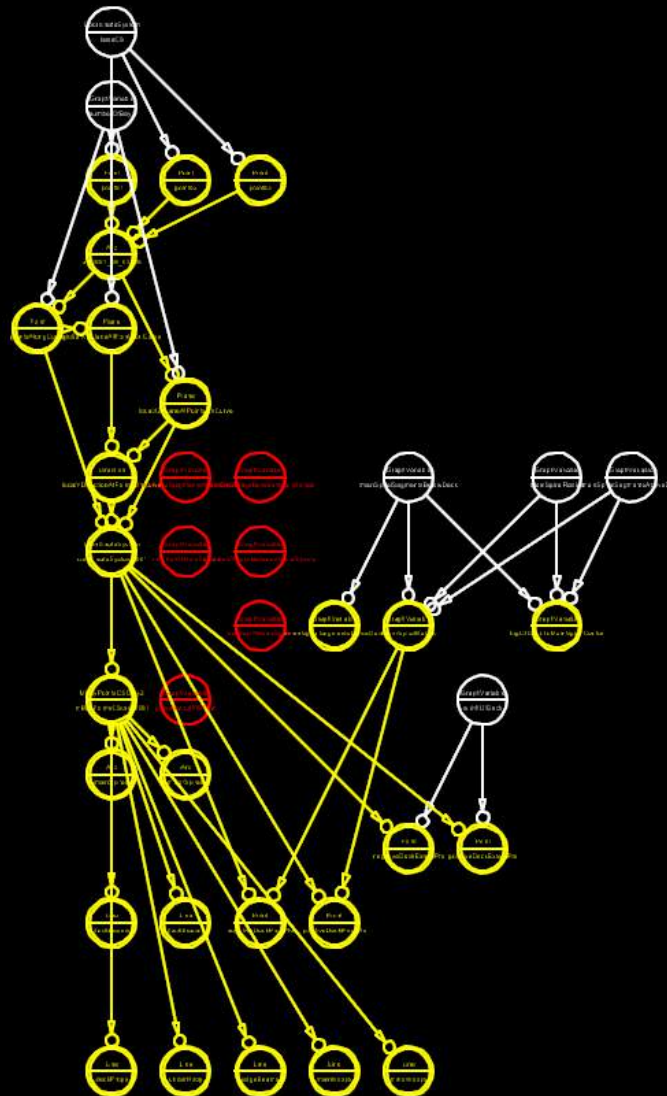
# Melbourne Rectangular Stadium Generative Components





