BIM & SIMULATION

Linking Building Design Performance and BIM

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RAEng Professor of Innovation – University of Salford

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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 you business processes to the limitations of the software?

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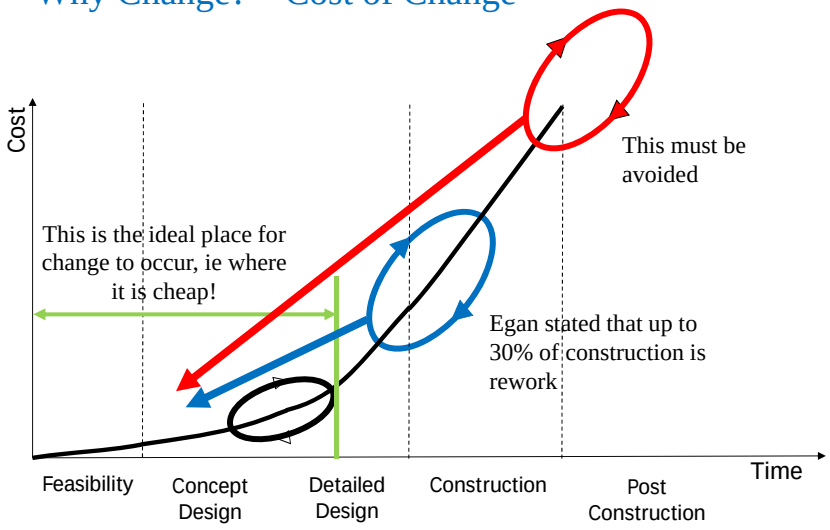
Why Change? – Cost of Change



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

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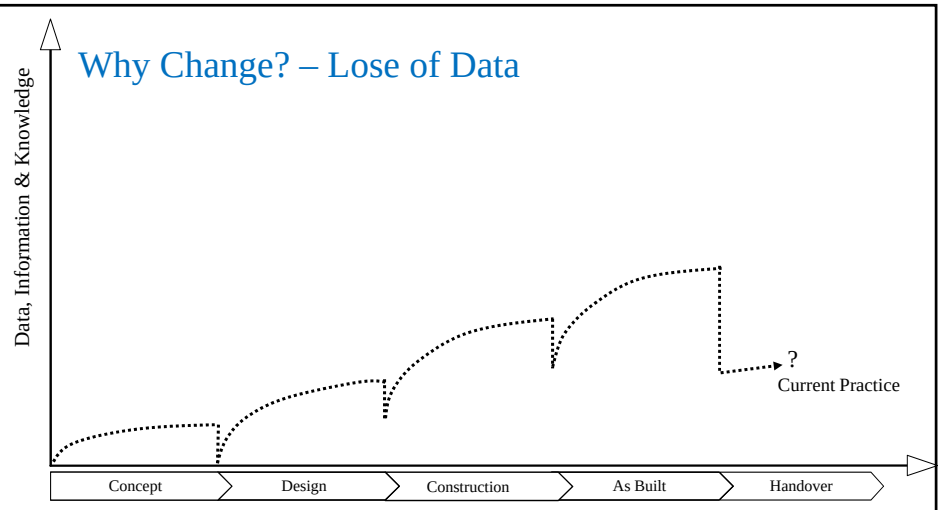
Why Change? – Lose of Data



Example

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!)

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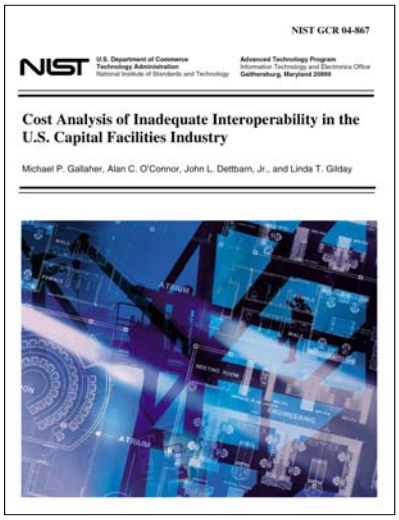
Why Change? – Duplication of work


NIST GCR 04-867

NIST U.S. Department of Commerce Technology Administration National Institute of Standards and Technology

Advanced Technology Program Information Technology and Electronics Office Gaithersburg, Maryland 20899

Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry

Michael P. Gallaher, Alan C. O'Connor, John L. Dettbarn, Jr., and Linda T. Gilday

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

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Because the government tells you to?

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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

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Defining BIM?

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

PAS 1192-2

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Defining BIM?

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

* Sharing Structured Information

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A 3D model that…

- Contains no object attributes
- Has no additional information
- Is composed of only 2D CAD references
- Is not geometrically accurate
  Cannot be shared
  or requires another party to duplicate information or processes
- and allows you to cheat

...Is not BIM!

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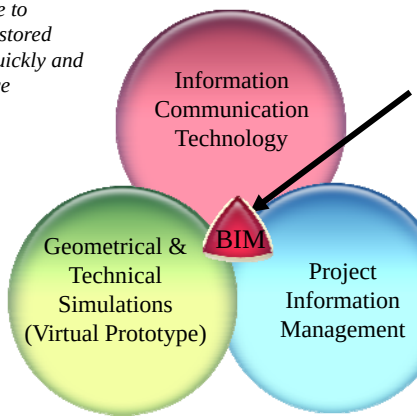
BIM is....

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



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

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What are we doing really well?

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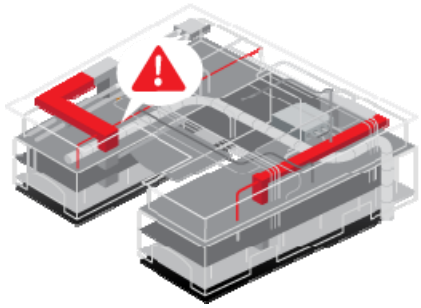
Co-ordination



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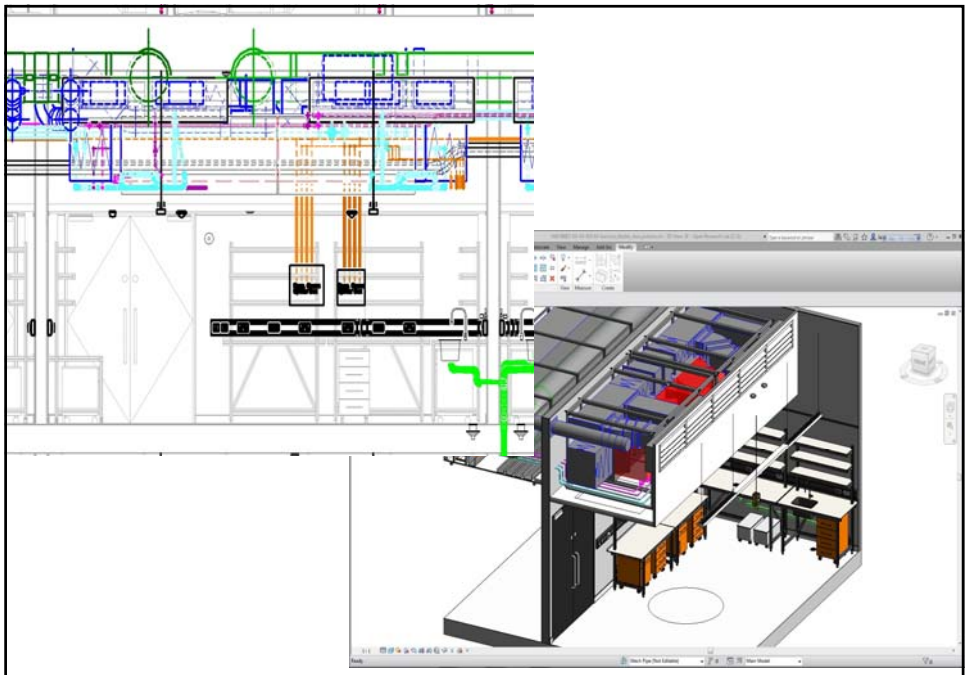