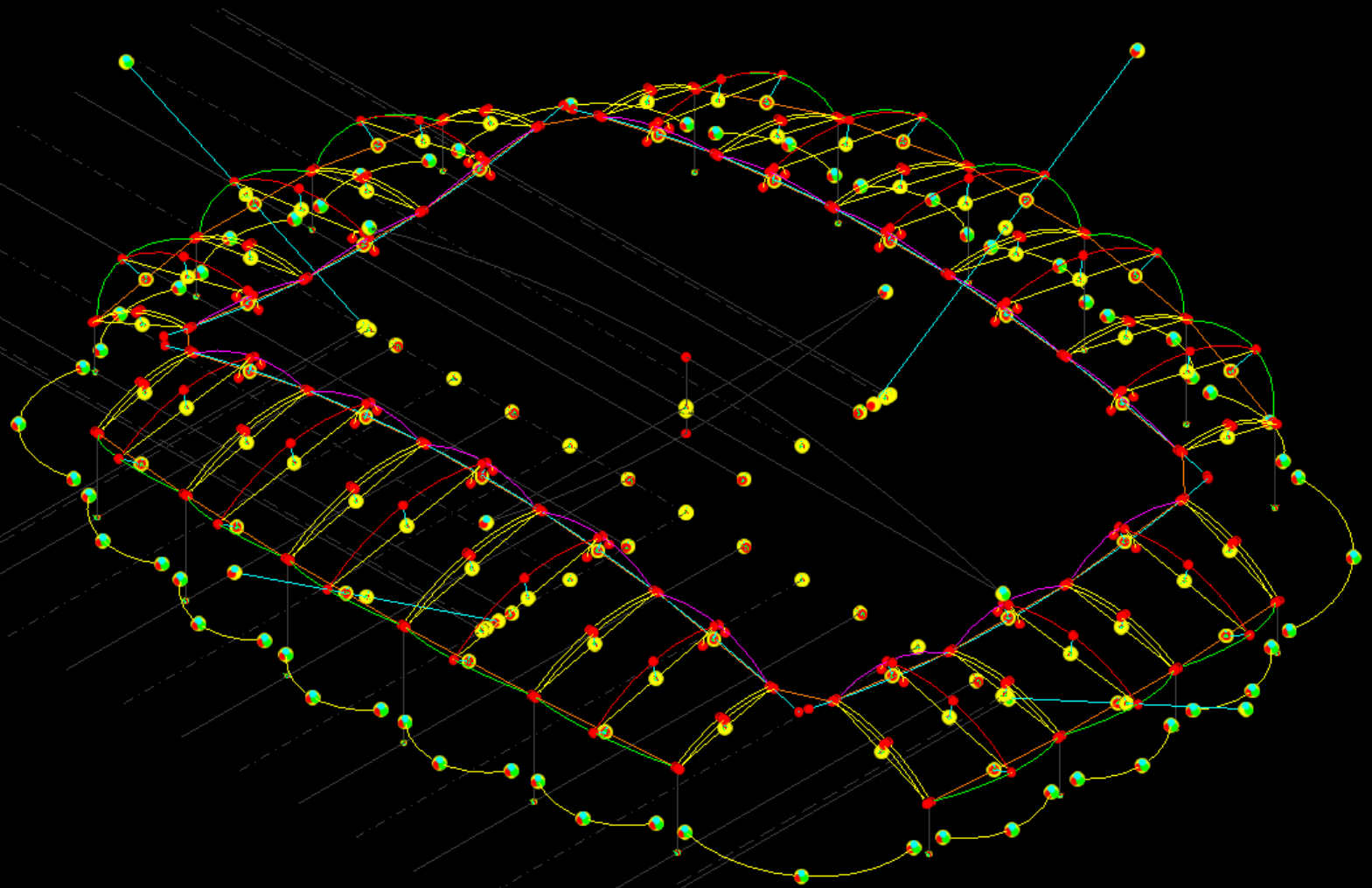
# Melbourne Rectangular Stadium

## Generative Components



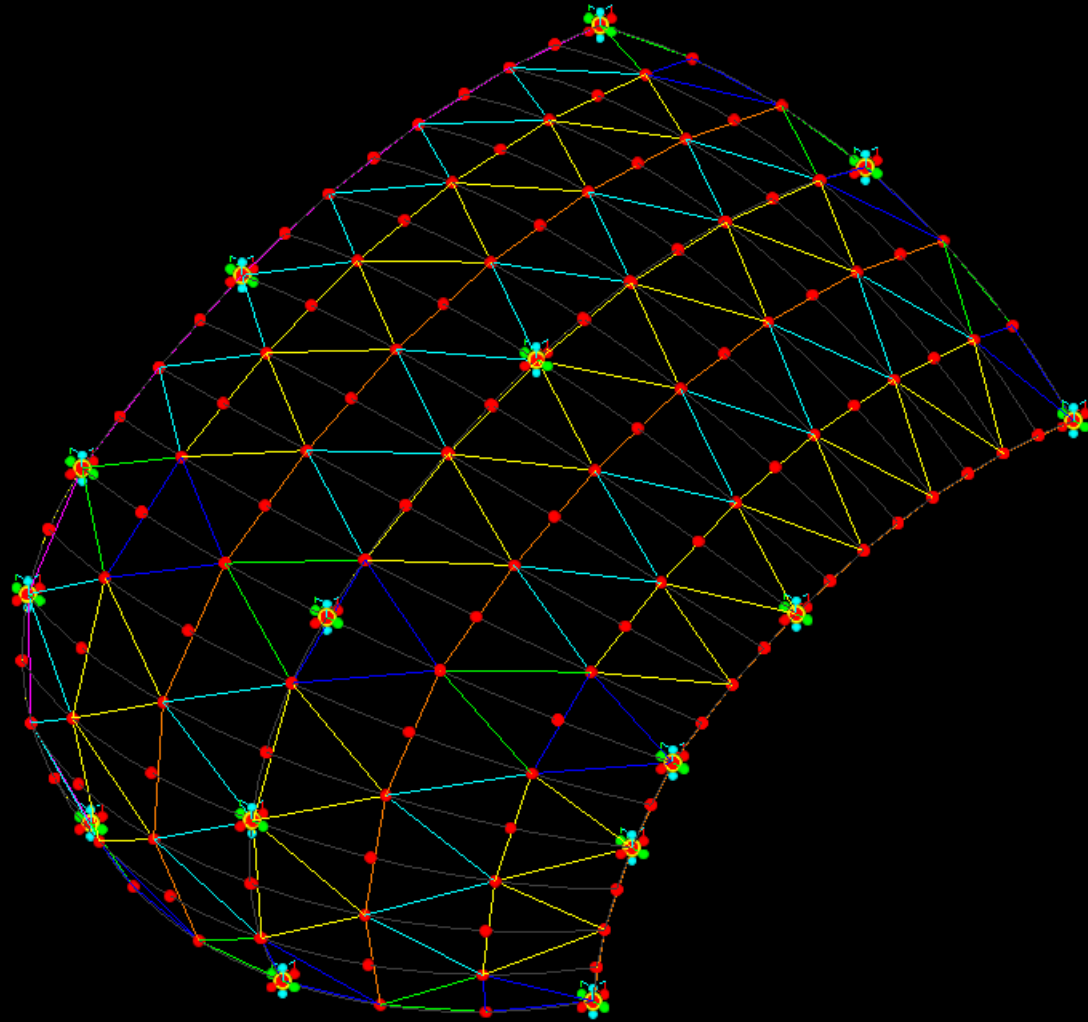
# Melbourne Rectangular Stadium

## Generative Components

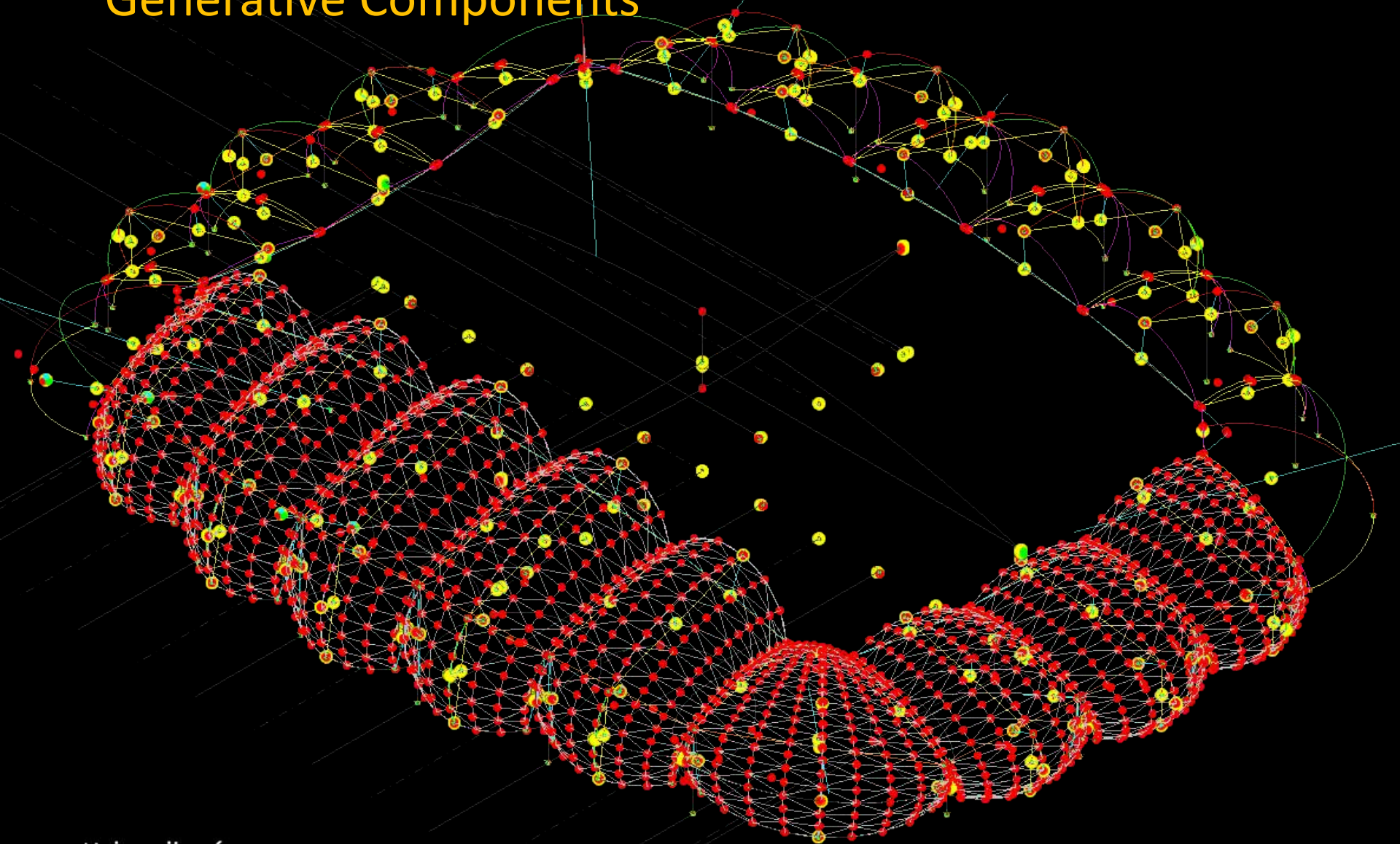


# Melbourne Rectangular Stadium Generative Components

Shell Component

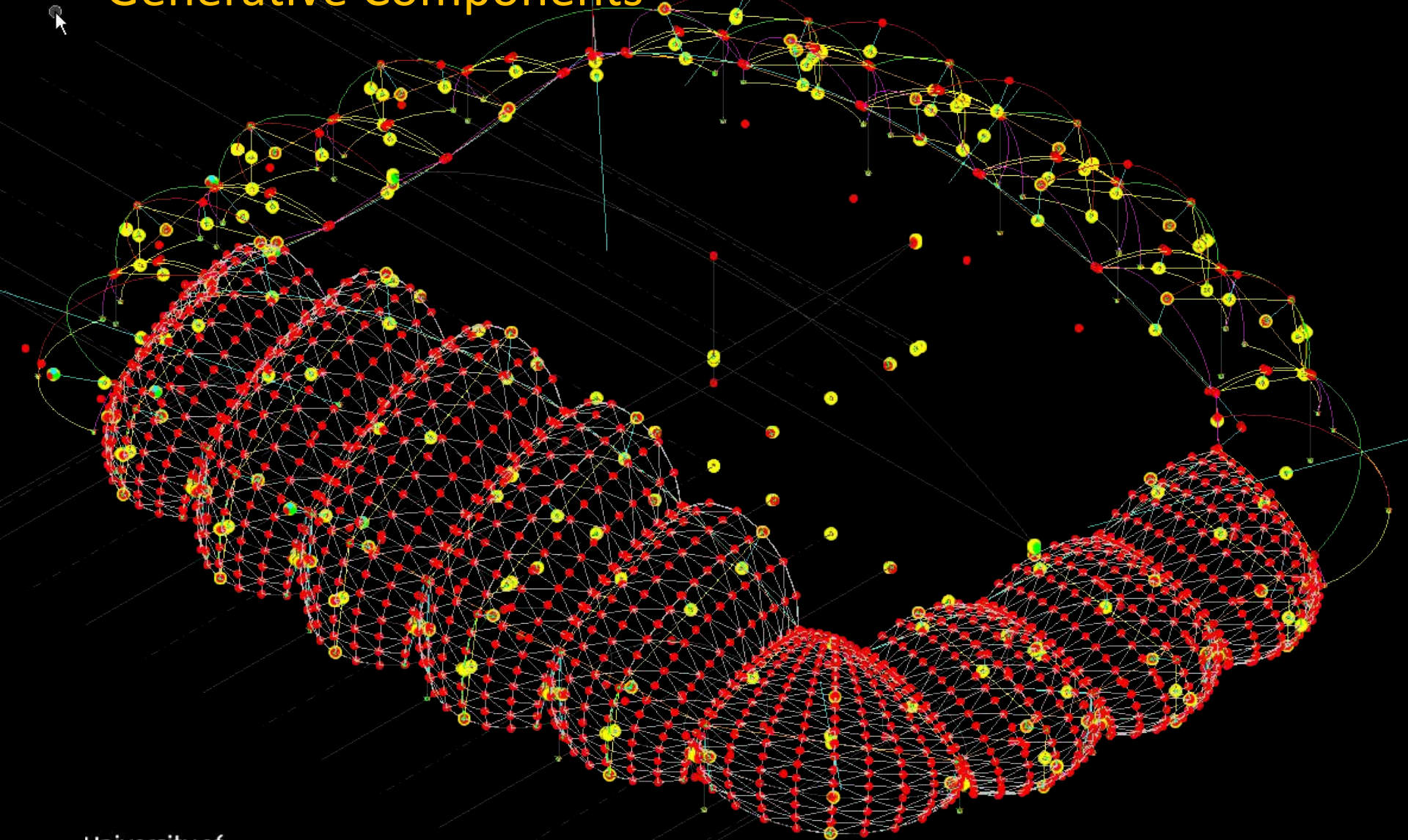


# Melbourne Rectangular Stadium Generative Components

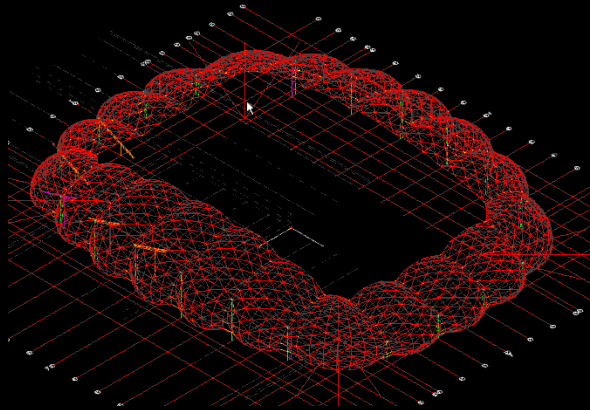
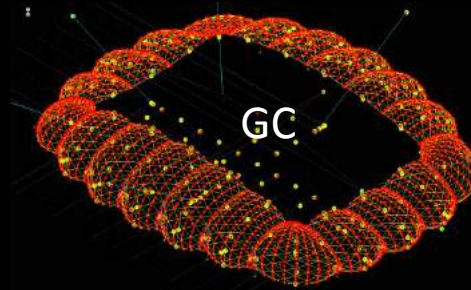




# Melbourne Rectangular Stadium Generative Components

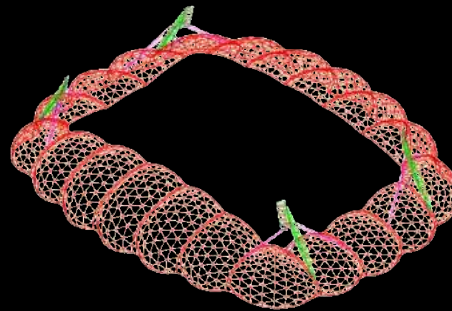


# Melbourne Rectangular Stadium Generative Components



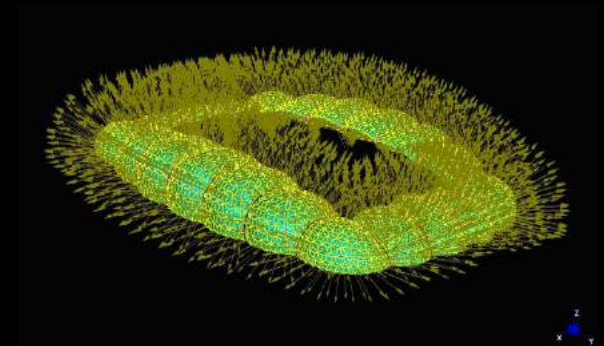
Fabrication

Wireframe



Bentley STF

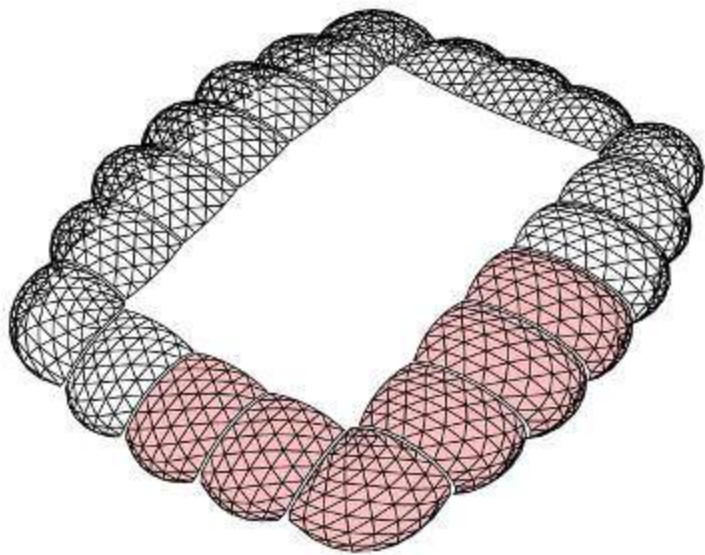
Model



Strand

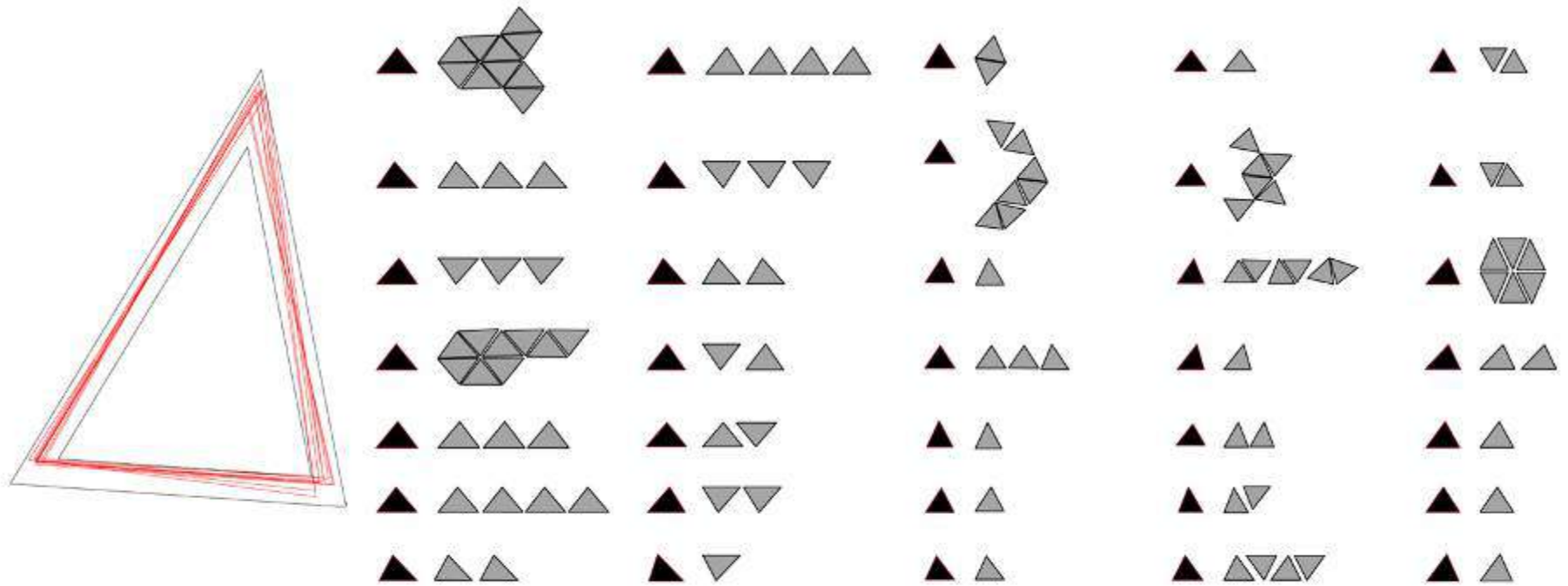
Analysis



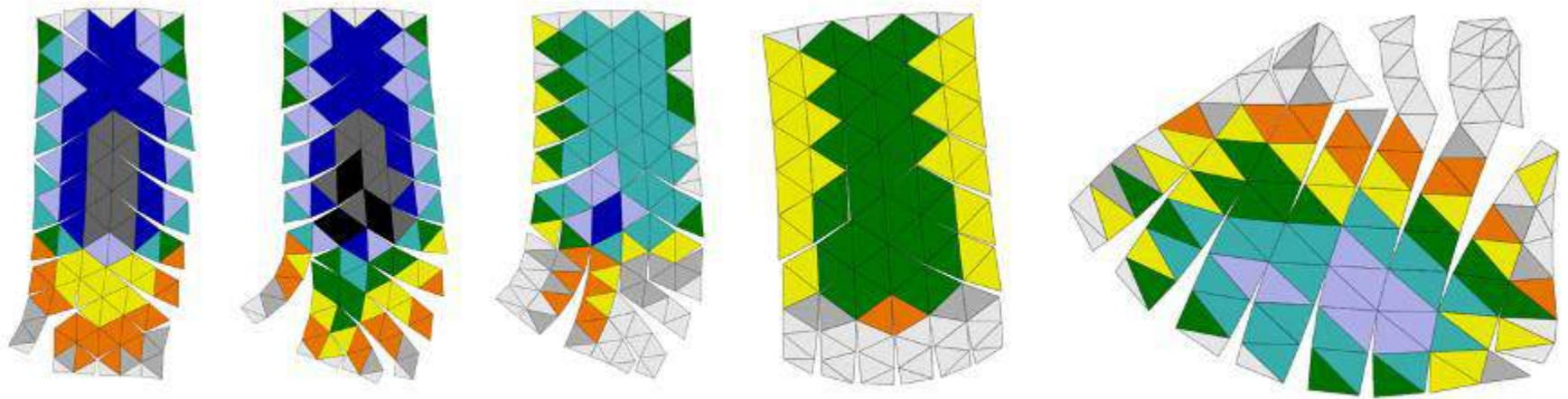


analysing panel area sizes from 3D model





extracting similar shapes



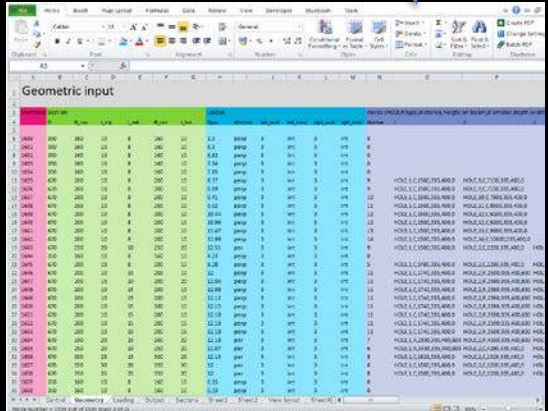


# 52 Lime Street

- 'The Scalpel'
- 190m - 40 Storey tower
- 60,000 sqm office space
- Tall buildings cluster in City of London







Inquire Object

Id: 183693 Type: 2 Assembly phase: 1 Part phase: 1

Name	Profile	Grids	Part position	Assembly position
SS_BEAM	H1670-8-20*	D/3-A	M0 (?)	A0 (?)

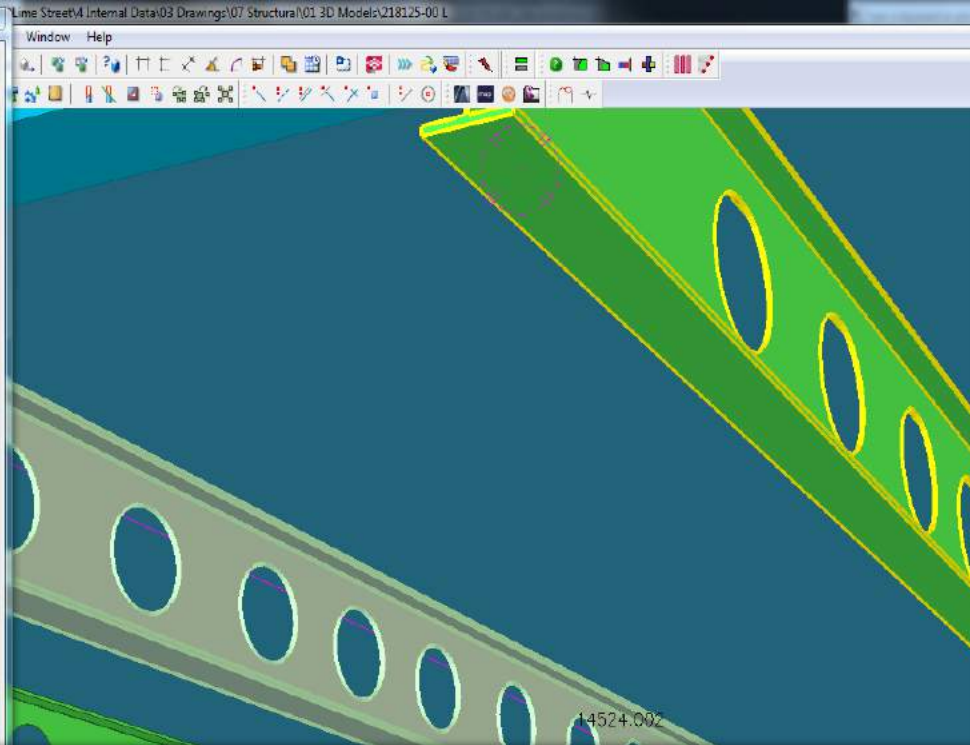
Total 11460 Parts: 17981.01 T, 166445.06 m