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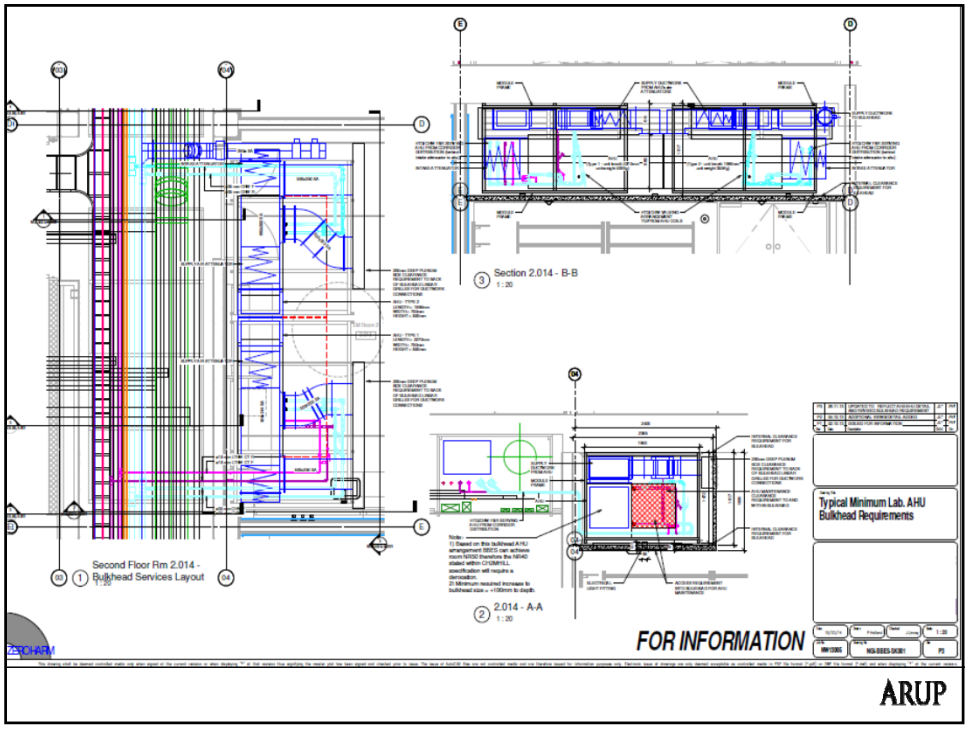
Section 2.014 - B-B
1 : 20
Second Floor Rm 2.014 - Bulkhead Services Layout
1 : 20
2.014 - A-A
1 : 20
Typical Minimum Lab. AHU Bulkhead Requirements
FOR INFORMATION
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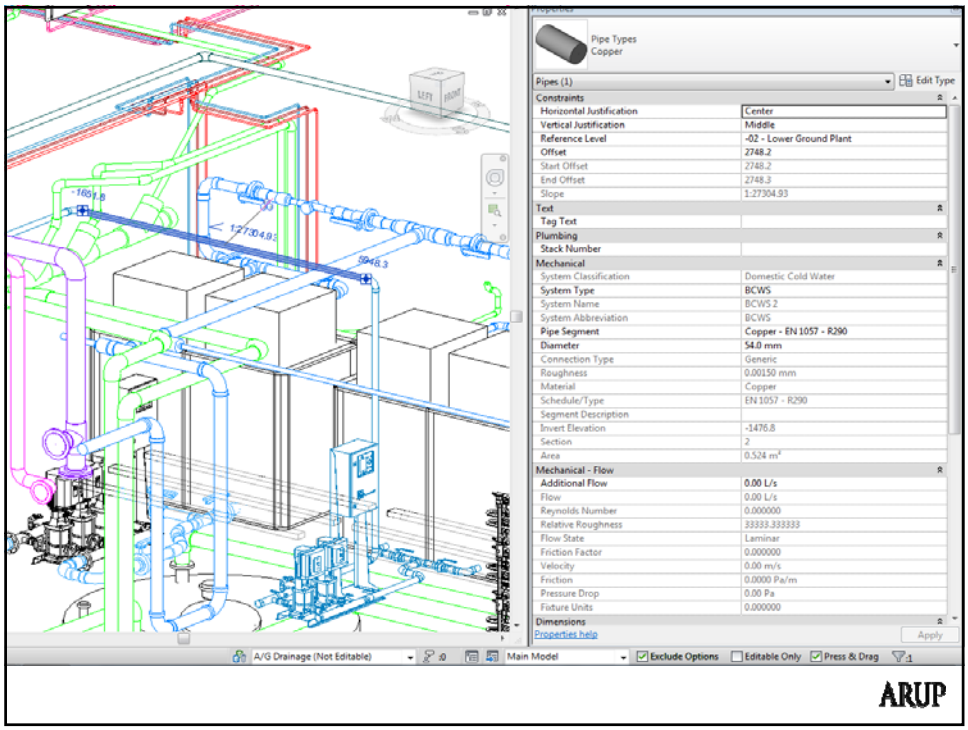
Pipe Types
Copper
Pipes (1)
Edit Type
Constraints
Horizontal Justification Center
Vertical Justification Middle
Reference Level -02 - Lower Ground Plant
Offset 2748.2
Start Offset 2748.2
End Offset 2748.3
Slope 1:27304.93
Text
Tag Text
Plumbing
Stack Number
Mechanical
System Classification Domestic Cold Water
System Type BCWS
System Name BCWS 2
System Abbreviation BCWS
Pipe Segment Copper - EN 1057 - R290
Diameter 54.0 mm
Connection Type Generic
Roughness 0.00150 mm
Material Copper
Schedule/Type EN 1057 - R290
Segment Description
Invert Elevation -1476.8
Section 2
Area 0.524 m²
Mechanical - Flow
Additional Flow 0.00 L/s
Flow 0.00 L/s
Reynolds Number 0.000000
Relative Roughness 33333.333333
Flow State Laminar
Friction Factor 0.000000
Velocity 0.00 m/s
Friction 0.0000 Pa/m
Pressure Drop 0.00 Pa
Fixture Units 0.000000
Dimensions
Properties help
Apply
A/G Drainage (Not Editable)
Main Model
Exclude Options
Editable Only
Press & Drag
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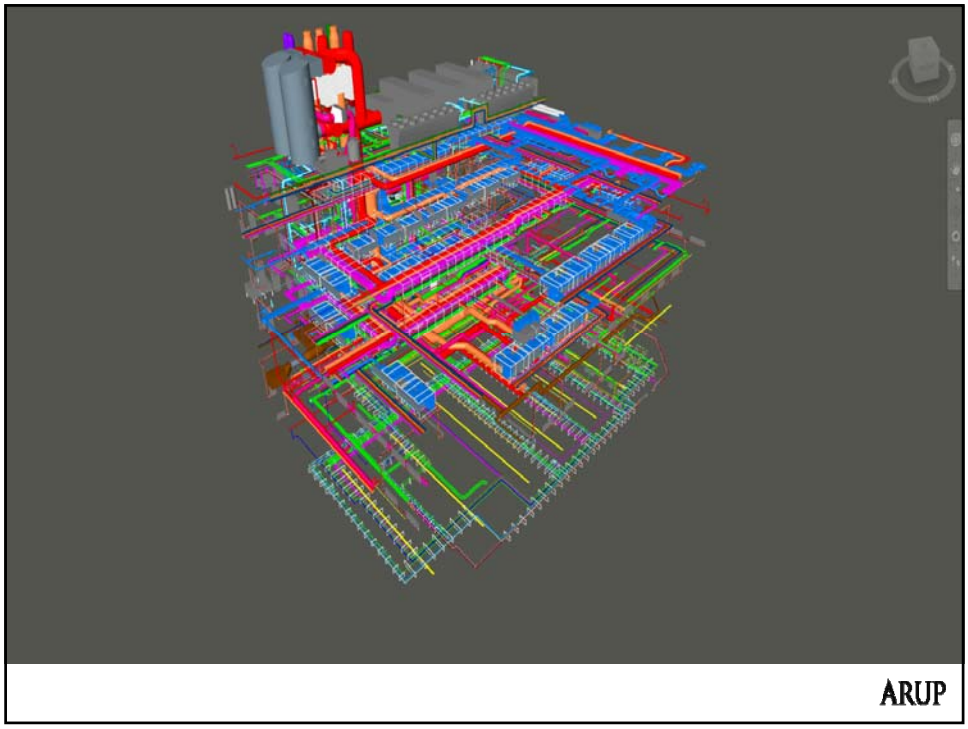
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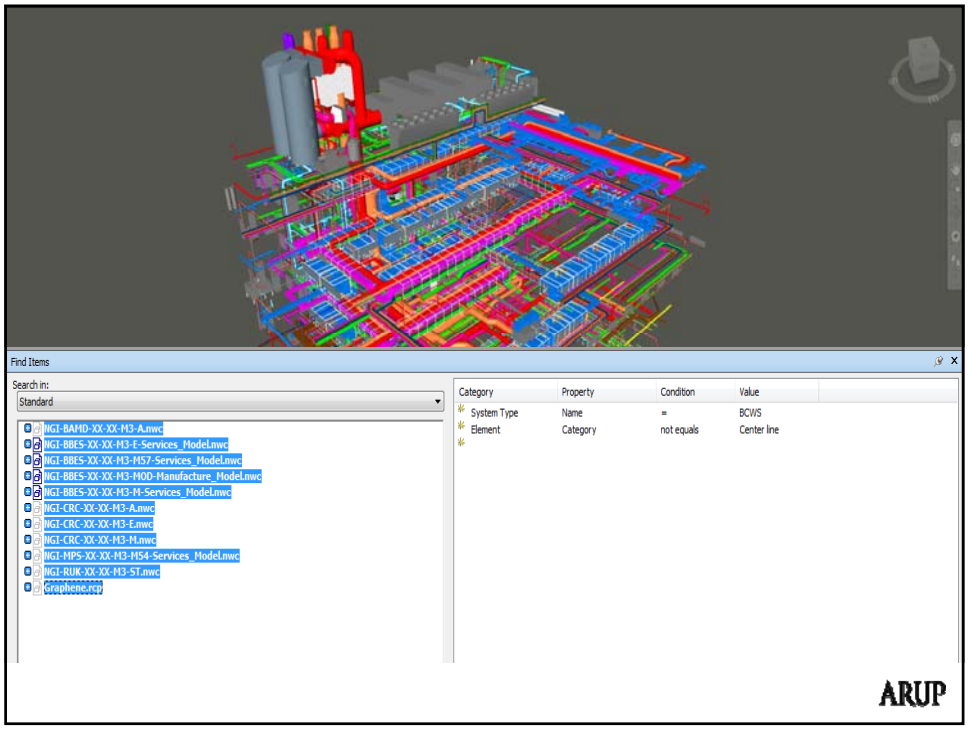
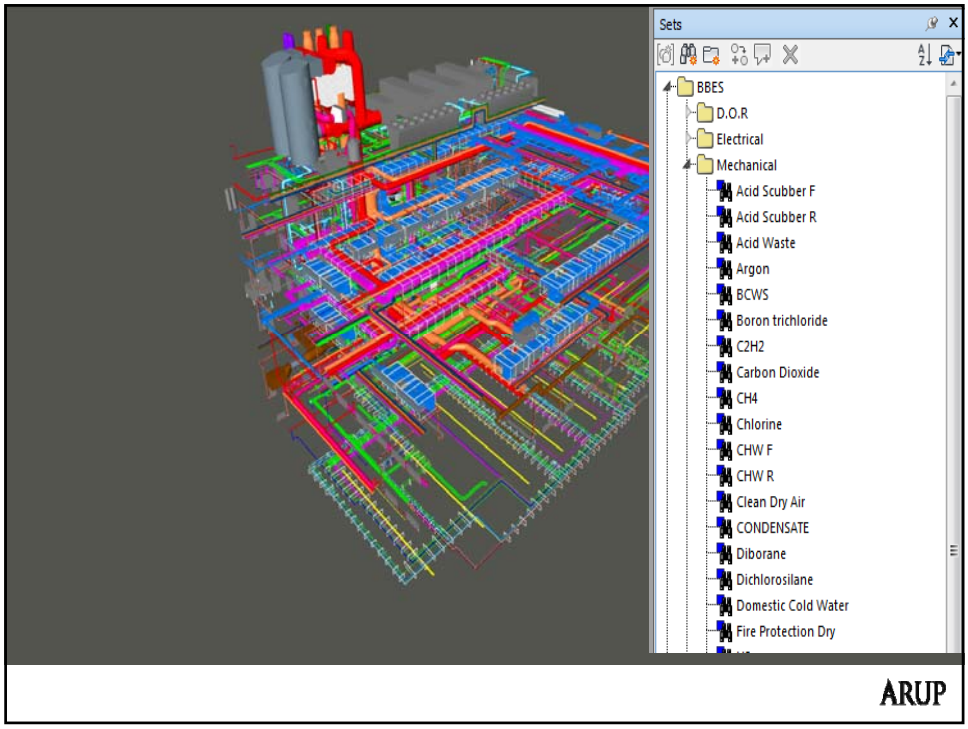
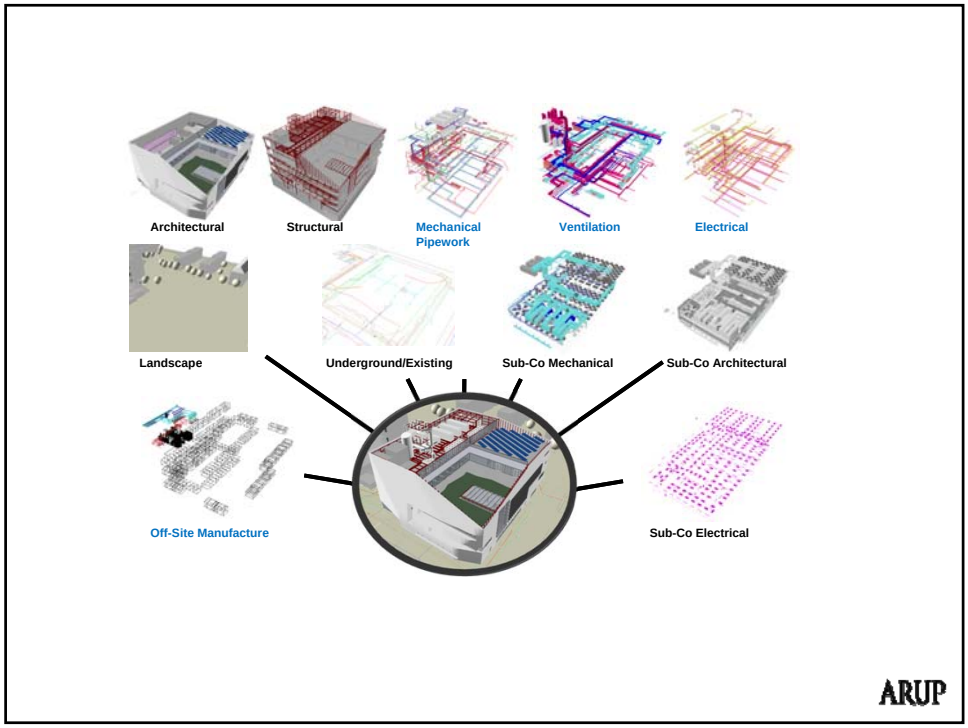

Find Items
Search in:
Standard
NGI-BAMD-XX-XX-M3-A.nwc
NGI-BBES-XX-XX-M3-E-Services_Model.nwc
NGI-BBES-XX-XX-M3-MS7-Services_Model.nwc
NGI-BBES-XX-XX-M3-MOD-Manufacture_Model.nwc
NGI-BBES-XX-XX-M3-M-Services_Model.nwc
NGI-CRC-XX-XX-M3-A.nwc
NGI-CRC-XX-XX-M3-E.nwc
NGI-CRC-XX-XX-M3-M.nwc
NGI-MPS-XX-XX-M3-MS4-Services_Model.nwc
NGI-RUK-XX-XX-M3-ST.nwc
Graphene.rcp
Category
Property
Condition
Value
System Type
Name
=
BCWS
Element
Category
not equals
Center line
ARUP


Sets
BBES
D.O.R
Electrical
Mechanical
Acid Scubber F
Acid Scubber R
Acid Waste
Argon
BCWS
Boron trichloride
C2H2
Carbon Dioxide
CH4
Chlorine
CHW F
CHW R
Clean Dry Air
CONDENSATE
Diborane
Dichlorosilane
Domestic Cold Water
Fire Protection Dry
ARUP


Architectural
Structural
Mechanical Pipework
Ventilation
Electrical
Landscape
Underground/Existing
Sub-Co Mechanical
Sub-Co Architectural
Off-Site Manufacture
Sub-Co Electrical
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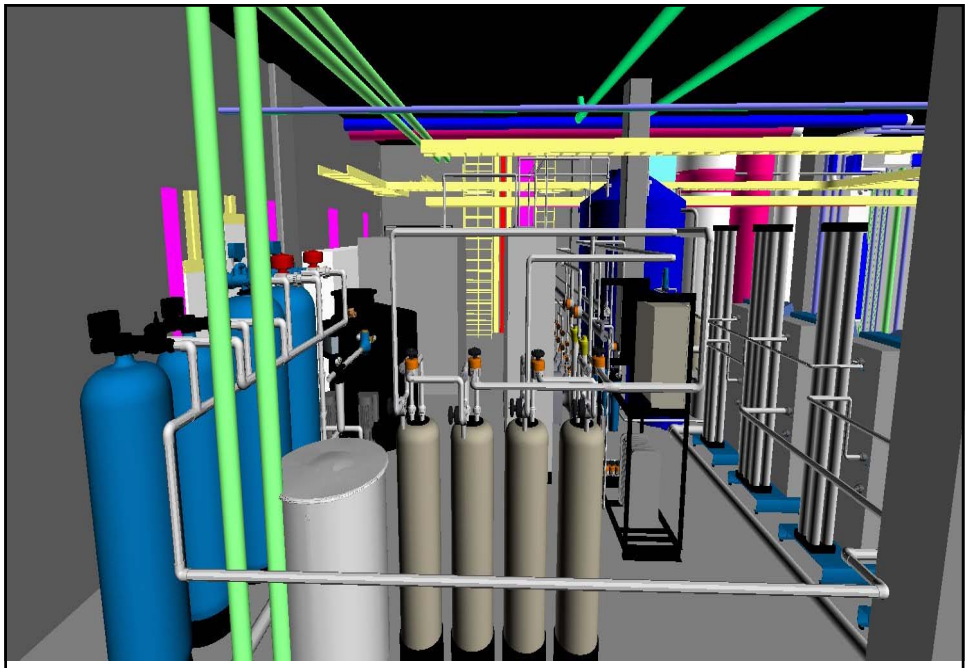