Part GUID: ID509B7D4E-0000-0518-3193-953239378230

Start point : X= 32210.0 mm Y= 97320.0 mm Z= 32460.0 mm  
End point : X= 32210.0 mm Y= 52326.3 mm Z= 32460.0 mm  
Center of gravity : X= 32210.0 mm Y= 44519.6 mm Z= 32459.1 mm

Top level : +32.795  
Bottom level : +32.125  
Part position : M0 (?)  
Assembly position : A0 (?)  
Net length : 14524.0 mm  
Gross length : 14524.0 mm  
Weight : 1565.02 kg  
Weight (Net) : 1565.02 kg  
Weight (Gross) : 1709.09 kg  
Volume : 0.200 m³  
Area : 293842.05 cm²

Name : SS\_BEAM  
Material : S355  
Finish :  
Profile : H1670-8-20\*250-20\*250



Tekla Structures x64 Beam (1)

Workflow End Conditions Analysis IFC export General Design

Arup Steel Properties Parameters Drawing Output Control

DRAWING OUTPUT CONTROL

Arup Layer Name ☐ SS\_BEAM\_PRIM

BEAM REFERENCE

Arup Beam Ref ☐ B100

Arup Beam Mark ☐ 1001

COLUMN REFERENCE

Arup Column Ref ☐

Arup Column Mark ☐

PLATE REFERENCE

Arup Plate Ref ☐

MEMBER PROPERTIES

Arup Paint Spec ☐ Galvanised

Arup Fire Rating (mins) ☐ 90

Arup Fire Protection ☐ Intumescent

Arup Shear Studs ☐ 1-200c/c

Arup Cast In Plate Ref ☐ NA

Arup Pre-camber (mm) ☐ 0

Arup Connection Detail ☐ Detail A

Arup Phase/Area ☐ SUPER\_LEVEL\_03

More:

Shorten (mm)

Assembly Status:

Output Member Type

Arup Layer Name

Arup Connection

Arup Pre-camber

Arup Cast In Plate

Arup Shear Studs

Arup Fire Protection

Arup Fire Rating (mins) : 90

Arup Paint Spec : Galvanised

Arup Beam Mark : 1001

Arup Beam Ref : B100

Arup Phase/Area : SUPER\_LEVEL\_03

Owner : GLOBAL/ Joe, DukeLow

GUID : ID509B7D4E-0000-0518-3193-

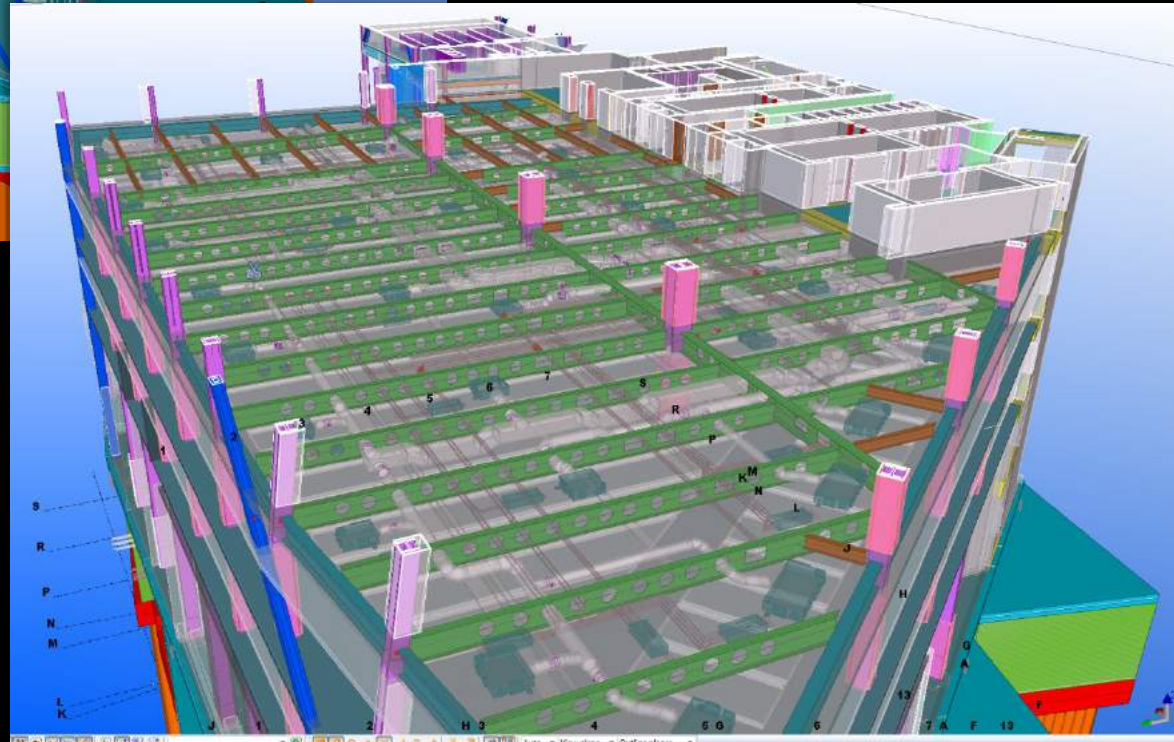
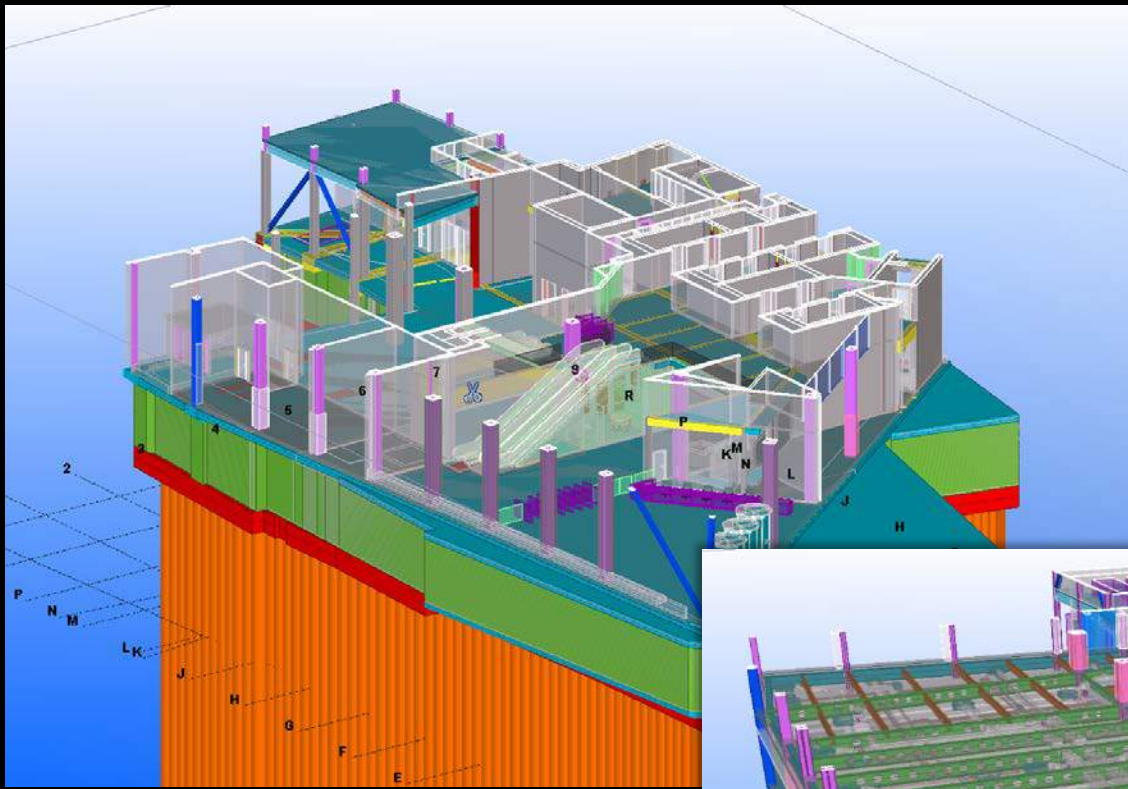
OK

### One Lime Street Square - Steel Beam Schedule

Level/Phase	Model Element ID	Beam Reference	Profile	End Reactions (Member Start)								End Reactions (Member End)								Member Specifications					
				Force (kN)				Moment (kNm)				Force (kN)				Moment (kNm)				Pre-Camber (mm)	Shear Studs	Paint Spec	Fire Rating (mins)	Cast-In Plate Ref	Specified Connection
				Axial (Compression) P <sub>x</sub>	Axial (Tension) P <sub>t</sub>	Shear P <sub>y</sub>	Shear P <sub>z</sub>	M <sub>xx</sub>	M <sub>yy</sub>	M <sub>zz</sub>	Axial (Compression) P <sub>x</sub>	Axial (Tension) P <sub>t</sub>	Shear P <sub>y</sub>	Shear P <sub>z</sub>	M <sub>xx</sub>	M <sub>yy</sub>	M <sub>zz</sub>								
SUPER_LEVEL_03	183407	B01	H1670-15-45-250	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		
SUPER_LEVEL_03	183418	B01	H1670-10-40-250	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		
SUPER_LEVEL_03	183429	B01	H1670-15-45-250	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		
SUPER_LEVEL_03	183440	B01	H1670-15-45-250	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		
SUPER_LEVEL_03	183451	B01	H1670-20-50-300	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		
SUPER_LEVEL_03	183462	B01	H1670-50-50-400	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		
SUPER_LEVEL_03	183473	B01	H1670-15-45-300	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		
SUPER_LEVEL_03	183484	B01	H1670-25-20-350-30-350	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		
SUPER_LEVEL_03	183495	B01	H1670-25-30-400	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		
SUPER_LEVEL_03	183506	B01	H1670-30-30-450	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		
SUPER_LEVEL_03	183517	B01	H1670-10-12-200-15-200	300	100	100	500	700	600	200	400	300	100	500	7700	660	200	0	1-200c/c	Galvanised	90	N/A	Detail A		

Floor Beams





- SMEP Co-ordination
- Linking of design team models
- Model collaboration & review



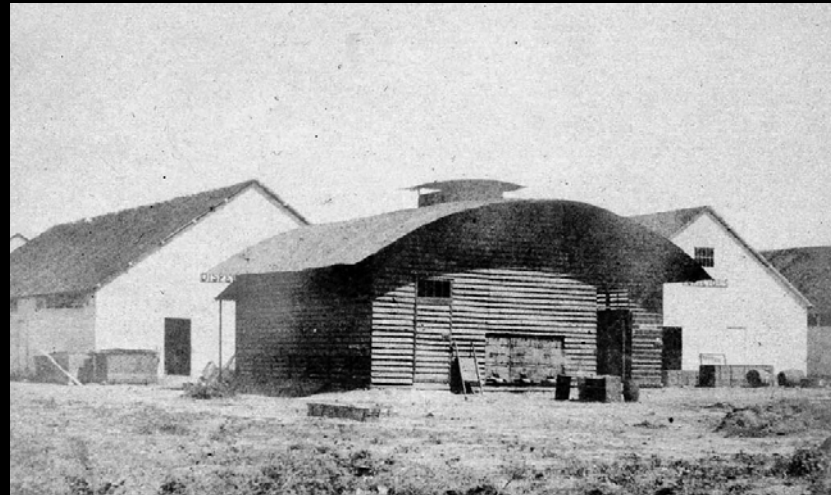


# Fabrication



# Renkioi Hospital, Dardanelles

- Commissioned February 1855
- Brunel played the roles of architect, planner, structural engineer, mechanical, electrical and public health engineers and management contractor.
- Design Period: **6 days**

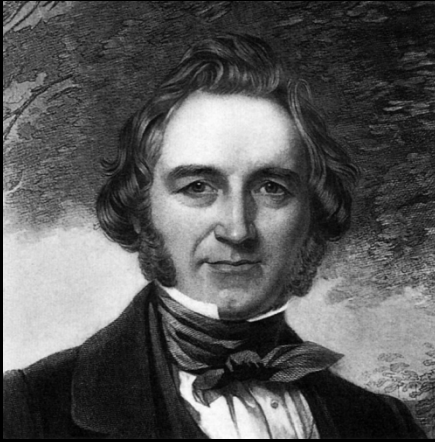


# Crystal Palace – The Great Exhibition

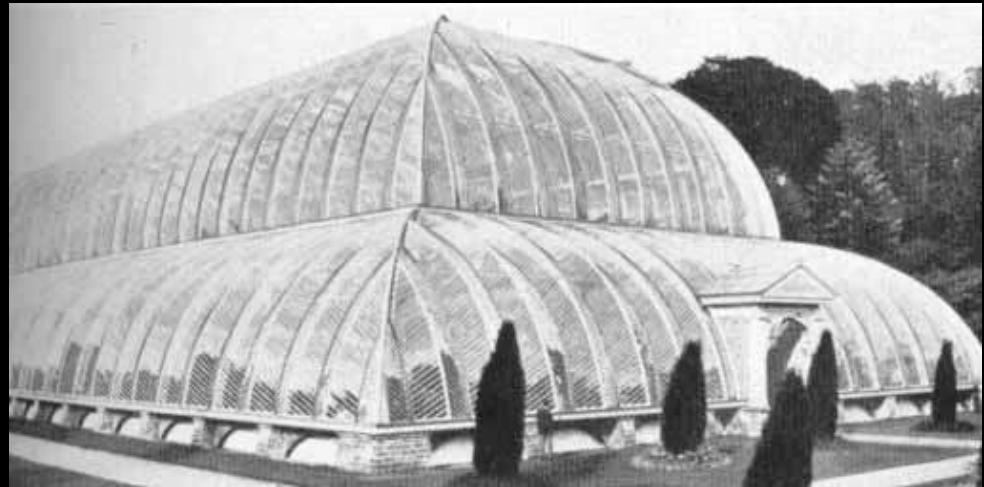




# Crystal Palace - Design Team



Joseph Paxton  
Head Gardener at Chatsworth House  
Experience: Orangery & The Large Greenhouse