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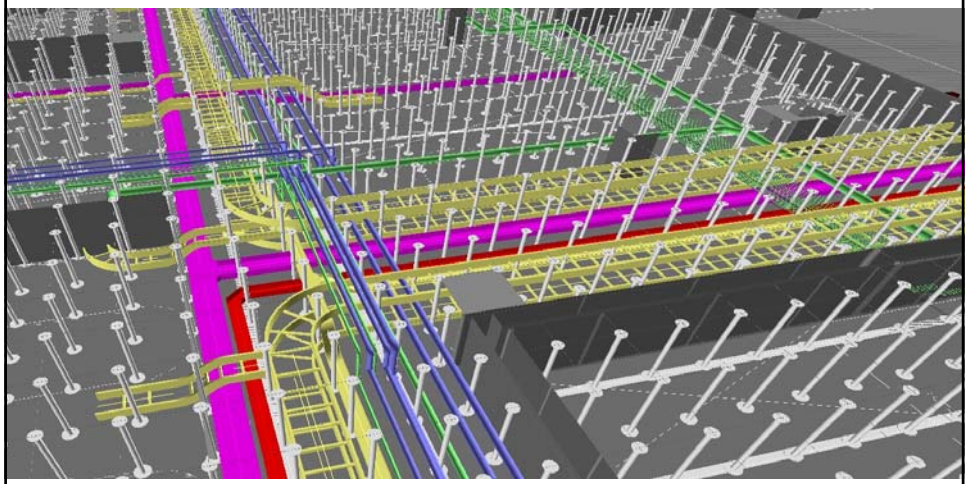

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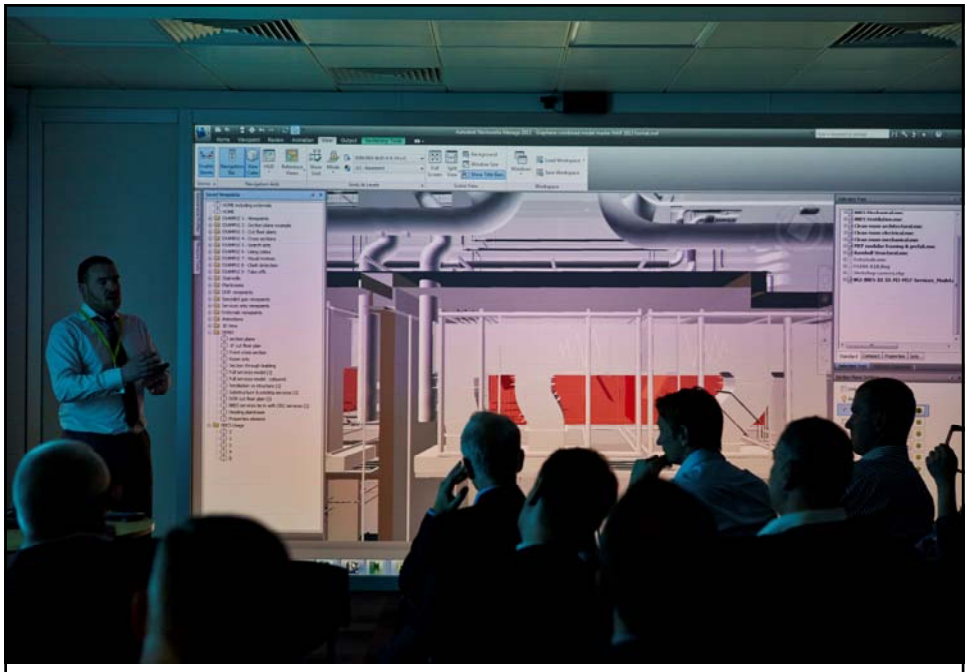

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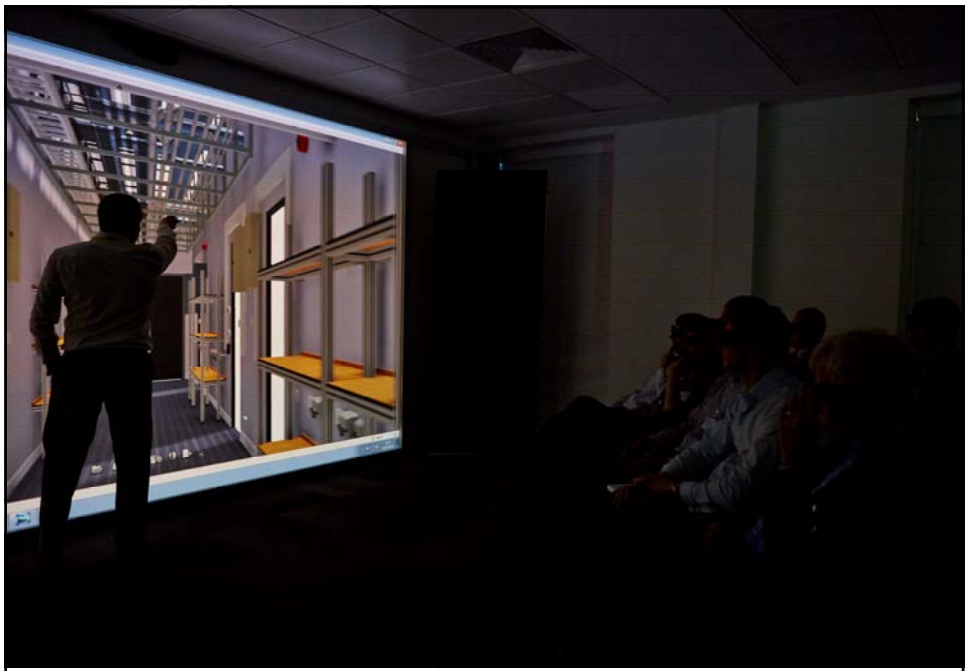

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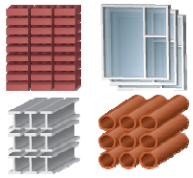
Quantification



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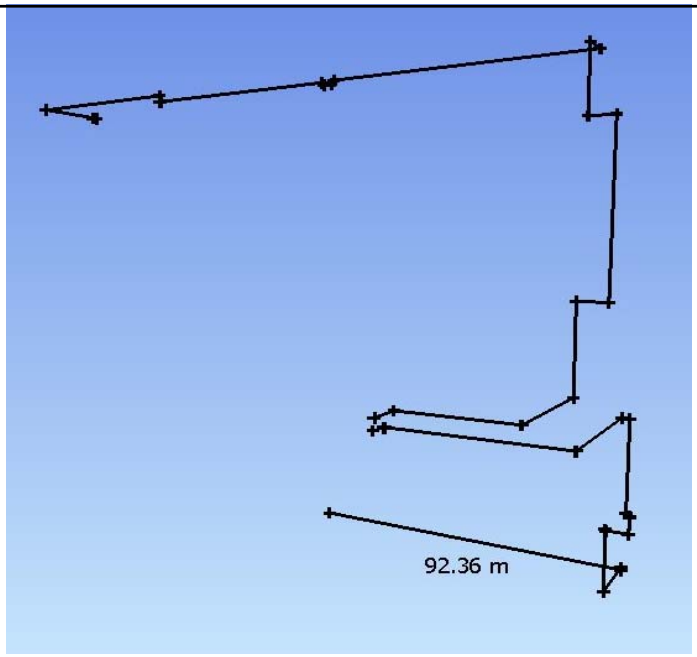

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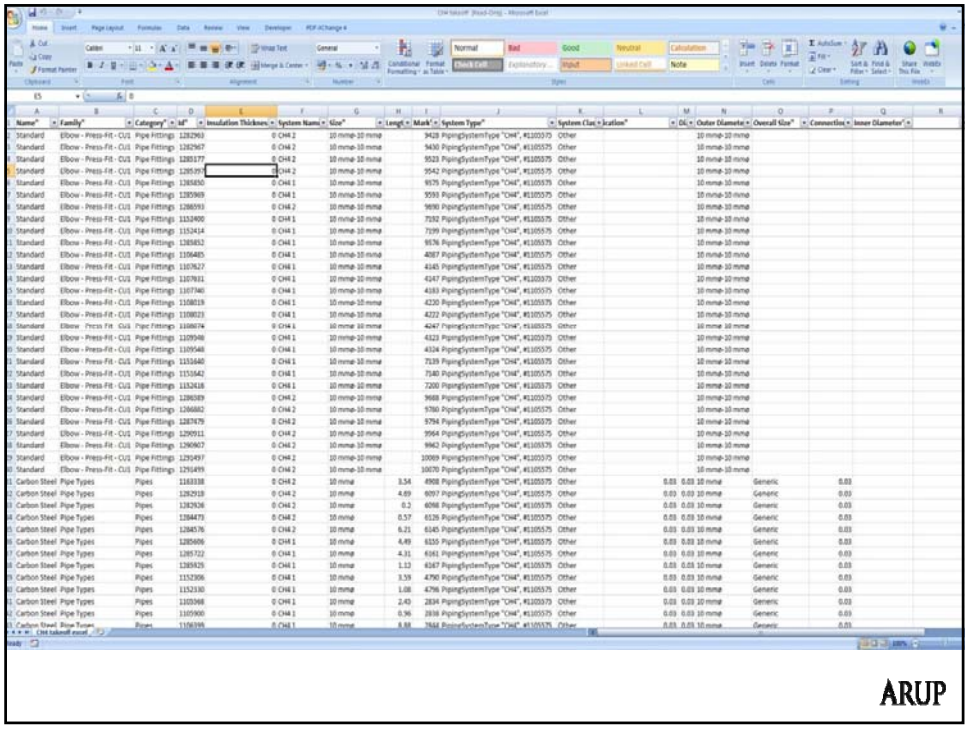

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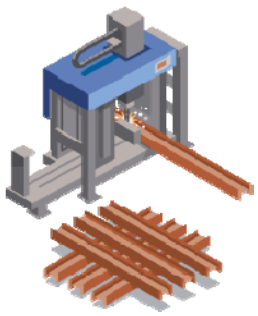
Fabrication