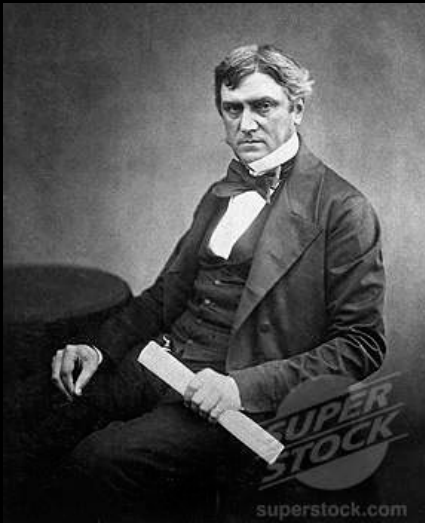




# Crystal Palace - Design Team



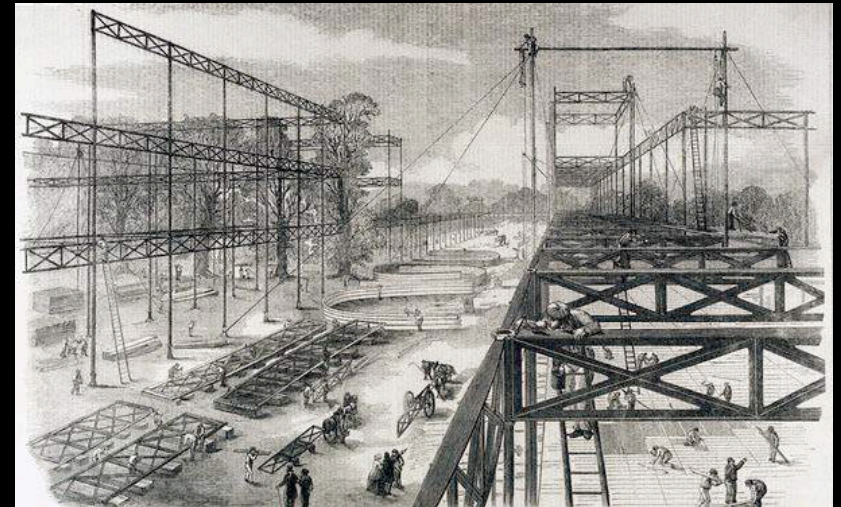
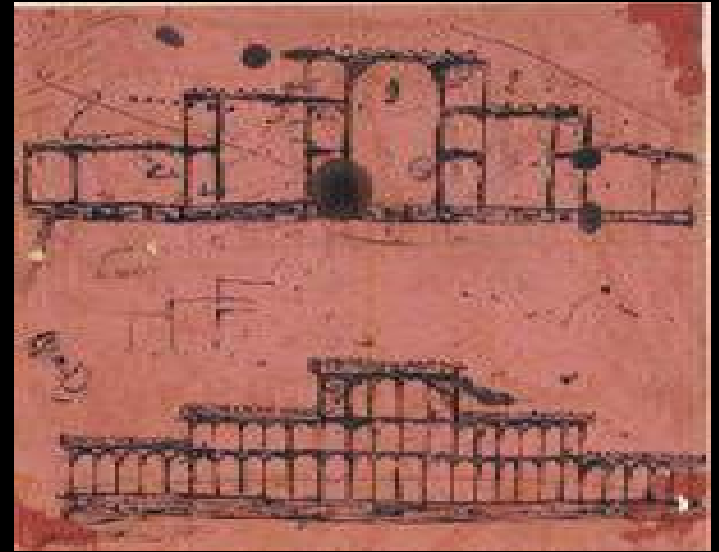
William Cubitt  
Chairman of Building Committee of Great  
Exhibition and consulting engineer



Charles Fox  
Specialist Contractor

# Crystal Palace – The Great Exhibition

- First Plans in 9 days
- Built in 9 months



# Empire State Building

Drawings produced in **2 weeks**

Official opened on 1 May 1931

( **1 year 45 days** )





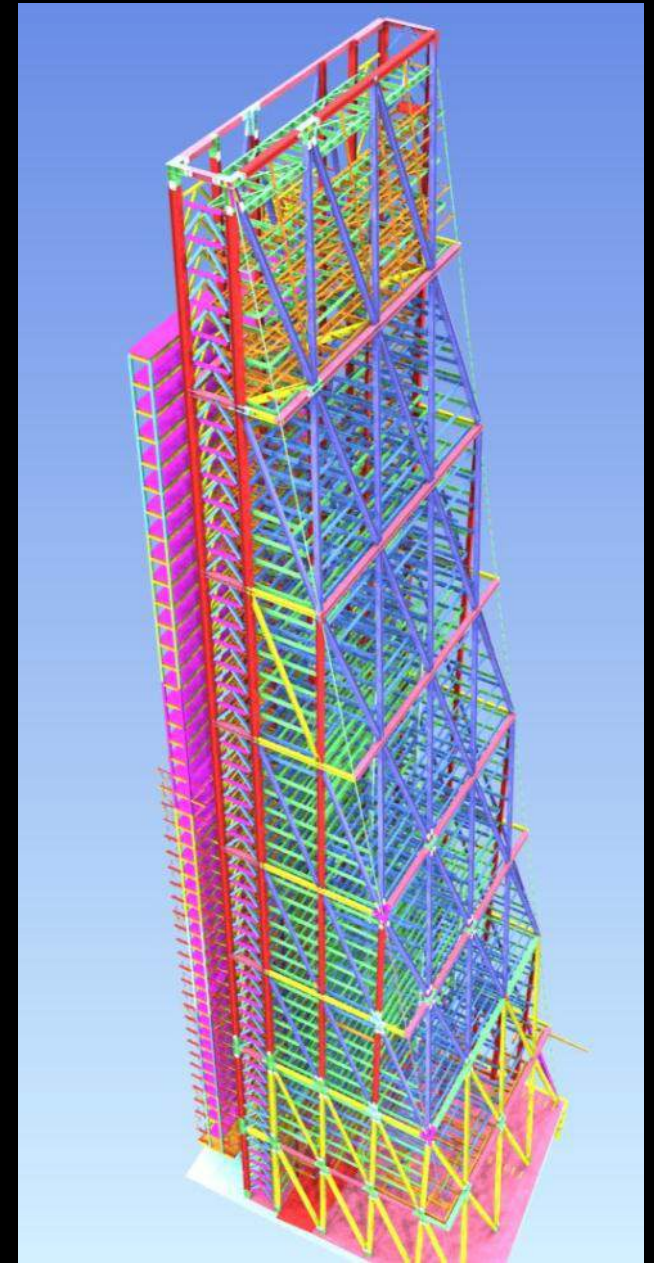
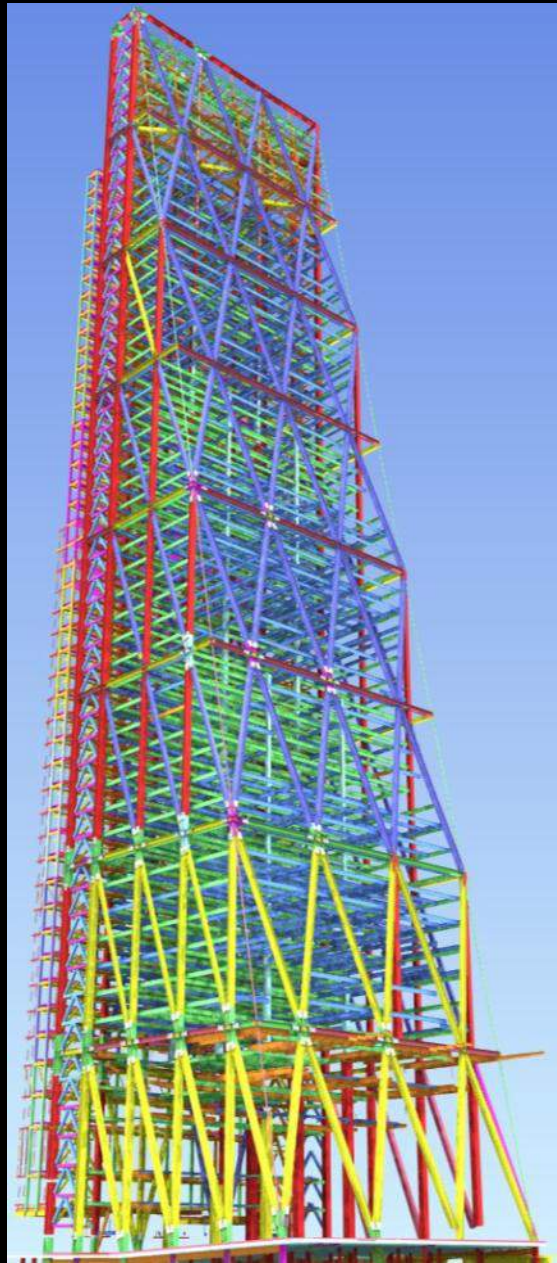
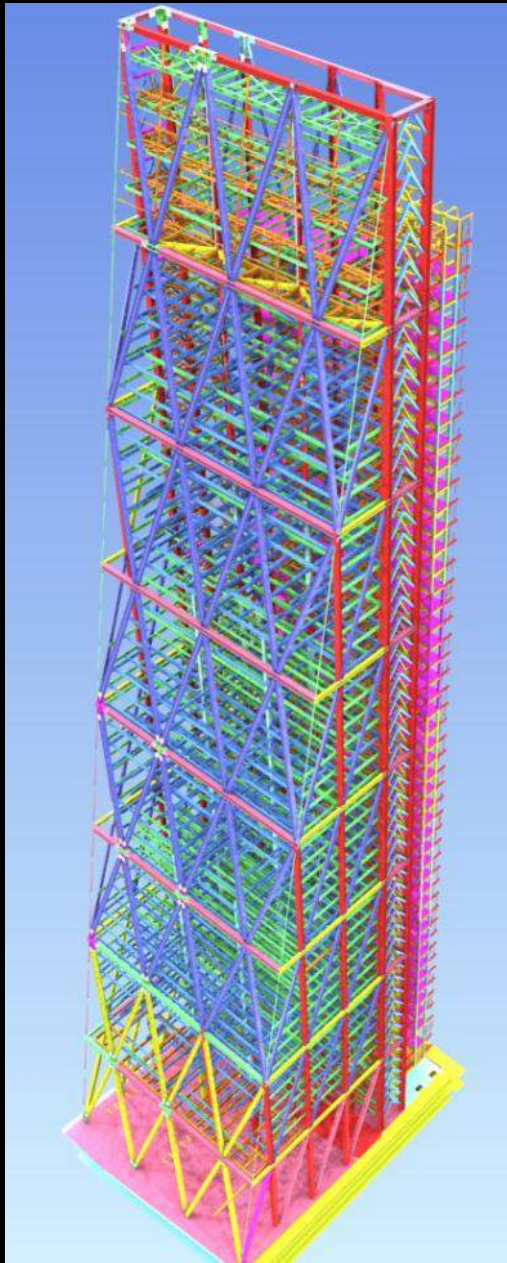
# Design for Manufacture – 122 Leadenhall Street

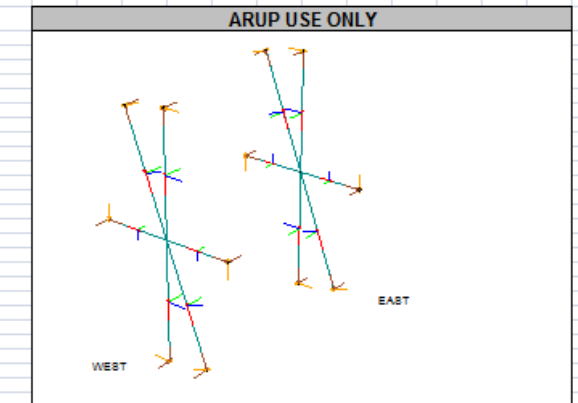
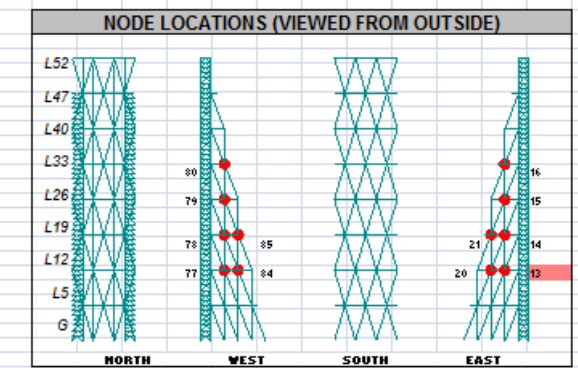
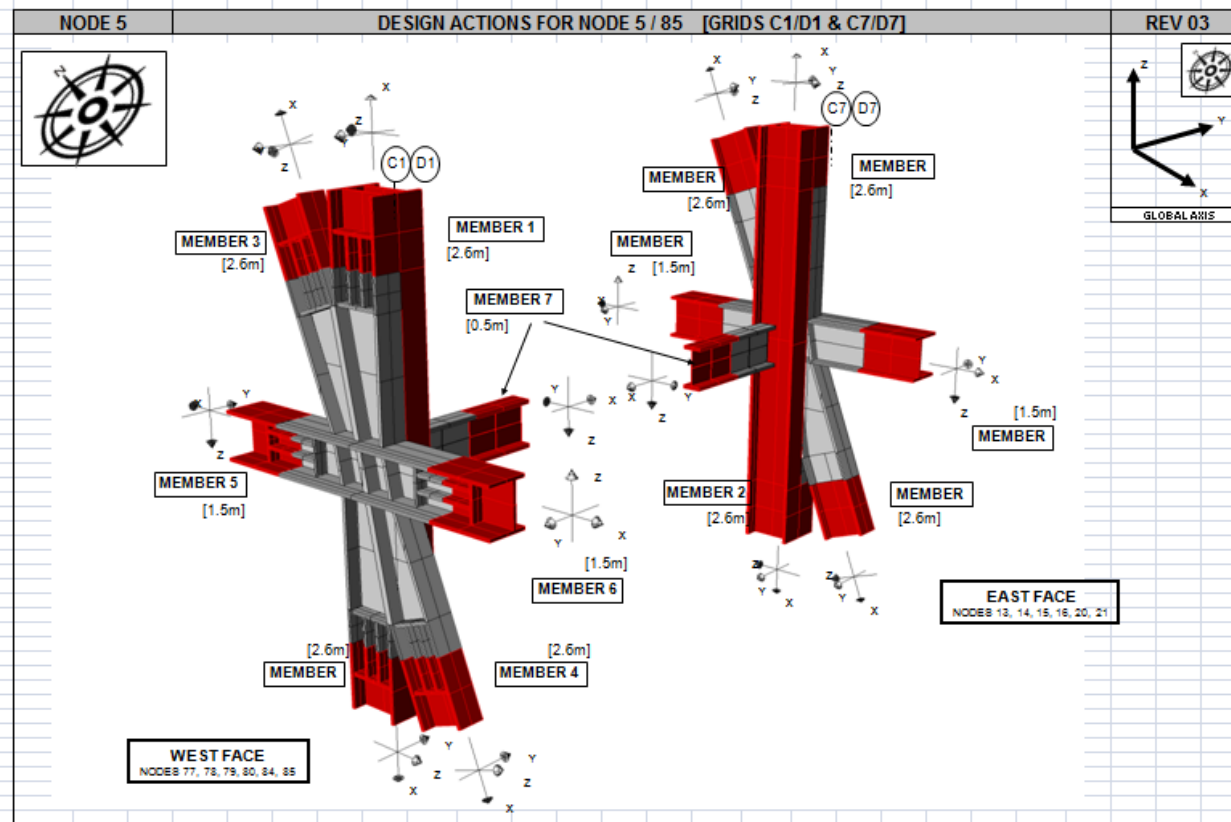


Client: British Land/Oxford Properties  
Architect: Rogers Stirk Harbour + Partners  
University of Salford  
MANCHESTER

Main Contractor: Laing O'Rourke  
Specialist Steelwork: Wastons ARUP





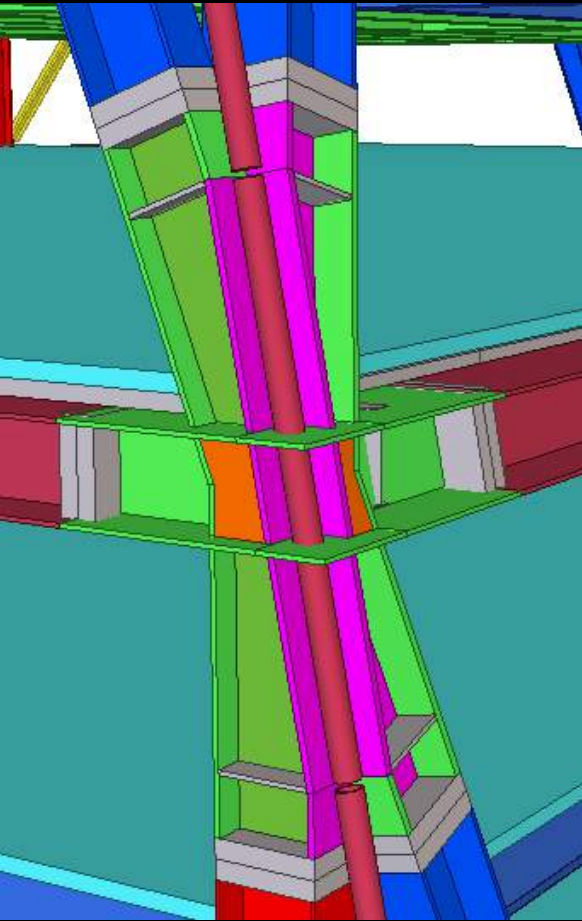


Made to extract member design forces from: 85 28.500 0.000 98.200

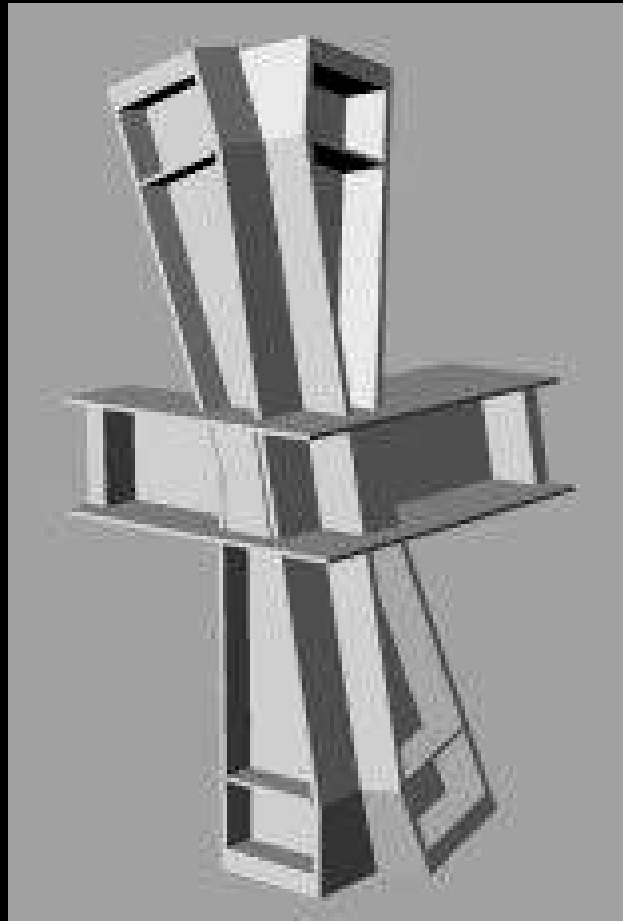
MEMBER SERVICE DESIGN FORCES FROM GSA																																					
Load case	Type	MEMBER 1						MEMBER 2						MEMBER 3						MEMBER 4						MEMBER 5						MEMBER 6					
		Fx kN	My kNm	Mx kNm	Fx kN	Fy kN	Mx kNm	Fx kN	My kNm	Mx kNm	Fx kN	Fy kN	Mx kNm	Fx kN	My kNm	Mx kNm	Fx kN	Fy kN	Mx kNm	Fx kN	My kNm	Mx kNm	Fx kN	Fy kN	Mx kNm	Fx kN	My kNm	Mx kNm	Fx kN	Fy kN	Mx kNm						
Dead+Super Dead	D+SDL	-6,528	223	22	34	10	1	-7,245	-249	-48	30	24	1	264	139	1	32	0	0	310	-126	-1	24	-1	0	4	254	-2	-5	0	-38	-1	-547	2	-175	3	11
Active Alignment	AA	2,426	-169	3	-21	-3	1	2,311	245	-5	-29	-4	2	2,074	-119	1	-44	0	0	2,078	132	-1	-43	0	0	-12	-588	0	152	-1	0	-7	151	0	40	1	0
Live	LL	-2,673	65	4	10	31	0	-2,829	-74	-26	8	50	0	118	39	-3	8	1	0	114	-34	3	7	0	0	-3	159	-1	-41	0	0	1	-57	-2	-15	2	0
Nat X	NHL	145	-55	1	-10	-1	0	108	-44	-1	1	-1	0	-870	-28	0	-6	0	0	-847	14	0	-1	0	0	28	-98	-1	26	0	0	0	34	1	9	-1	0
Nat -X	NHL	-145	55	-1	10	1	0	-108	-44	1	-1	1	0	870	28	0	6	0	0	847	-14	0	1	0	0	-28	98	1	-26	0	0	0	-34	-1	-9	1	0
Nat Y	NHL	628	-10	10	-2	-1	0	799	3	13	0	10	0	124	-9	1	-3	0	0	-55	1	2	-1	1	0	-61	-5	-4	3	0	0	-2	21	-4	5	5	0
Nat -Y	NHL	-628	10	-10	2	1	0	-799	-3	-13	0	-10	0	-124	9	-1	3	0	0	55	-1	-2	1	-1	0	61	5	4	-3	0	0	2	-21	4	-5	-5	0
Wind 0	WL	-149	-88	4	-11	-3	0	-336	70	-5	-9	-5	0	-1,666	-41	1	-8	0	0	-1,495	20	-1	-3	0	0	66	-159	0	42	0	0	-1	56	3	15	-3	0
Wind 30	WL	-763	-63	-5	-7	-1	0	-1,064	53	-17	-7	-13	0	-1,494	-25	0	-4	0	0	-1,198	15	-3	-2	-1	0	107	-124	3	32	0	0	1	26	6	7	-7	0
Wind 60	WL	-778	-62	-5	-7	-1	0	-1,083	53	-17	-7	-13	1	-1,496	-25	0	-4	0	0	-1,196	15	-3	-2	-1	0	108	-124	3	31	0	0	1	25	6	7	-7	0
Wind 90	WL	-642	7	-9	1	2	0	-788	-2	-12	0	-9	0	-173	7	-1	2	0	0	-21	-2	-2	1	-1	0	54	1	5	-2	0	0	3	-19	3	-5	-5	0
Wind 120	WL	-533	78	-12	10	5	0	-545	-58	-9	7	-6	0	1,157	41	-1	8	0	0	1,188	-18	-2	3	0	0	6	128	5	-35	1	0	3	-64	2	-17	-3	0
Wind 150	WL	-521	100	-14	13	6	0	-500	-75	-9	9	-5	0	1,557	51	-2	10	0	0	1,559	-23	-2	4	0	0	-6	167	6	-46	1	0	4	-79	2	-21	-3	0
Wind 180	WL	169	104	-4	12	5	0	385	-82	6	11	5	0	1,967	48	0	9	0	0	1,769	-25	1	4	1	0	-74	188	4	-50	1	0	2	-66	-2	-17	1	0



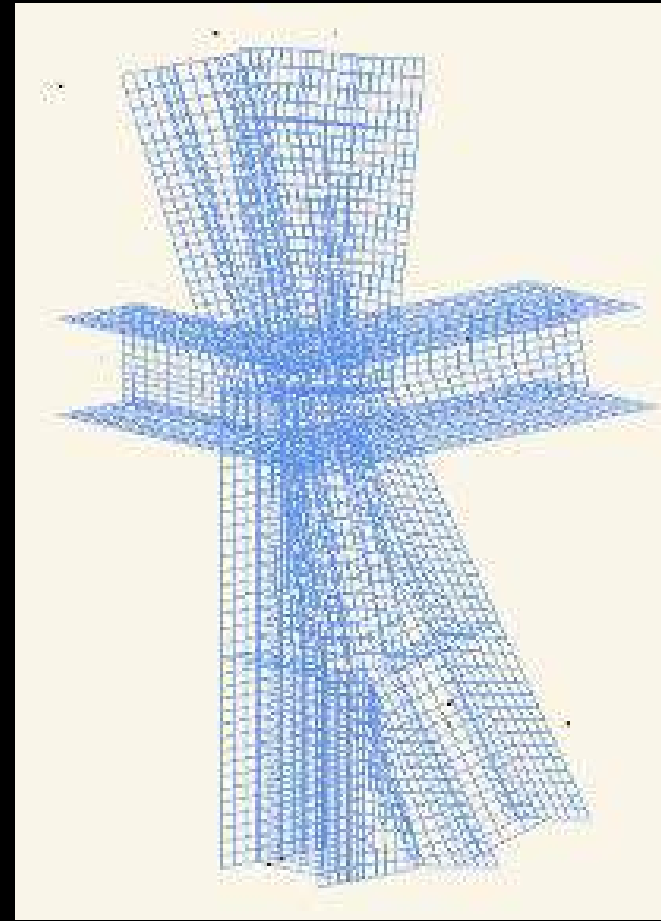
## Steelwork Design for fabrication process



TEKLA



RHINO



GSA

The diagram shows a cross-section of a wellhead seal assembly. A wellhead is shown on the left, with a wellhead seal assembly on the right. The wellhead seal assembly consists of a wellhead seal and a wellhead seal assembly. The wellhead seal is shown as a black, wedge-shaped component. The wellhead seal assembly is shown as a black, rectangular component. The wellhead seal assembly is shown as a black, rectangular component. The wellhead seal assembly is shown as a black, rectangular component.

[illegible]

SECTION 2-2

CB1	21/12/11	AK	AS	DE
Issued for Certification				
PS1	25/08/11	AK	AS	DE
Issued for Information				
E	04/01/11	AK	AS	DE
Issued for Design and Build Tender				
Issue	Date	By	Chkd	Appd