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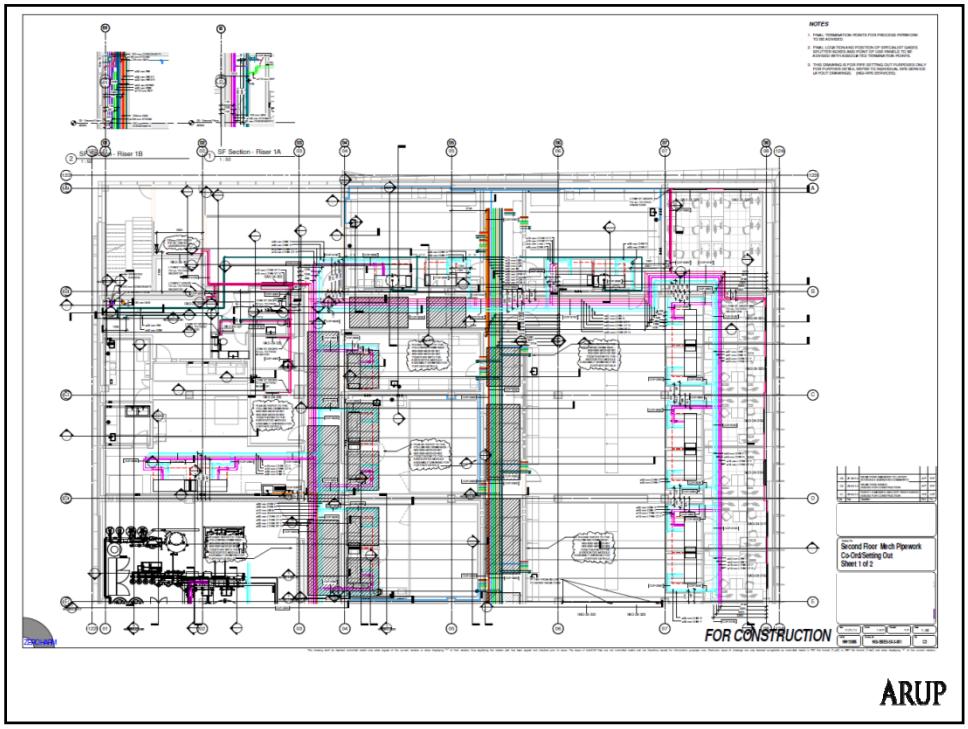
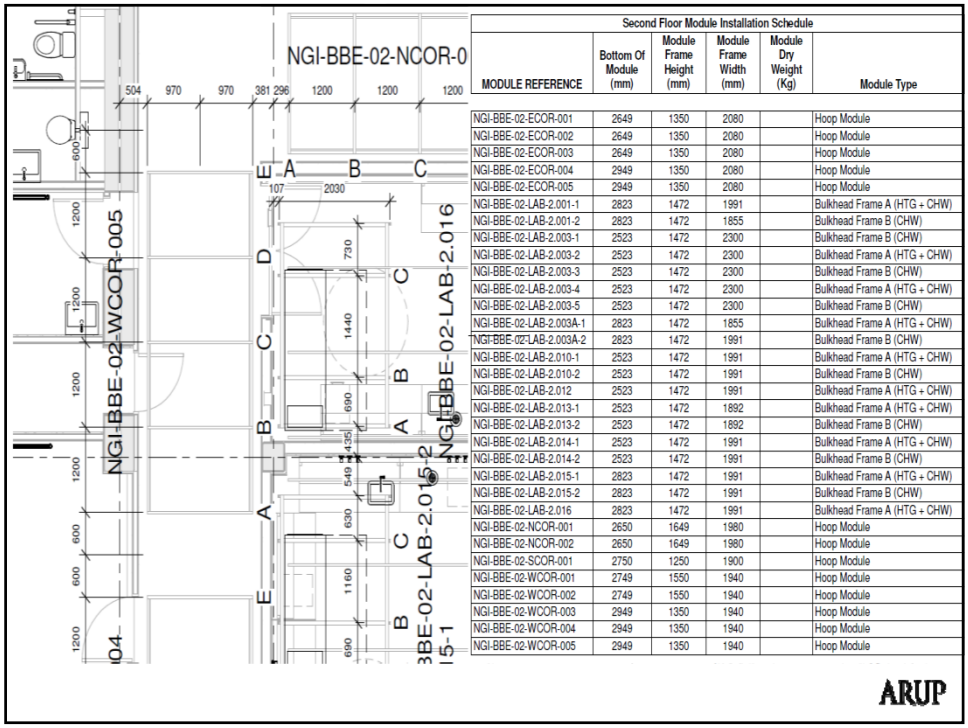
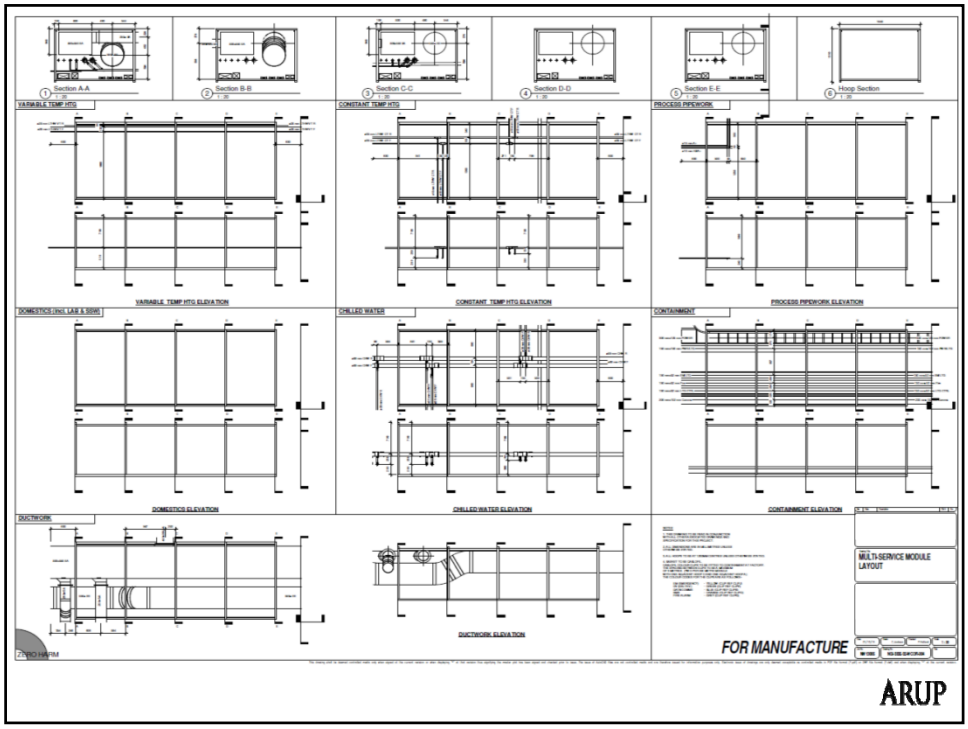
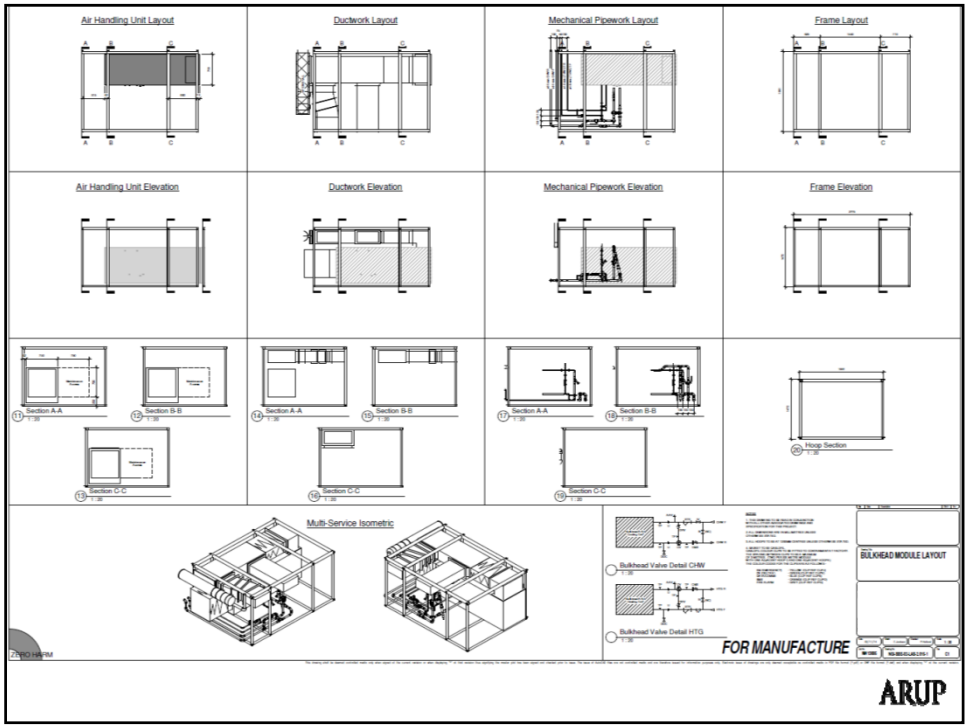


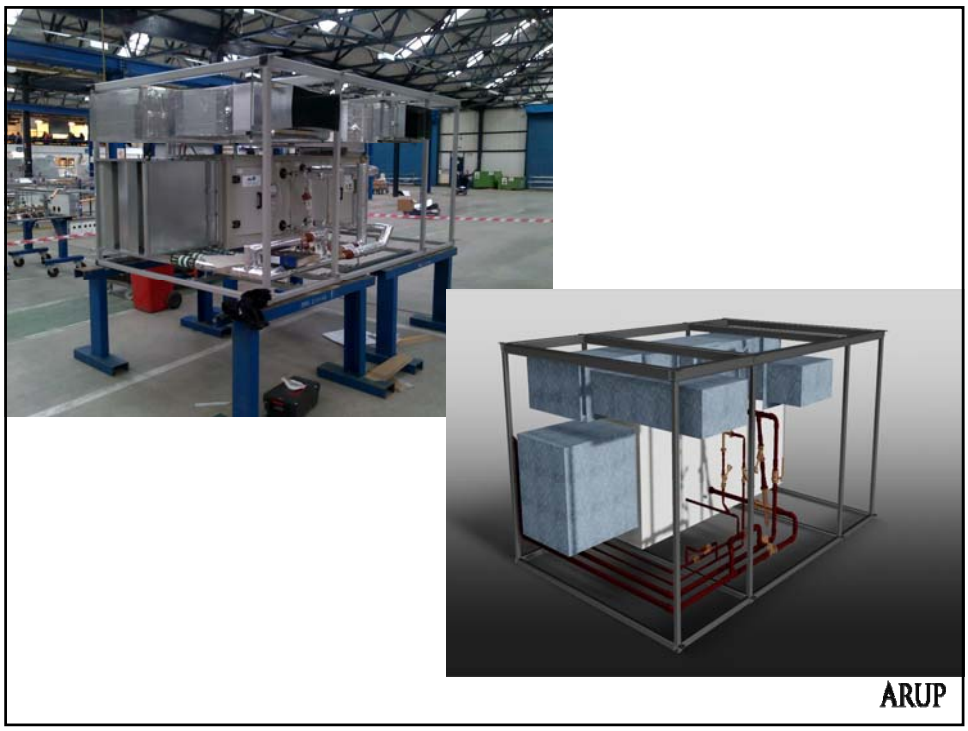


Second Floor Module Installation Schedule

MODULE REFERENCE	Bottom Of Module (mm)	Module Frame Height (mm)	Module Frame Width (mm)	Module Dry Weight (Kg)	Module Type
NGI-BBE-02-ECOR-001	2649	1350	2080		Hoop Module
NGI-BBE-02-ECOR-002	2649	1350	2080		Hoop Module
NGI-BBE-02-ECOR-003	2649	1350	2080		Hoop Module
NGI-BBE-02-ECOR-004	2949	1350	2080		Hoop Module
NGI-BBE-02-ECOR-005	2949	1350	2080		Hoop Module
NGI-BBE-02-LAB-2.001-1	2823	1472	1991		Bulkhead Frame A (HTG + CHW)
NGI-BBE-02-LAB-2.001-2	2823	1472	1855		Bulkhead Frame B (CHW)
NGI-BBE-02-LAB-2.003-1	2523	1472	2300		Bulkhead Frame B (CHW)
NGI-BBE-02-LAB-2.003-2	2523	1472	2300		Bulkhead Frame A (HTG + CHW)
NGI-BBE-02-LAB-2.003-3	2523	1472	2300		Bulkhead Frame B (CHW)
NGI-BBE-02-LAB-2.003-4	2523	1472	2300		Bulkhead Frame A (HTG + CHW)
NGI-BBE-02-LAB-2.003-5	2523	1472	2300		Bulkhead Frame B (CHW)
NGI-BBE-02-LAB-2.003A-1	2823	1472	1855		Bulkhead Frame A (HTG + CHW)
NGI-BBE-02-LAB-2.003A-2	2823	1472	1991		Bulkhead Frame B (CHW)
NGI-BBE-02-LAB-2.010-1	2523	1472	1991		Bulkhead Frame A (HTG + CHW)
NGI-BBE-02-LAB-2.010-2	2523	1472	1991		Bulkhead Frame B (CHW)
NGI-BBE-02-LAB-2.012	2523	1472	1991		Bulkhead Frame A (HTG + CHW)
NGI-BBE-02-LAB-2.013-1	2523	1472	1892		Bulkhead Frame A (HTG + CHW)
NGI-BBE-02-LAB-2.013-2	2523	1472	1892		Bulkhead Frame B (CHW)
NGI-BBE-02-LAB-2.014-1	2523	1472	1991		Bulkhead Frame A (HTG + CHW)
NGI-BBE-02-LAB-2.014-2	2523	1472	1991		Bulkhead Frame B (CHW)
NGI-BBE-02-LAB-2.015-1	2823	1472	1991		Bulkhead Frame A (HTG + CHW)
NGI-BBE-02-LAB-2.015-2	2823	1472	1991		Bulkhead Frame B (CHW)
NGI-BBE-02-LAB-2.016	2823	1472	1991		Bulkhead Frame A (HTG + CHW)
NGI-BBE-02-NCOR-001	2650	1649	1980		Hoop Module
NGI-BBE-02-NCOR-002	2650	1649	1980		Hoop Module
NGI-BBE-02-SCOR-001	2750	1250	1900		Hoop Module
NGI-BBE-02-WCOR-001	2749	1550	1940		Hoop Module
NGI-BBE-02-WCOR-002	2749	1550	1940		Hoop Module
NGI-BBE-02-WCOR-003	2949	1350	1940		Hoop Module
NGI-BBE-02-WCOR-004	2949	1350	1940		Hoop Module
NGI-BBE-02-WCOR-005	2949	1350	1940		Hoop Module


Section A-A
Section B-B
Section C-C
Section D-D
Section E-E
Hoop Section
VARIABLE TEMP HTG
CONSTANT TEMP HTG
PROCESS PIPEWORK
VARIABLE TEMP HTG ELEVATION
CONSTANT TEMP HTG ELEVATION
PROCESS PIPEWORK ELEVATION
DOMESTICS (Incl. LAB & SSW)
CHILLED WATER
CONTAINMENT
DOMESTICS ELEVATION
CHILLED WATER ELEVATION
CONTAINMENT ELEVATION
DUCTWORK
DUCTWORK ELEVATION
MULTI-SERVICE MODULE LAYOUT
FOR MANUFACTURE
ZERO HARM
ARUP


Air Handling Unit Layout
Ductwork Layout
Mechanical Pipework Layout
Frame Layout
Air Handling Unit Elevation
Ductwork Elevation
Mechanical Pipework Elevation
Frame Elevation
Section A-A
Section B-B
Section C-C
Hoop Section
Multi-Service Isometric
Bulkhead Valve Detail CHW
Bulkhead Valve Detail HTG
BULKHEAD MODULE LAYOUT
FOR MANUFACTURE
ZERO HARM
ARUP



Where are we going?

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https://www.youtube.com/watch?v=wjYszL9mDXc

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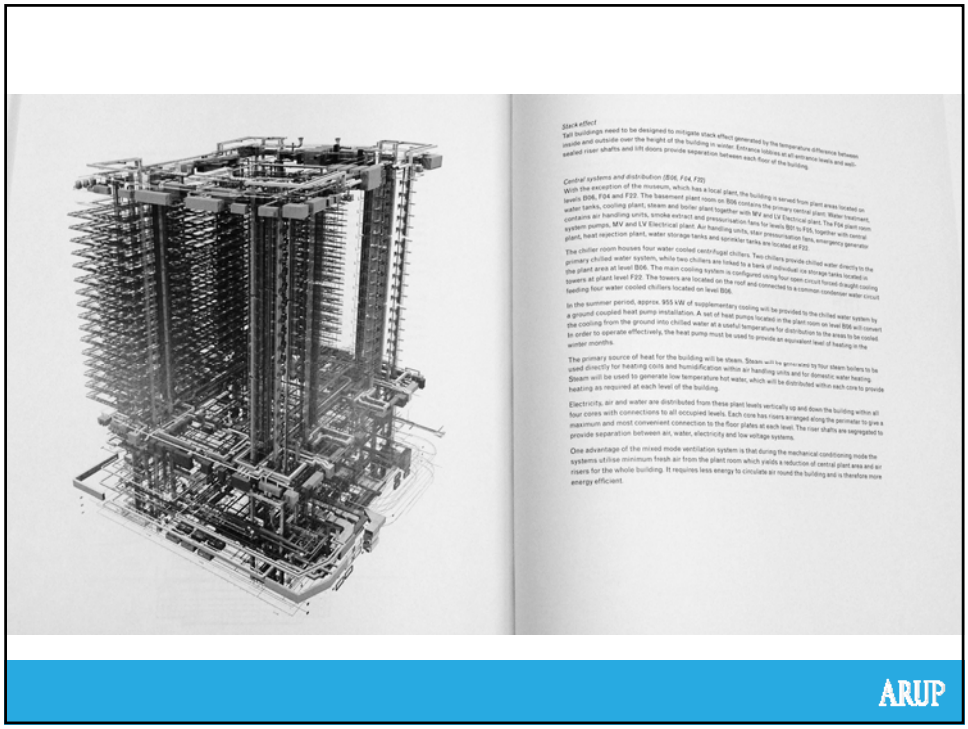
Stack effect
Tall buildings need to be designed to mitigate stack effect generated by the temperature difference between inside and outside over the height of the building in winter. Entrance lobbies at all entrance levels and well-sealed riser shafts and lift doors provide separation between each floor of the building.
Central systems and distribution (B06, F04, F22)
With the exception of the museum, which has a local plant, the building is served from plant areas located on levels B06, F04 and F22. The basement plant room on B06 contains the primary central plant. Water treatment, water tanks, cooling plant, steam and boiler plant together with MV and LV Electrical plant. The F04 plant room contains air handling units, smoke extract and pressurisation fans for levels B01 to F05, together with central system pumps, MV and LV Electrical plant. Air handling units, stair pressurisation fans, emergency generator plant, heat rejection plant, water storage tanks and sprinkler tanks are located at F22.
The chiller room houses four water cooled centrifugal chillers. Two chillers provide chilled water directly to the primary chilled water system, while two chillers are linked to a tank of individual ice storage tanks located in the plant area at level B06. The main cooling system is configured using four open circuit forced draught cooling towers at plant level F22. The towers are located on the roof and connected to a common condenser water circuit feeding four water cooled chillers located on level B06.
In the summer period, approx. 955 kW of supplementary cooling will be provided to the chilled water system by a ground coupled heat pump installation. A set of heat pumps located in the plant room on level B06 will convert the cooling from the ground into chilled water at a useful temperature for distribution to the areas to be cooled. In order to operate effectively, the heat pump must be used to provide an equivalent level of heating in the winter months.
The primary source of heat for the building will be steam. Steam will be generated by four steam boilers to be used directly for heating coils and humidification within air handling units and for domestic water heating. Steam will be used to generate low temperature hot water, which will be distributed within each core to provide heating as required at each level of the building.
Electricity, air and water are distributed from these plant levels vertically up and down the building within all four cores with connections to all occupied levels. Each core has risers arranged along the perimeter to give a maximum and most convenient connection to the floor plates at each level. The riser shafts are segregated to provide separation between air, water, electricity and low voltage systems.
One advantage of the mixed mode ventilation system is that during the mechanical conditioning mode the systems utilise minimum fresh air from the plant room which yields a reduction of central plant area and air risers for the whole building. It requires less energy to circulate air round the building and is therefore more energy efficient.
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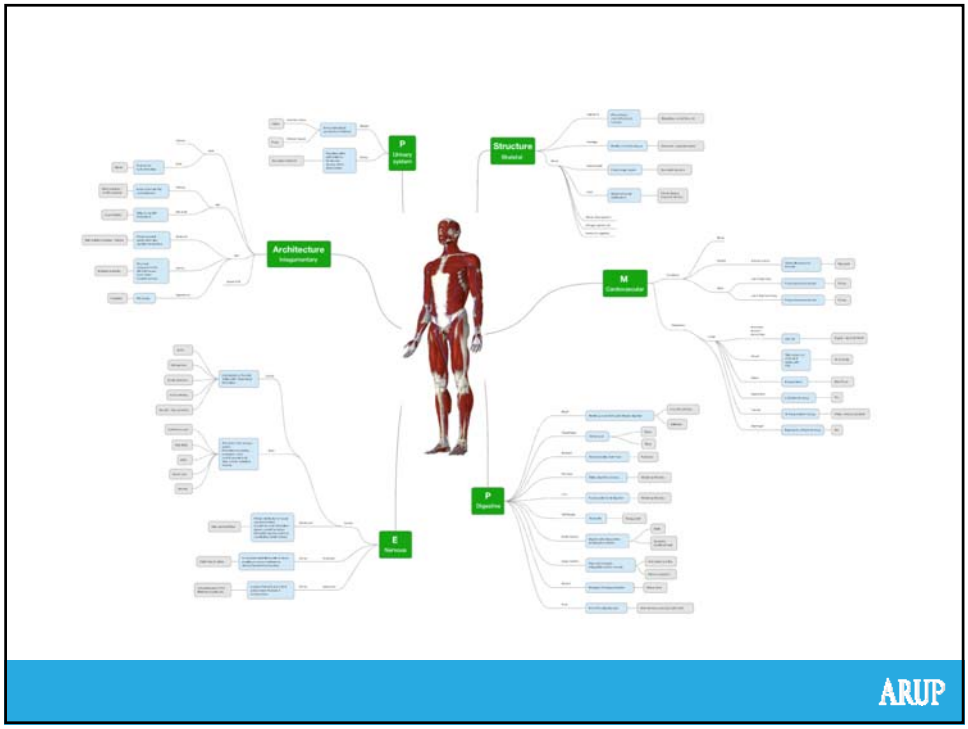
Architecture
Structure
M
P
E
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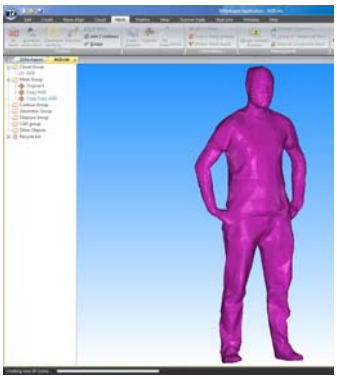

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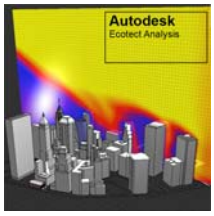
Virtually Human