Issue  
**C01**

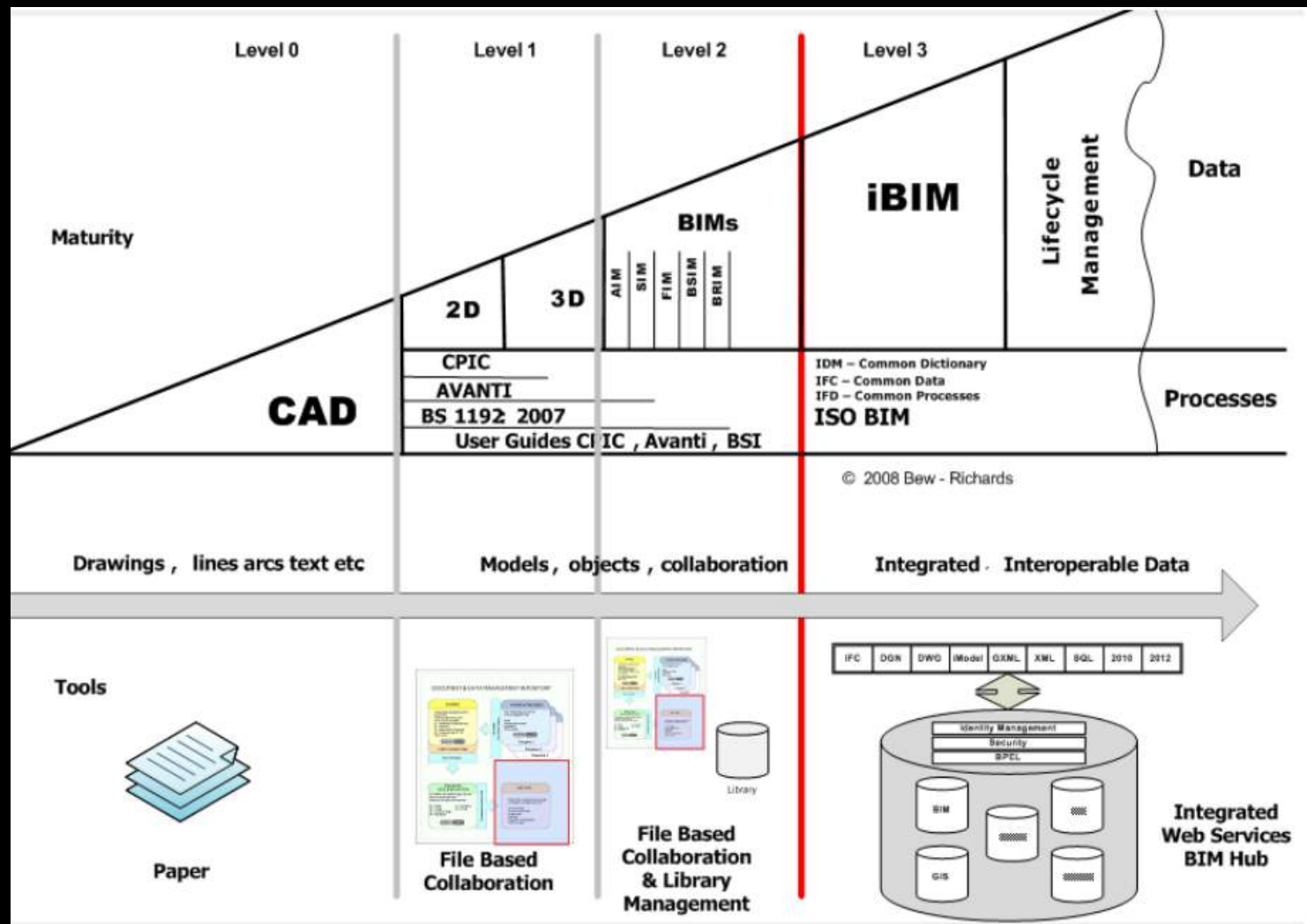




BIM is not business as usual



# BIM Maturity Model



P16. A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper March 2011

## Level 2 BIM

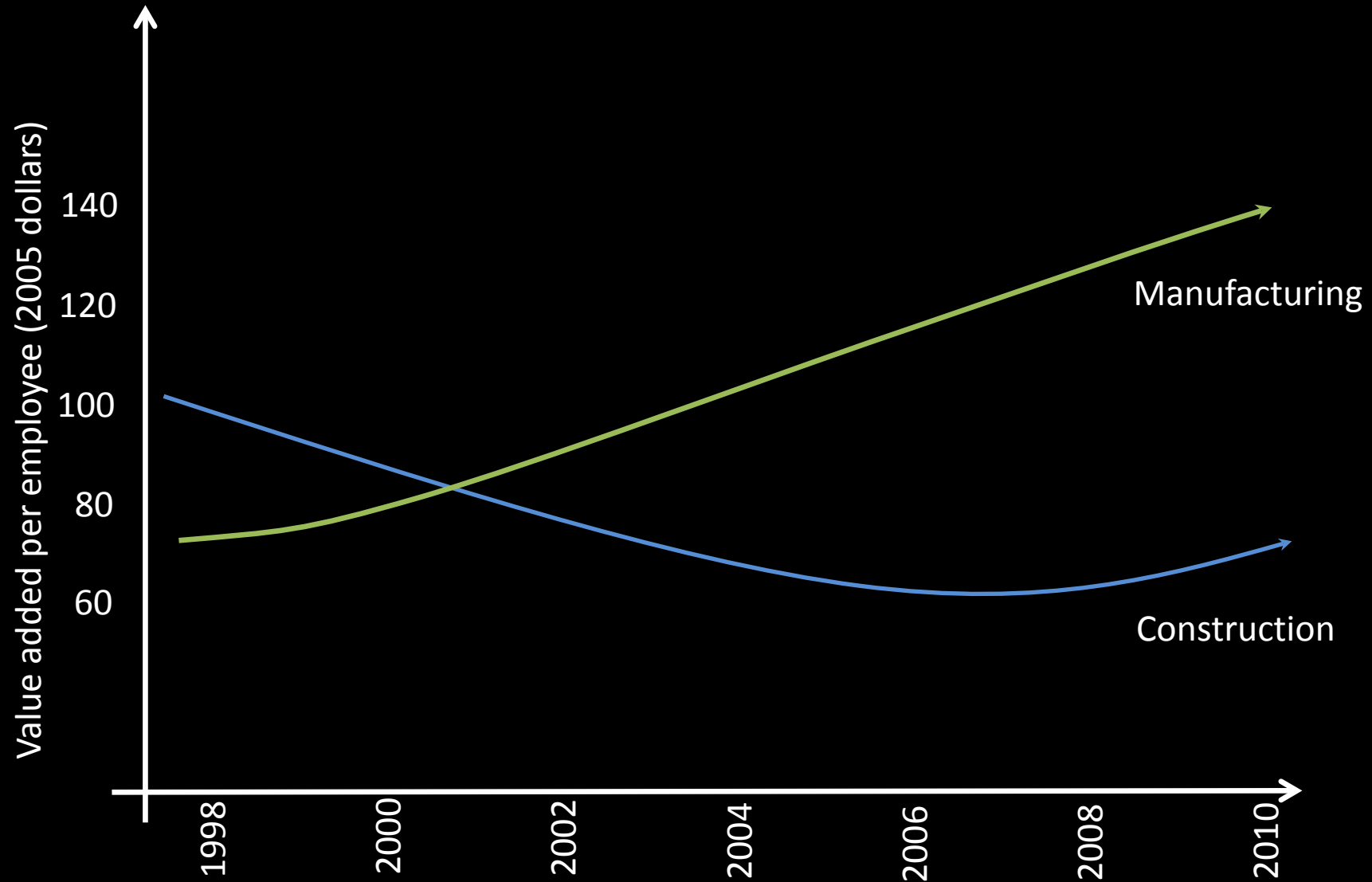
Delivery of open, transferable digital information

- 3D models in native format
- PDF drawings and documents
- A data exchange vehicle (COBie)

Implied is also

- Data standards
- Defined processes
- Defined and controlled data exchange
- Collaborative digital environment

# Productivity Manufacturing v Construction



Based on Figure 7 AECbytes Viewpoint #67 (March 14, 2013)



# What is certain is that predicting the future is difficult (especially with regard to technology)

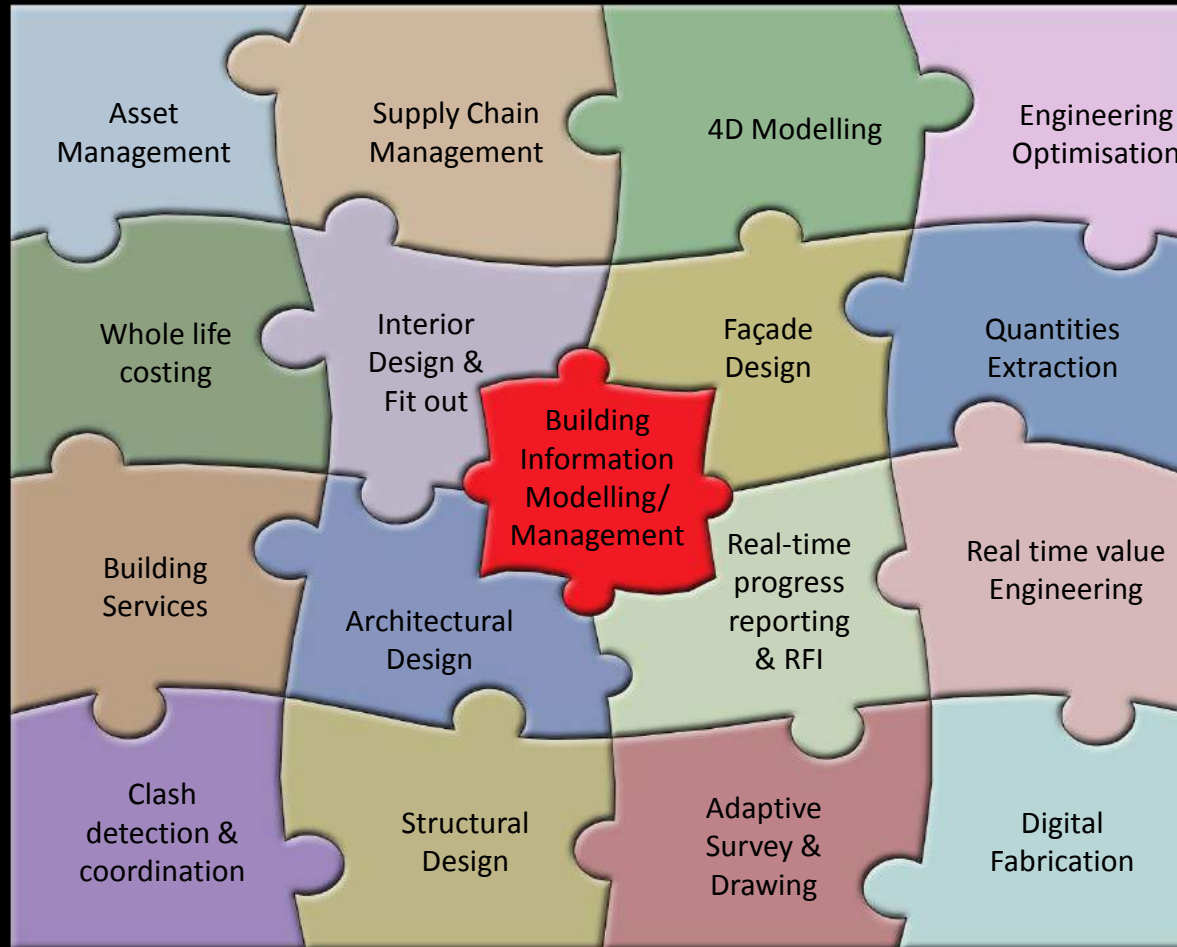
- “Computers in the future may weigh no more than 1.5 tons” – Popular Mechanics 1949
- “I think there is a world market for maybe five computers” – Thomas Watson, chairman of IBM, 1943
- “There is no reason anyone would want a computer in their home” – Ken Olson, president & founder of DEC

## Lessons from other industries

- In 1888 company founded
- In 1988 it employed 145,300 people and made a profit of \$1.17bn on \$13.3bn revenue
- In 2009 it employed 19,900 people and made a quarterly loss of \$111m
- 19 January 2012 files for bankruptcy
- The rise of the Digital Camera (even though they invented it in 1975)

# Conclusions

# Unified Approach to BIM(M)

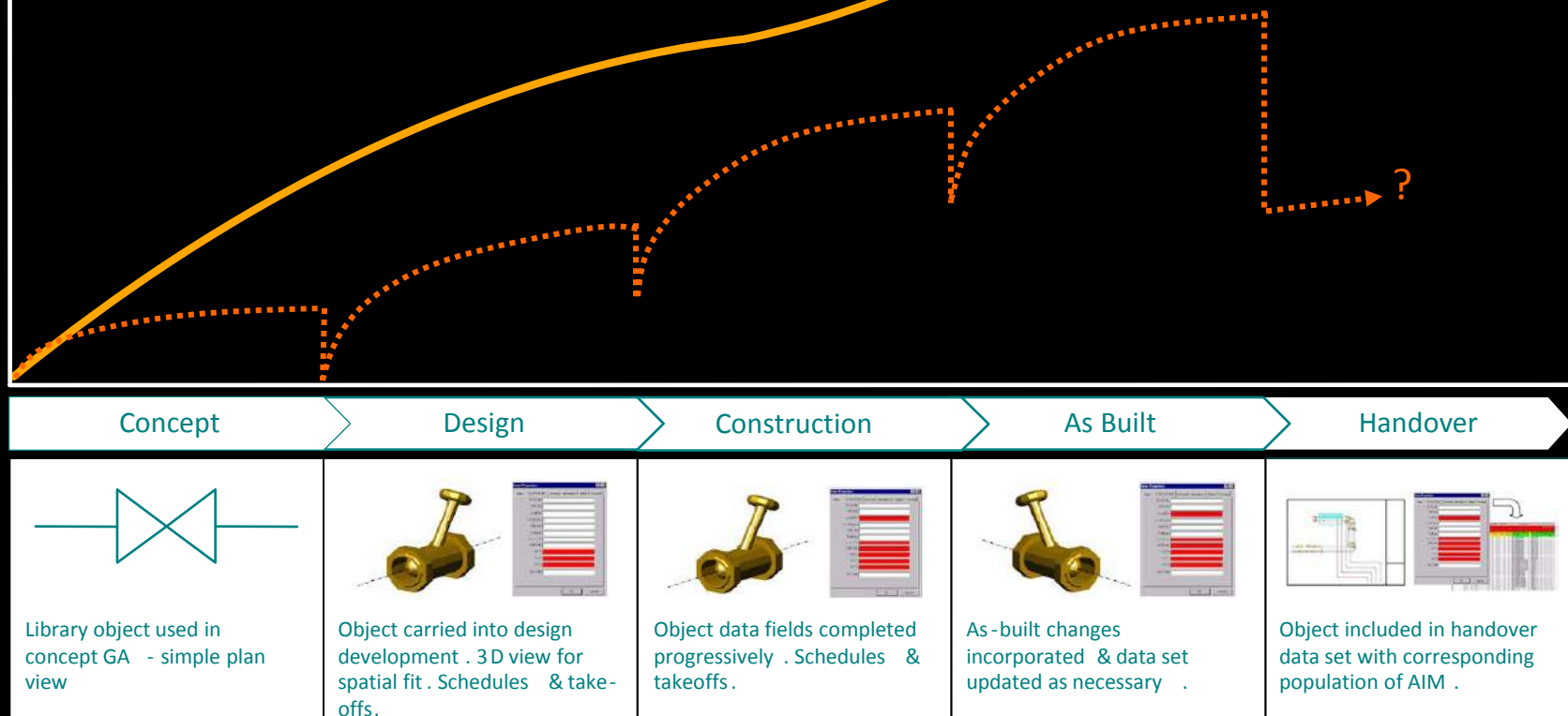




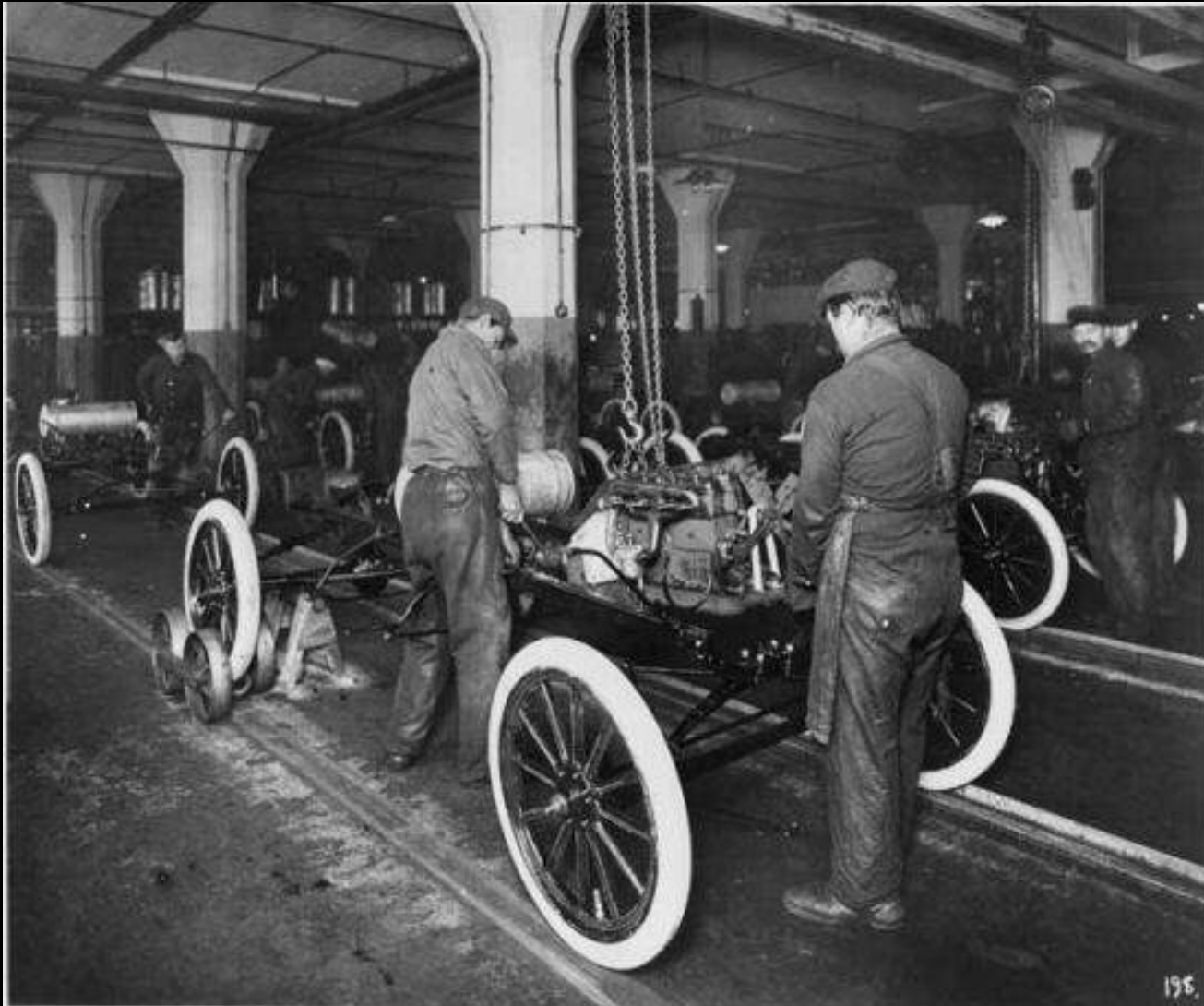
Data, Information & Knowledge

# Information Flow across the Project Life-Cycle

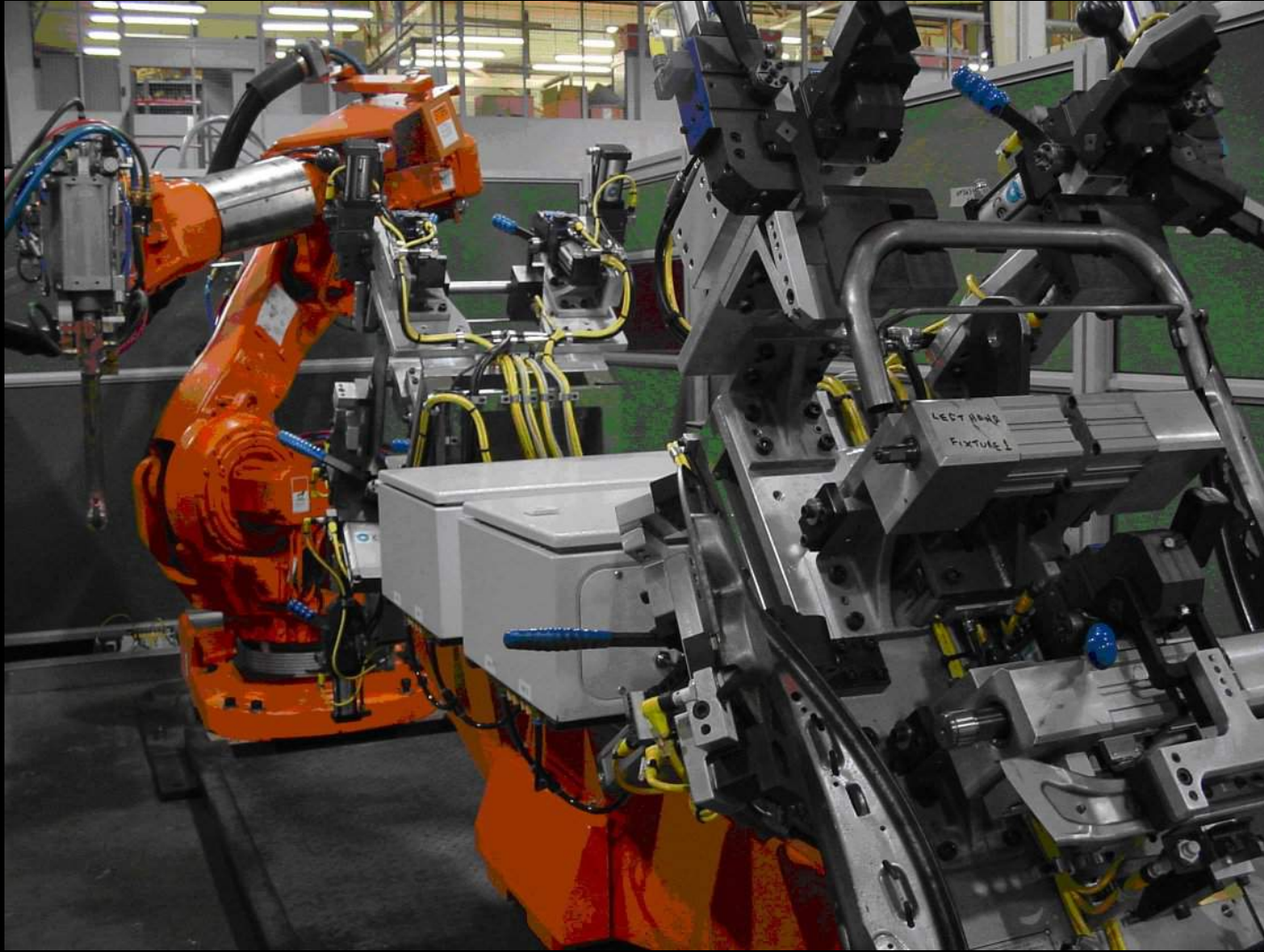
Whole Lifecycle  
Information  
Management



# The Future?



# The Future?





The only constant in this world is change....





There is only one planet earth







# BARRIERS TO BIM



# Barriers to change – Client & Project Inception

- **The Client's Business Model**
  - How does the client make money?
  - What are the drivers for the client's business?
  - What are the reasons behind the project?
- **The Client's Financial Model**
  - How does the client fund the project?
  - How is cash flow controlled?
- **Empty Site Syndrome**
  - Why is there pressure to start before the design is complete?
  - Who has set the completion date and why?



# Barriers to change – Client & Project Inception

- Design management and tendering process
  - How can late change be reduced by bringing suppliers and fabricators in much earlier into the design process
- Resistance to front end loading or investment in technology
  - It easier to see the headline figures instead of the savings.  
Why?
- Professional Indemnity
  - Lawyers!!!! Enough said!
- Aversion to Innovation
  - Why are you innovating on my project?

# Barriers to change - Designers

- Lack on integration between parties
  - Adversarial contracts.
  - Not getting appropriate experts at the right time
  - Software tools between disciplines do not share common basis.
- Paid for a service – not performance
  - MEP Engineers should be designing out kit; justifying their fee by the omission of services.
- Designer service is seen as a commodity
  - Cheapest design – you get what you pay for
- Difficult to justify fee for additional simulation.
  - Simulation at early stage can save many times the cost at a later

# Barriers to change - Construction

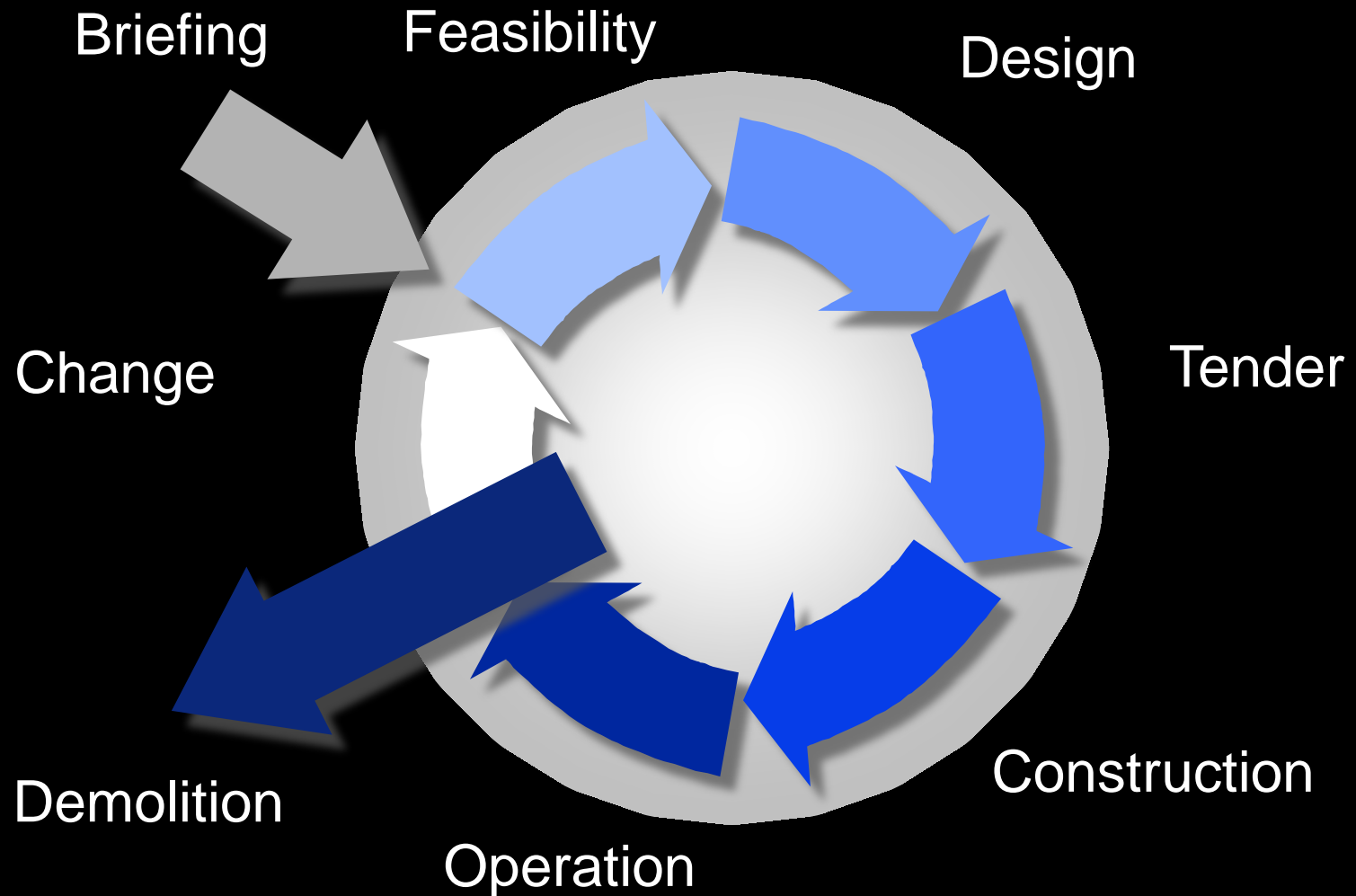
- **Lack on integration between parties**
  - Large fragmented supply chains of many SME
  - Adversarial contracts.
  - Pay when paid
- **Lack of CPD / Training / R&D**
  - Low profit means low rate of re-investment in improvement
  - Low profit also means not interesting to venture capitalists.
- **Low increase in productivity**
  - On-site construction sees low or even negative increases in productivity
  - Off-site construction has seen large increases in productivity