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Site location

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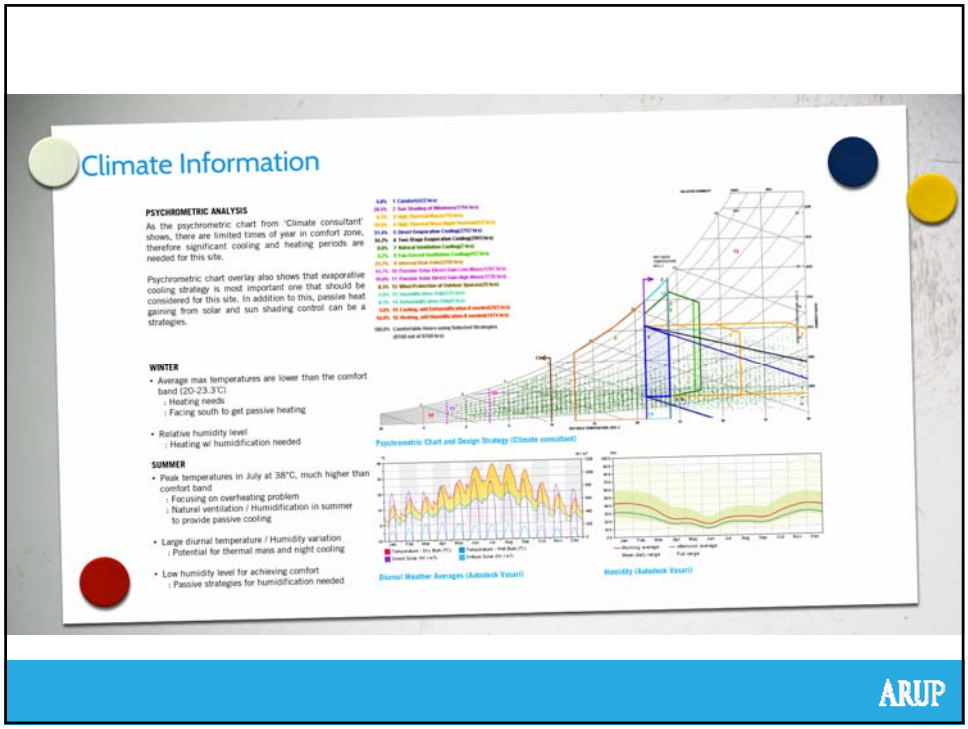
Climate Information
PSYCHROMETRIC ANALYSIS
As the psychrometric chart from 'Climate consultant' shows, there are limited times of year in comfort zone, therefore significant cooling and heating periods are needed for this site.
Psychrometric chart overlay also shows that evaporative cooling strategy is most important one that should be considered for this site. In addition to this, passive heat gaining from solar and sun shading control can be a strategies.
WINTER
• Average max temperatures are lower than the comfort band (20-23.3'C)
: Heating needs
: Facing south to get passive heating
• Relative humidity level
: Heating w/ humidification needed
SUMMER
• Peak temperatures in July at 38°C, much higher than comfort band
: Focusing on overheating problem
: Natural ventilation / Humidification in summer to provide passive cooling
• Large diurnal temperature / Humidity variation
: Potential for thermal mass and night cooling
• Low humidity level for achieving comfort
: Passive strategies for humidification needed
Psychrometric Chart and Design Strategy (Climate consultant)
Diurnal Weather Averages (Autodesk Vasari)
Humidity (Autodesk Vasari)
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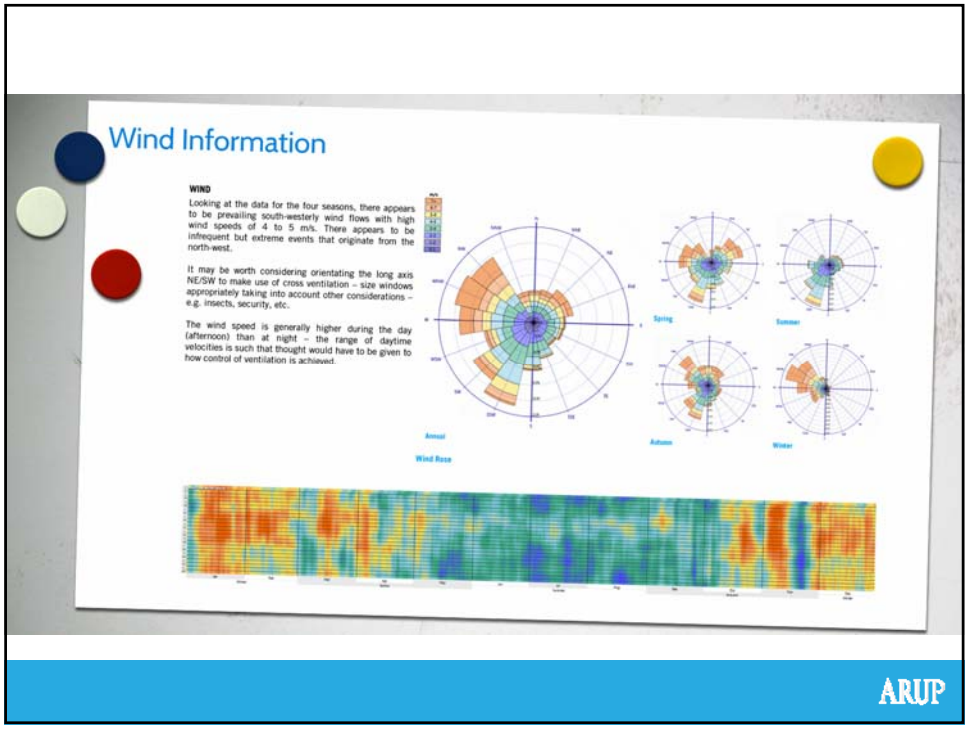
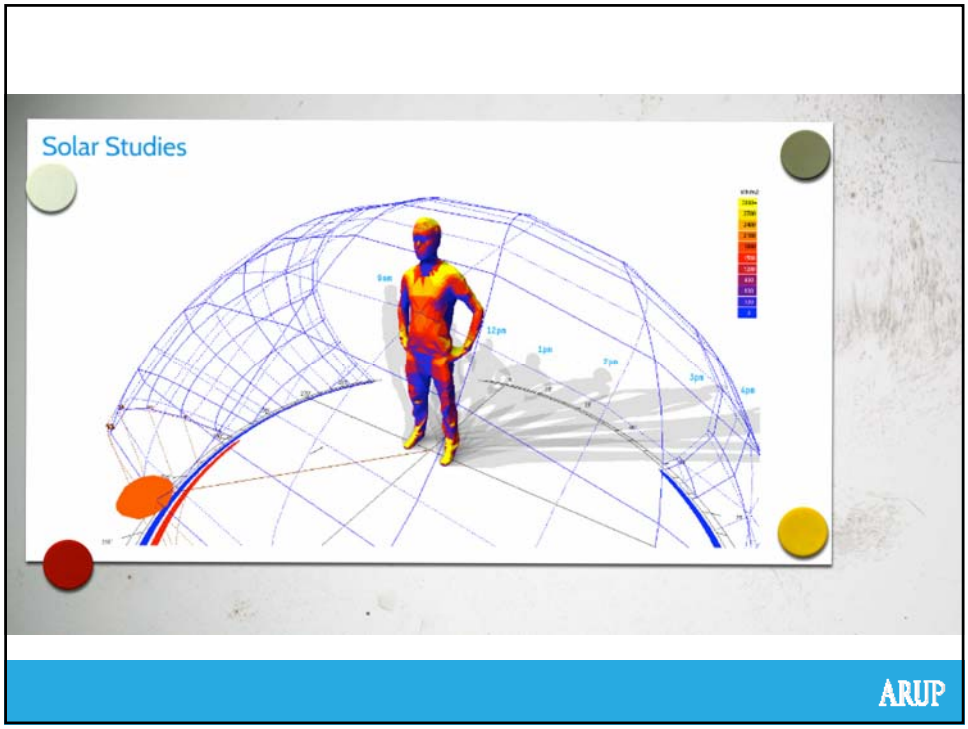
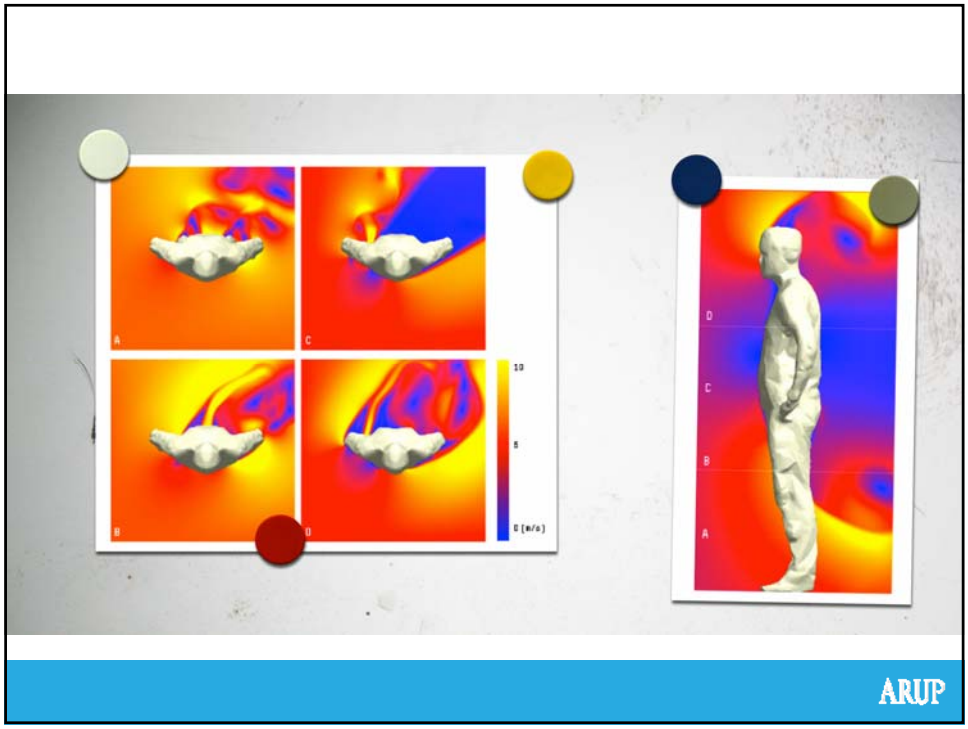
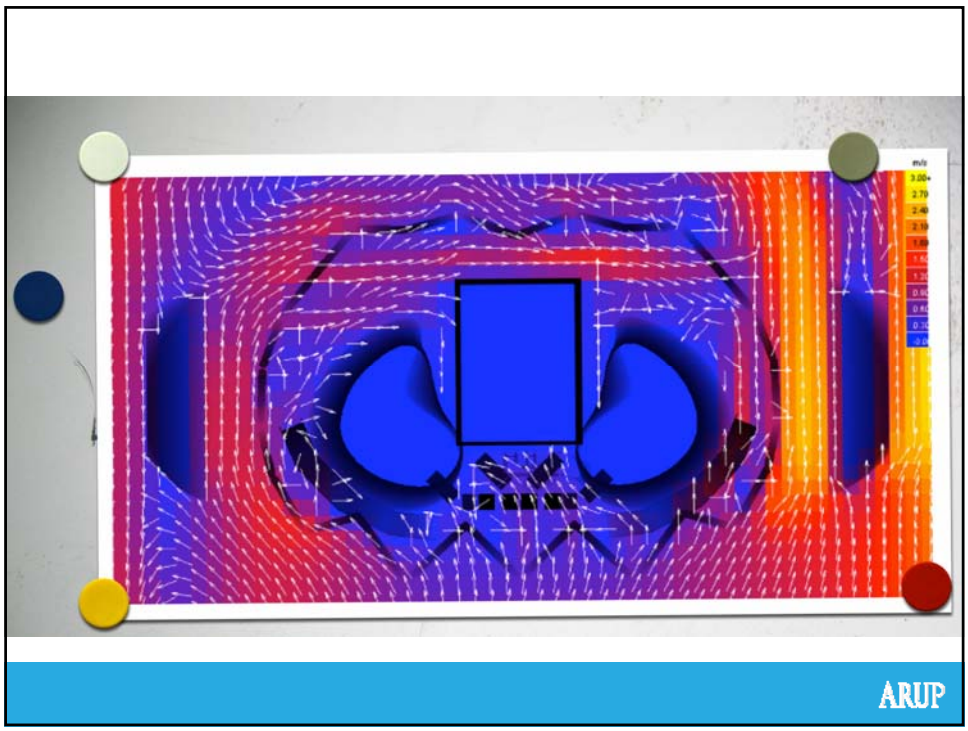
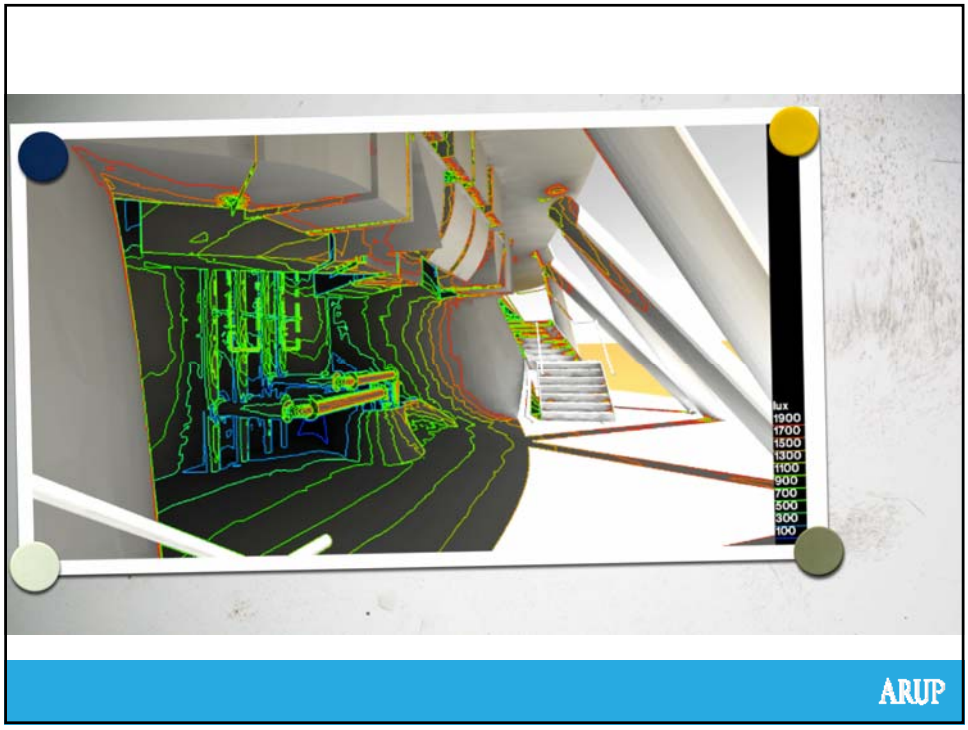

Wind Information
WIND
Looking at the data for the four seasons, there appears to be prevailing south-westerly wind flows with high wind speeds of 4 to 5 m/s. There appears to be infrequent but extreme events that originate from the north-west.
It may be worth considering orientating the long axis NE/SW to make use of cross ventilation – size windows appropriately taking into account other considerations – e.g. insects, security, etc.
The wind speed is generally higher during the day (afternoon) than at night – the range of daytime velocities is such that thought would have to be given to how control of ventilation is achieved.
Annual
Spring
Summer
Autumn
Winter
Wind Rose
ARUP


Solar Studies
ARUP


ARUP


ARUP


lux
1900
1700
1500
1300
1100
900
700
500
300
100
ARUP

Mass model into Revit

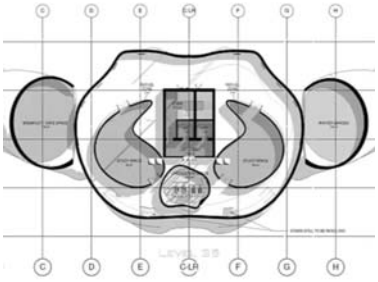
Modelling Using Rhino & Importing

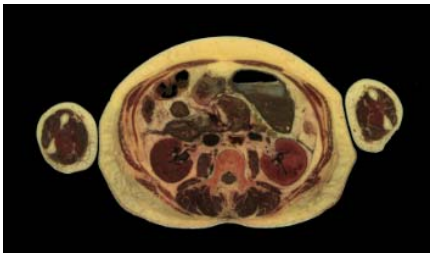
- Much Quicker
- Highly accurate
- Consistent
- Bi-directional