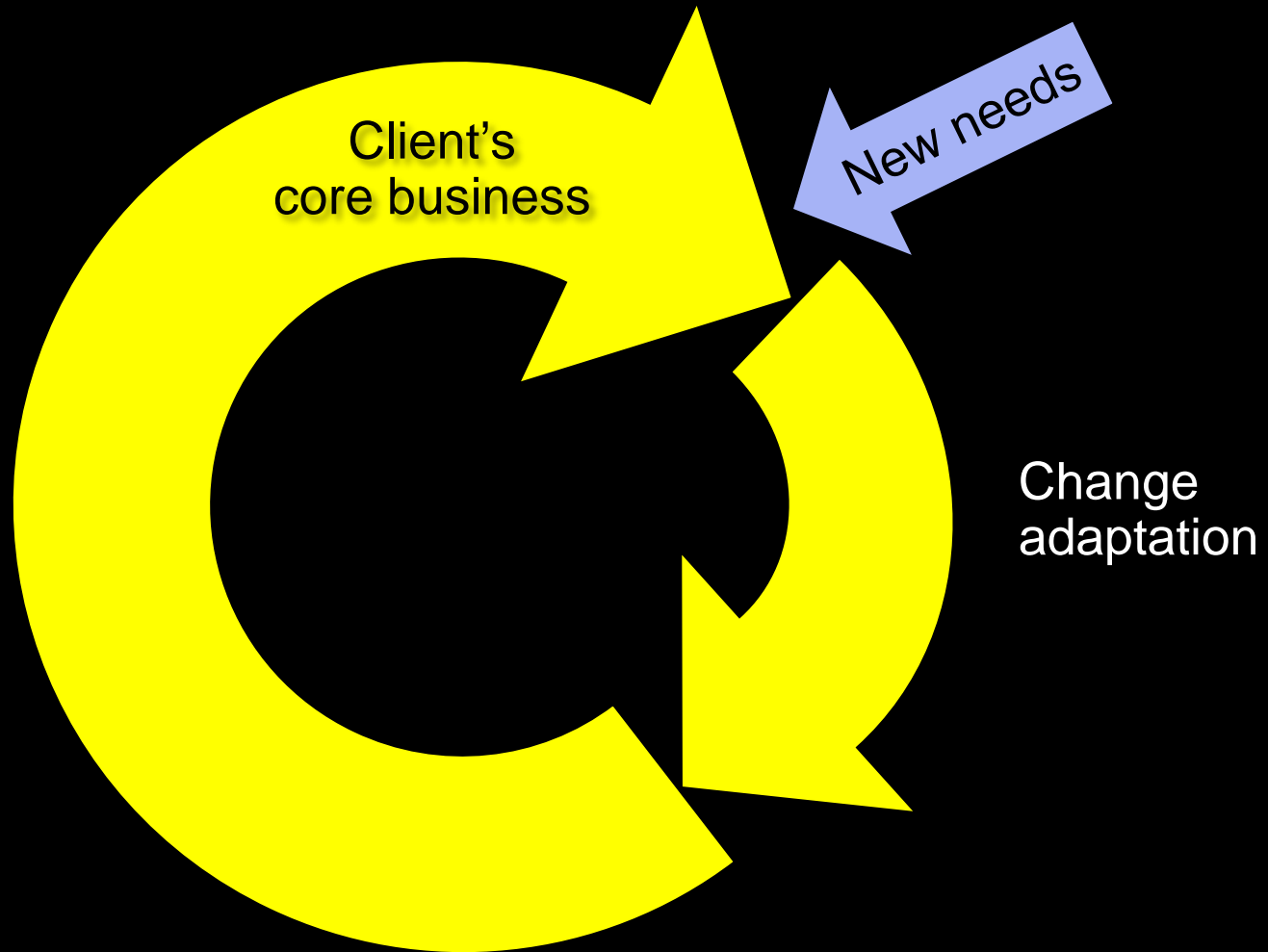
# Operation



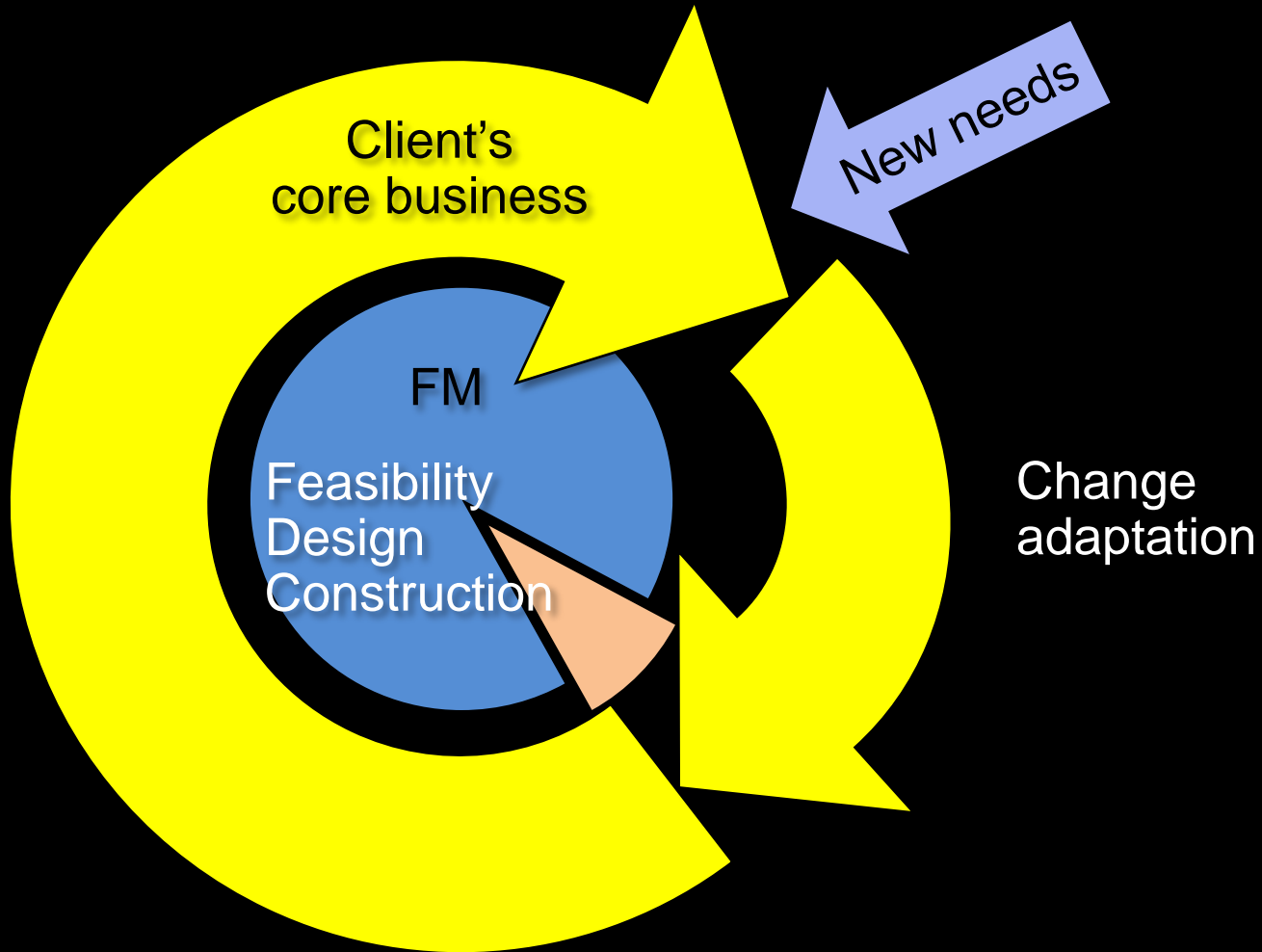
# The Project Life-Cycle



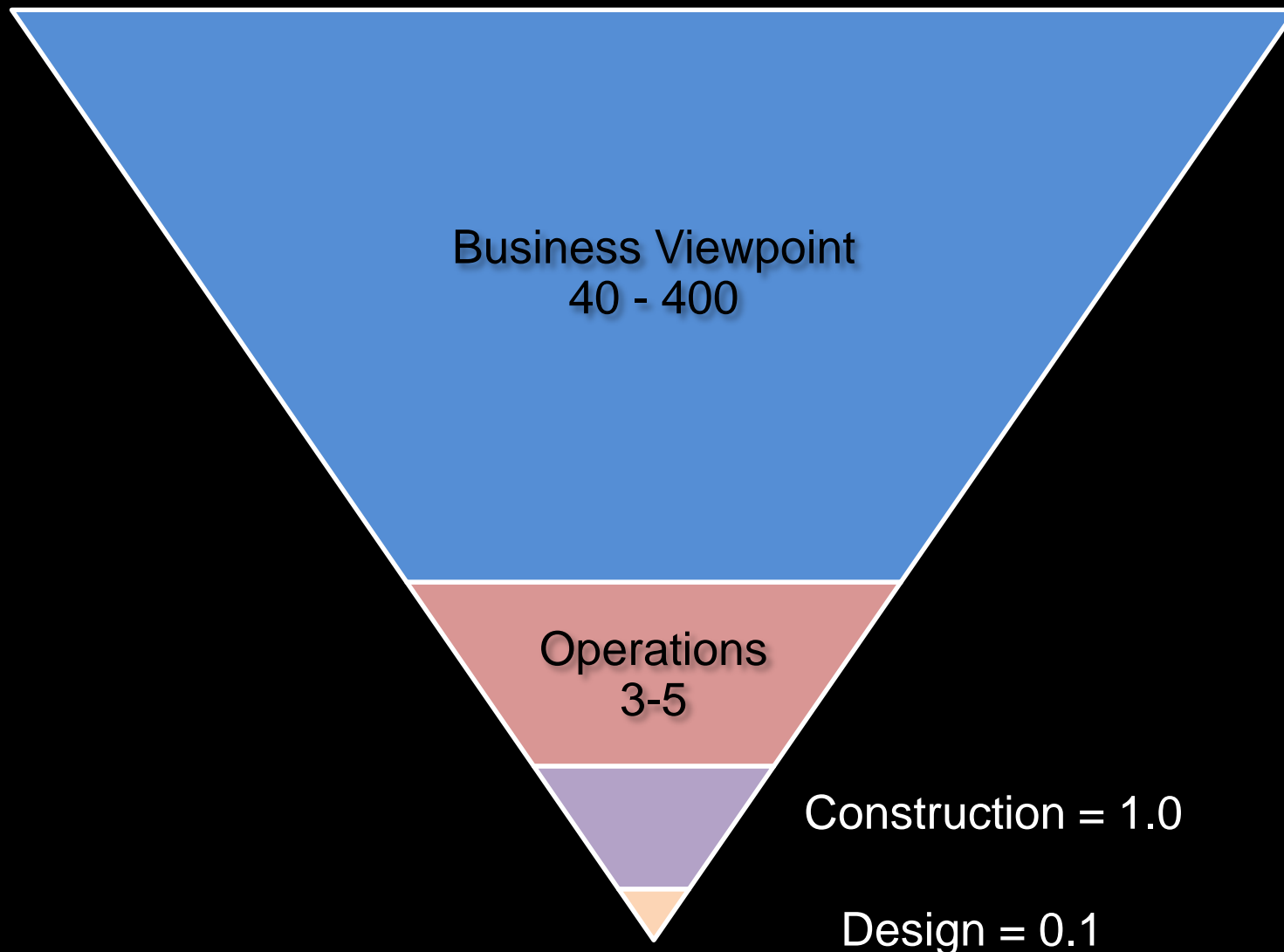
# The Business Cycle



# The Business Cycle

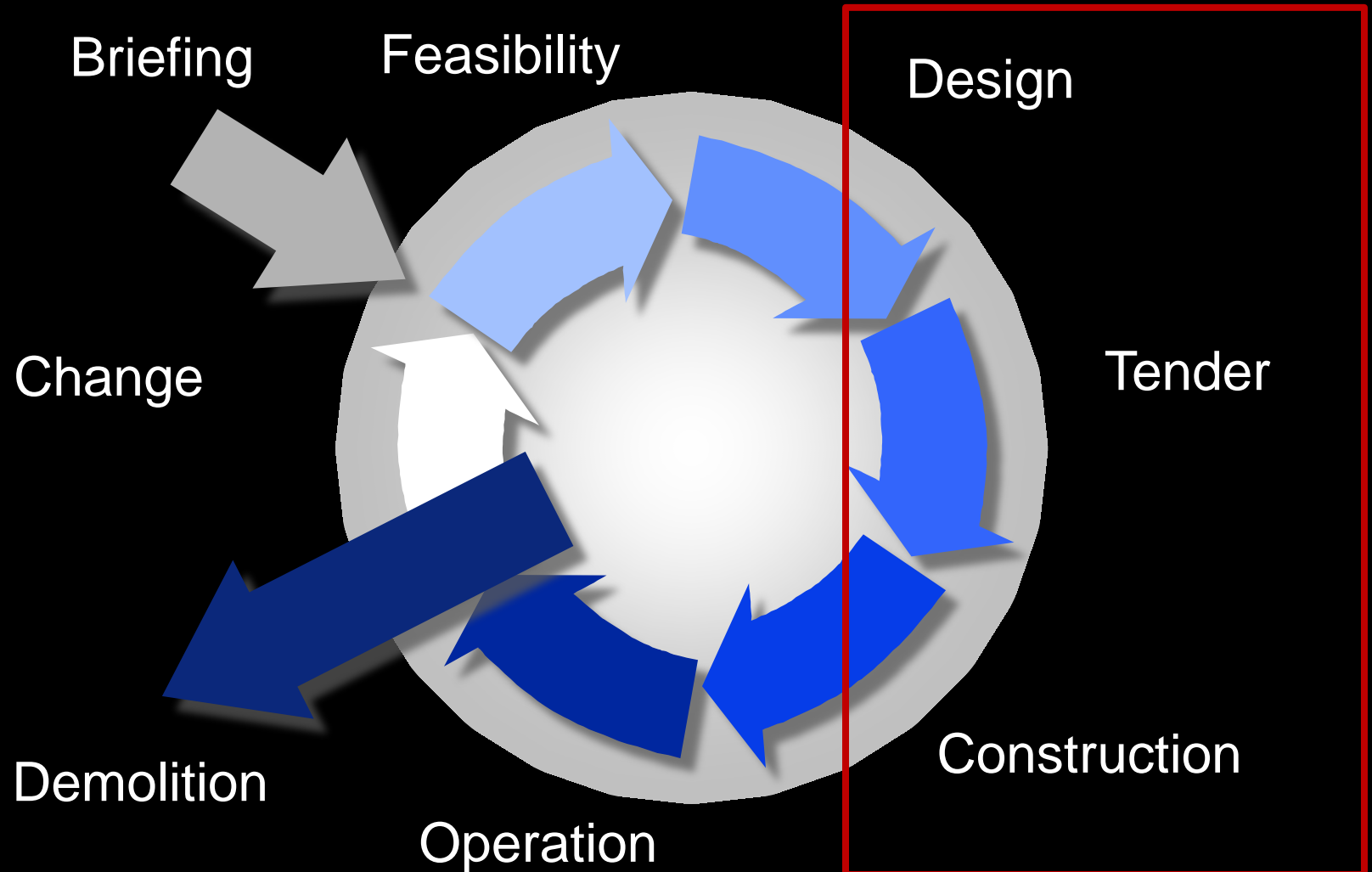


# The Business Cycle – Cost/Value Pyramid





# The Project Life-Cycle



Feasibility

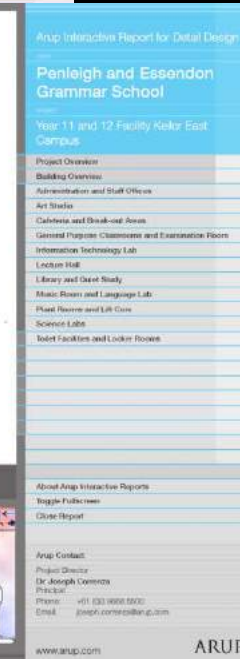
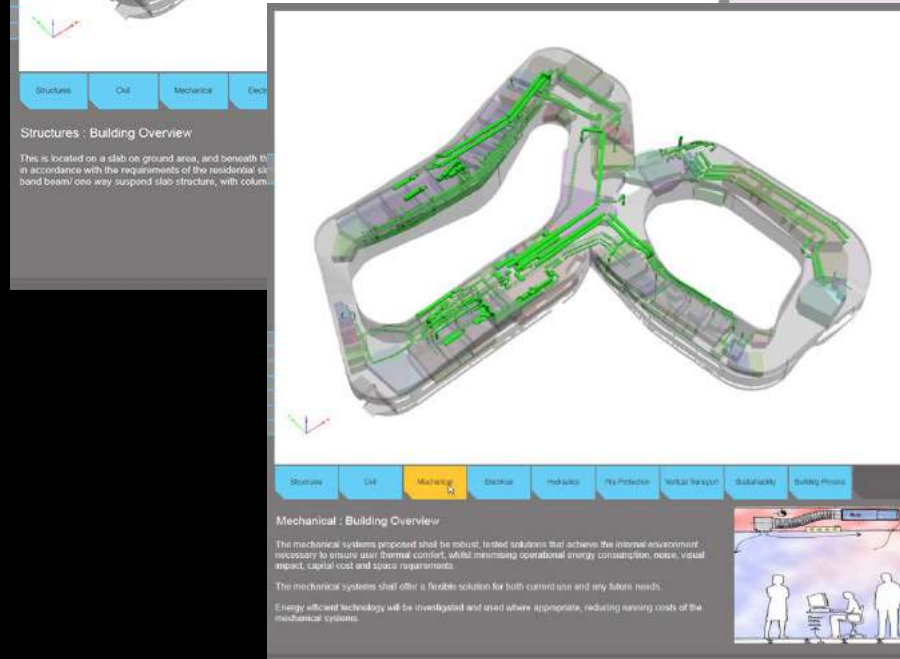
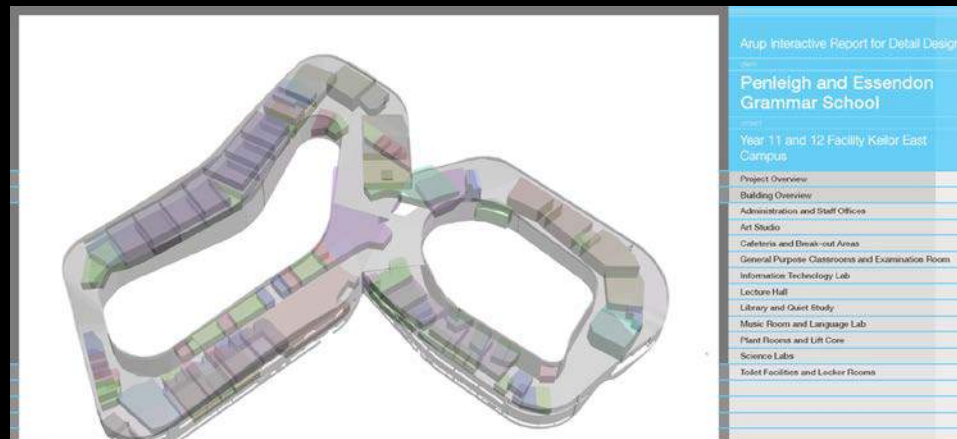
Pre-construction

Construction

Operation

Decommission

# Interactive O&M Manuals





Feasibility

Pre-construction

Construction

Operation

Decommission

## Energy Management/Tracking

## ELECTRICITY

TOTAL 340KWh

TODAY

LAST WEEK

LAST MONTH

LAST YEAR

LIGHTING

EQUIPMENT  
(COMPUTERS, PRINTERS, ETC.)

34KWh

51KWh

FOURTH FLOOR

26KWh

51KWh

THIRD FLOOR

59KWh

24KWh

SECOND FLOOR

57KWh

67KWh

FIRST FLOOR

48KWh

45KWh

GROUND FLOOR

24KWh

23KWh

BASEMENT

TOTAL PER PERSON  
BY FLOOR

ELECTRICITY

WATER

GAS

CO<sub>2</sub> EMISSIONS

10:45AM

GREEN BOOK