- Mass model used for Rule-of-thumb plant sizing

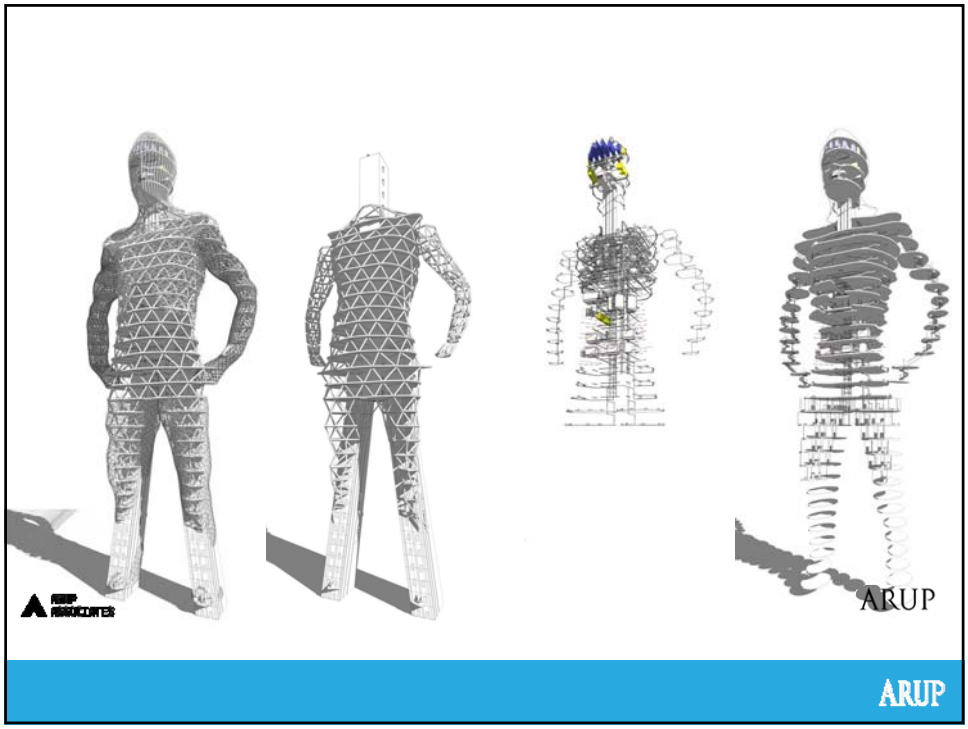
ARUP

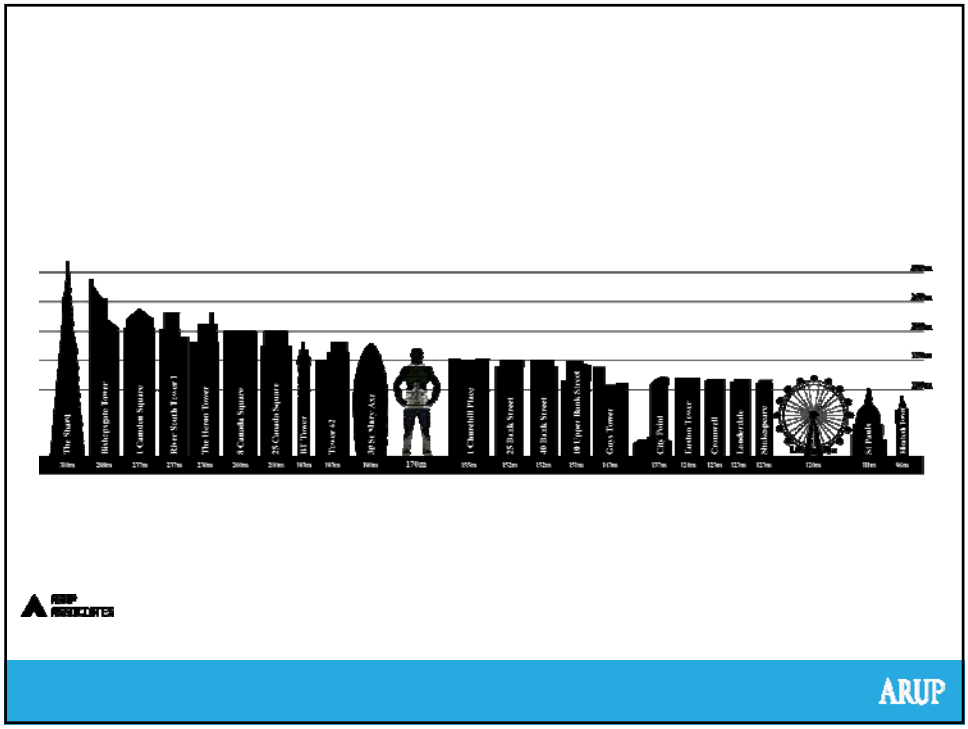
ARUP





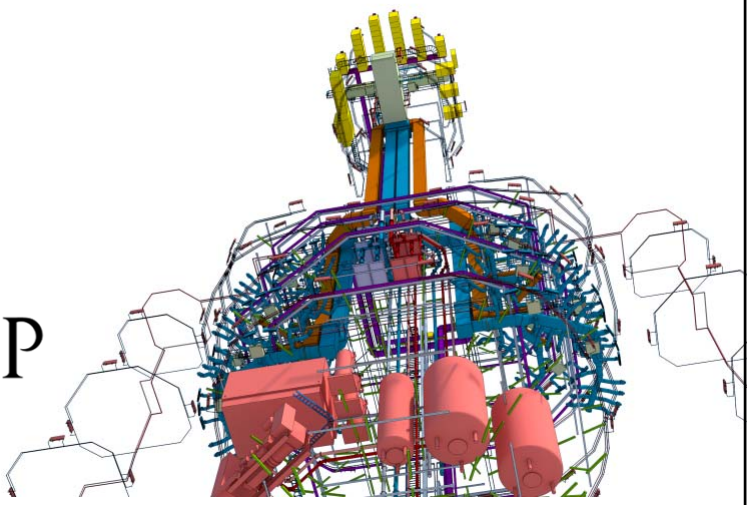
ARUP


ARUP
ARUP


ARUP

ARUP

MEP



ARUP

Intelligence

Automation

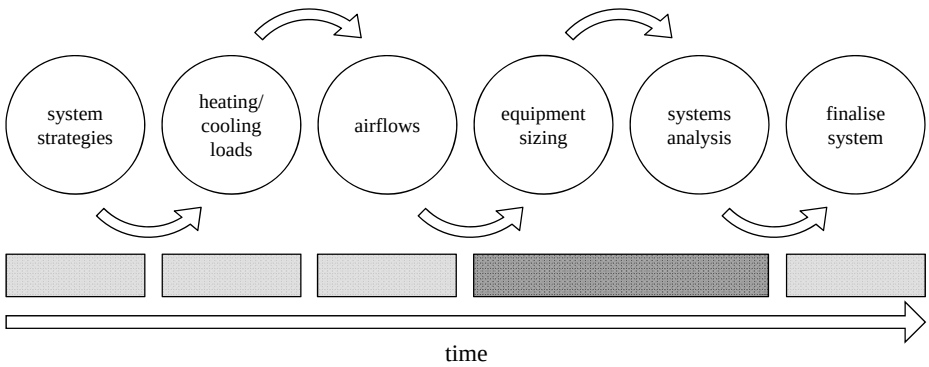
Efficiency

ARUP

Current Process

ARUP

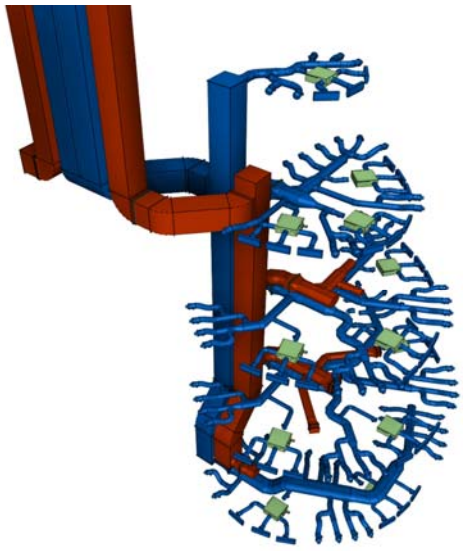
What are the opportunities to improve?



ARUP

ARUP

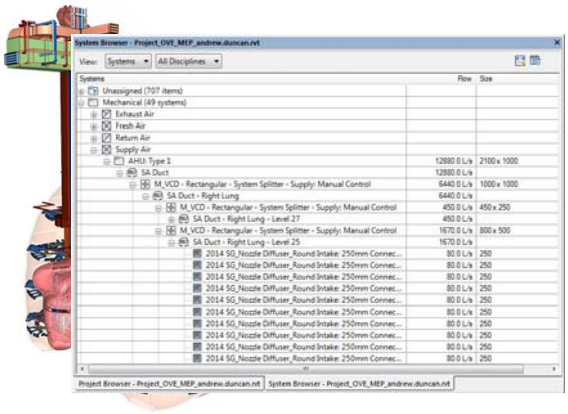
Ventilation



ARUP

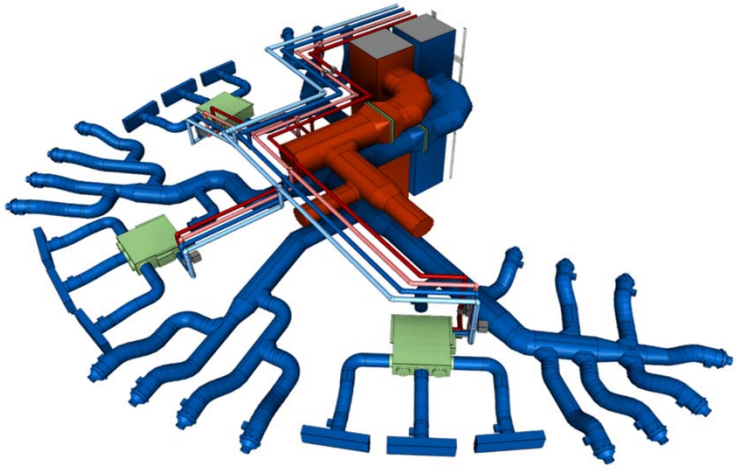
Ventilation = Respiratory

ARUP



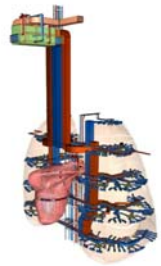
FCU System ➡ level system ➡ lungs ➡ AHU system

ARUP



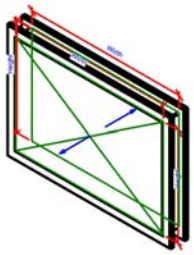
ARUP

Ventilation summary



model drives flow

neat system browser



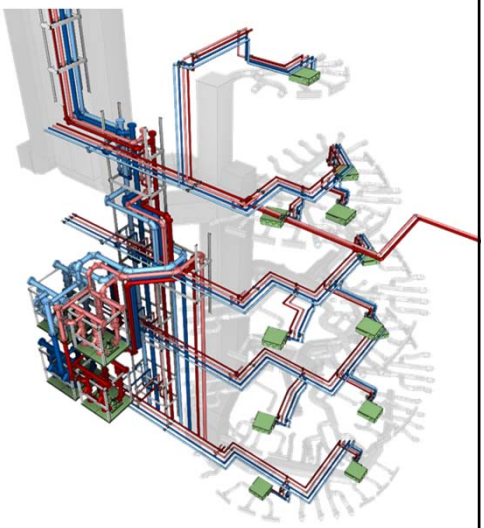
system splitter

but we are not finished with airflow yet…

ARUP

ARUP

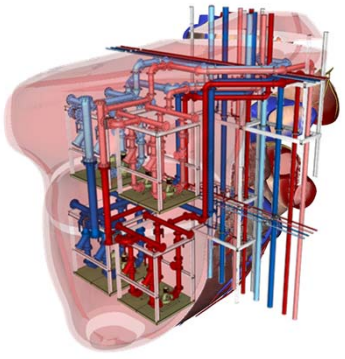
Pipework



ARUP

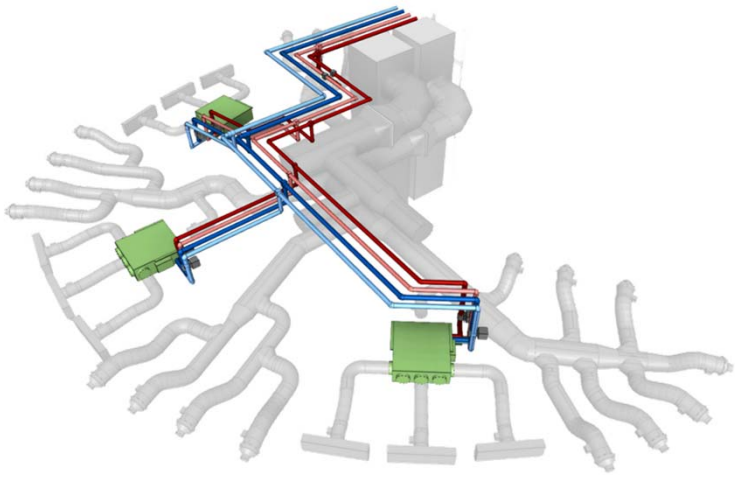
Pipework = Circulatory

ARUP



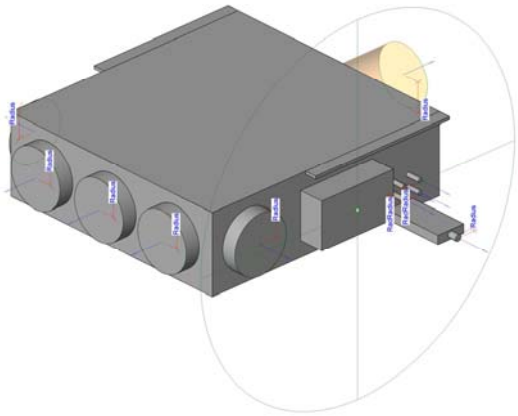
Terminal unit system → Level system → Riser system → Primary plant system

ARUP

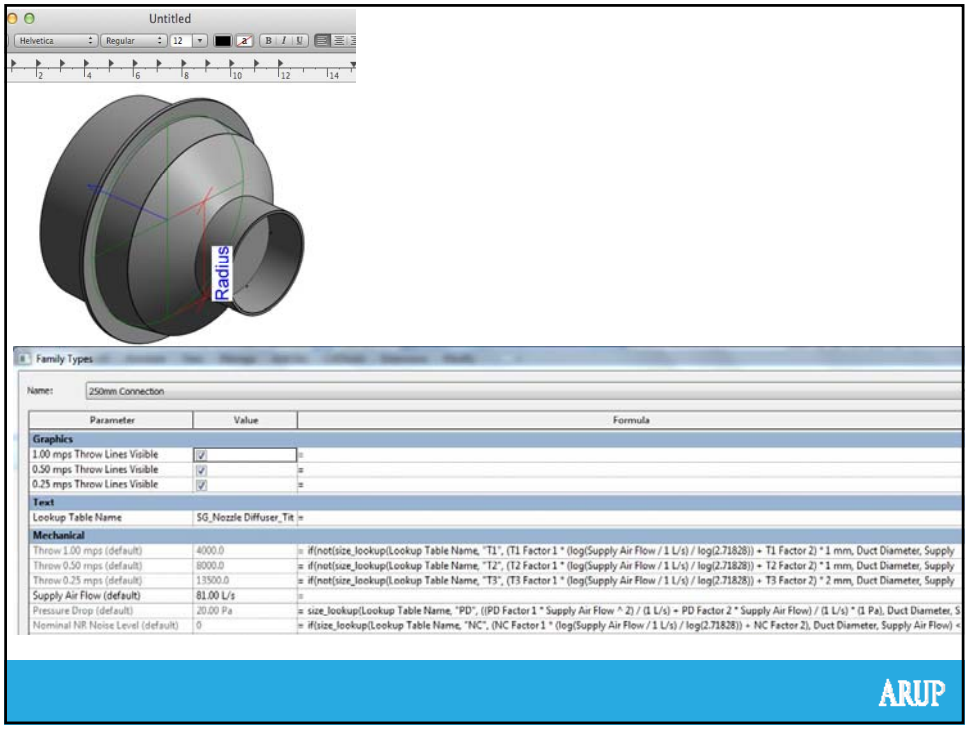


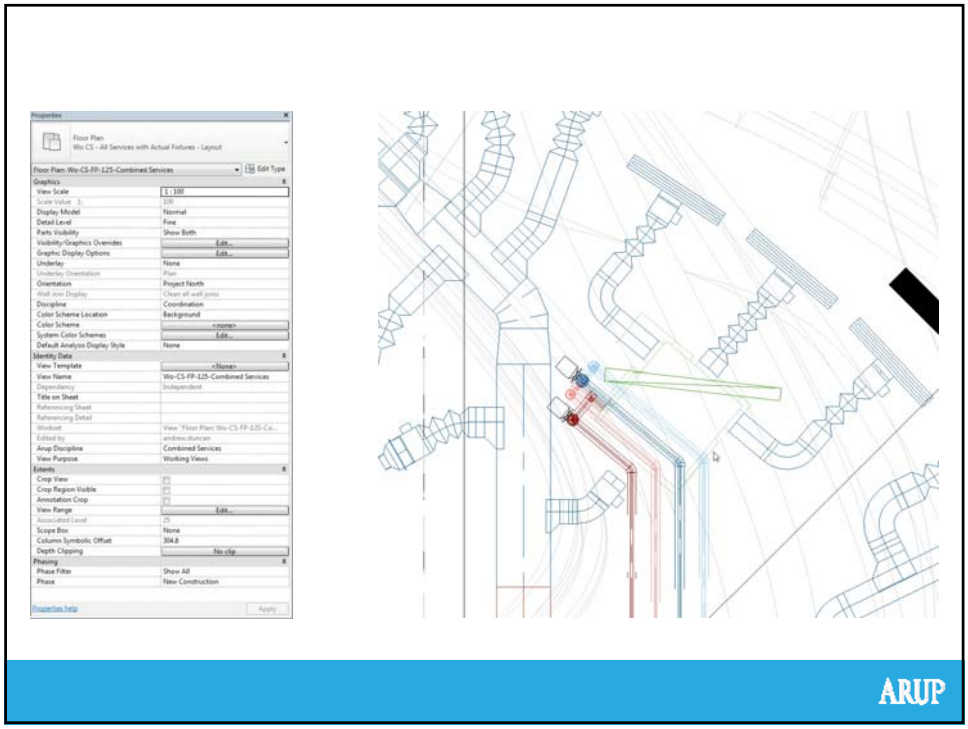
ARUP

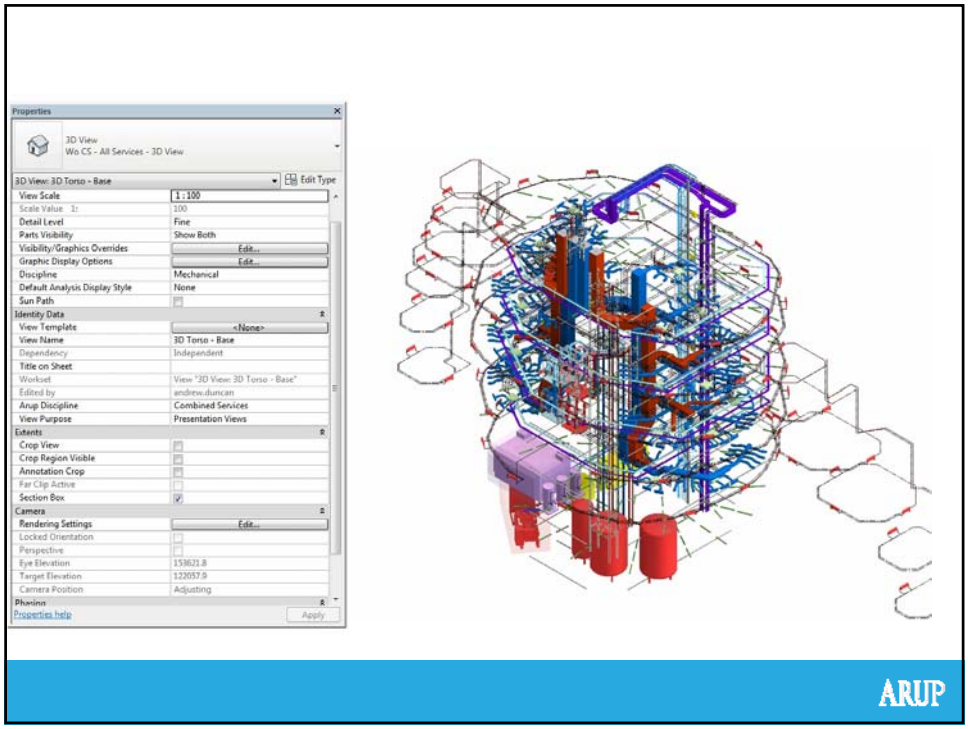
Maximise opportunity in families

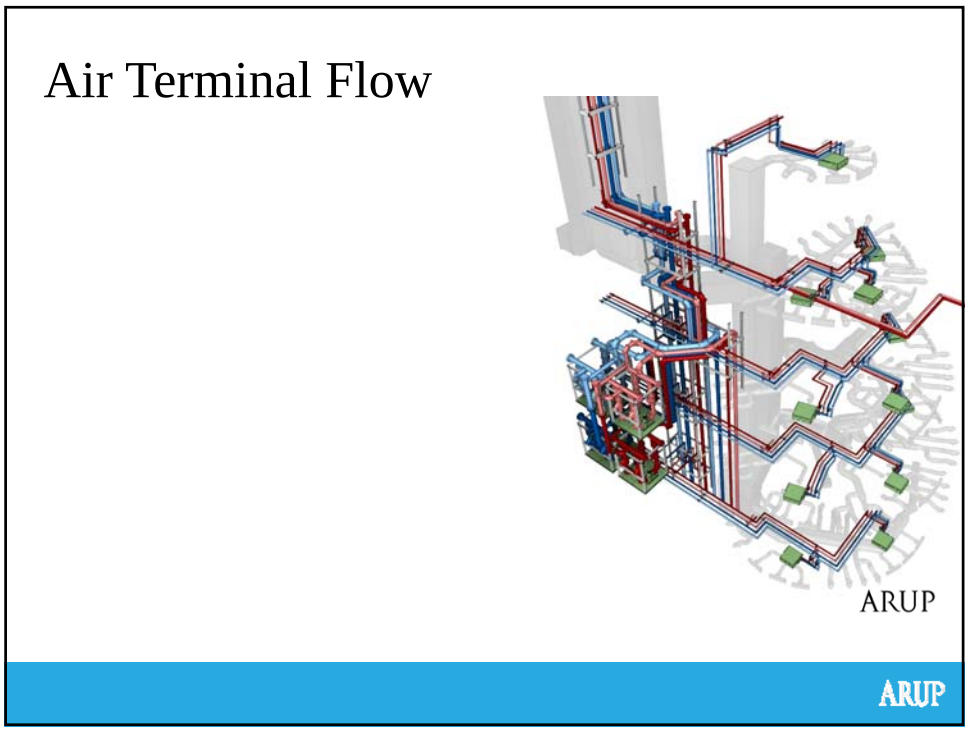


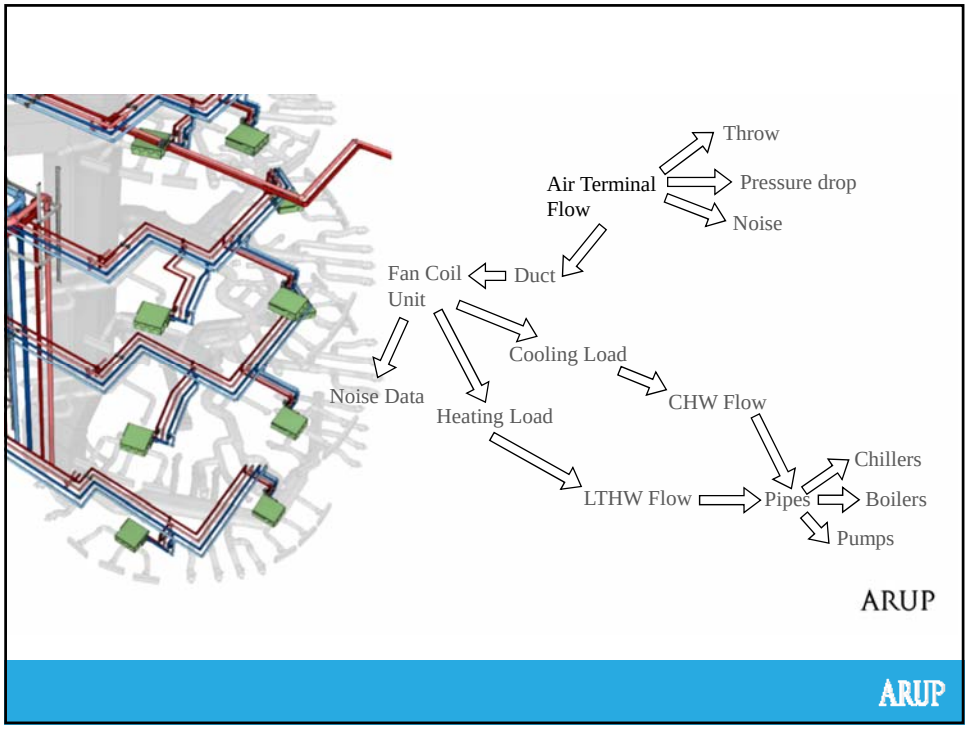
ARUP


Untitled
Radius
Family Types
Name:
250mm Connection
Parameter
Value
Formula
Graphics
1.00 mps Throw Lines Visible
0.50 mps Throw Lines Visible
0.25 mps Throw Lines Visible
Text
Lookup Table Name
SG_Nozzle Diffuser_Tit
Mechanical
Throw 1.00 mps (default)
Throw 0.50 mps (default)
Throw 0.25 mps (default)
Supply Air Flow (default)
Pressure Drop (default)
Nominal NR Noise Level (default)
ARUP


ARUP


Properties
3D View
Wo CS - All Services - 3D View
3D View: 3D Torso - Base
Edit Type
View Scale 1 : 100
Scale Value 1: 100
Detail Level Fine
Parts Visibility Show Both
Visibility/Graphics Overrides Edit...
Graphic Display Options Edit...
Discipline Mechanical
Default Analysis Display Style None
Sun Path
Identity Data
View Template <None>
View Name 3D Torso - Base
Dependency Independent
Title on Sheet
Workset View "3D View: 3D Torso - Base"
Edited by andrew.duncan
Arup Discipline Combined Services
View Purpose Presentation Views
Extents
Crop View
Crop Region Visible
Annotation Crop
Far Clip Active
Section Box
Camera
Rendering Settings Edit...
Locked Orientation
Perspective
Eye Elevation 153621.8
Target Elevation 122057.9
Camera Position Adjusting
Phasing
Properties help
Apply
ARUP

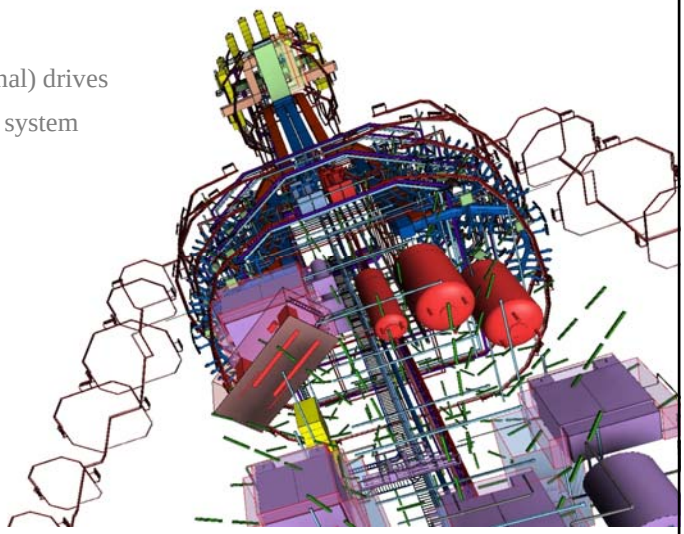

Air Terminal Flow
ARUP
ARUP



Services summary

Single input (air terminal) drives all other parameters in system

- Increase automation
- Maximise efficiency



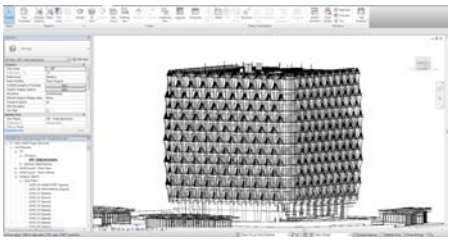
Improving Energy Modeling Efficiency

ARUP

Whole Building Energy Model

- Weather Data
- Geometry
- Internal Loads
- Envelope Performance
- Schedules
- HVAC Systems
- HVAC Plants
- Utility Rates

Revit Model



Aims:

- ❑Manage and share data
- ❑Increase efficiency
- ❑Improve model accuracy

Load / Energy Modeling Overview

ARUP

Conventional Method

Manual zoning diagrams in AutoCad

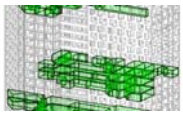
Manual documentation in Excel

Manual input into load / energy modeling software

BIM Method

Space creation with embedded data in Revit

gbXML export

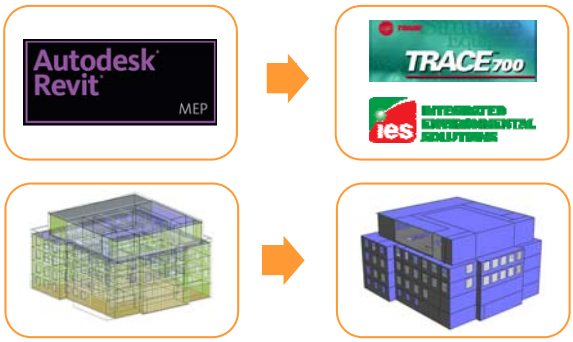


Import into load / energy modeling software

Workflow – Traditional vs BIM ARUP

Why use BIM over the conventional process?

- Automation
- Visualization
- Accuracy
- Checking
- Organization
- Time-saving
- Enhanced data-sharing among team
- Fun!



ARUP

Overview of the BIM to BEM workflow

ORGANIZE REVIT MEP MODEL FOR ANALYSIS

↓

CHOOSE ZONING METHOD & LINK CAD BACKGROUNDS OR REVIT ARCH. MODEL

↓

PLACE SPACES AND POPULATE SPACE DATA

↓

CHECK MODEL & EXPORT gbXML FILE

↓

IMPORT INTO LOAD / ENERGY MODEL AND CHECK

↓

COMPLETE ANALYSIS IN LOAD / ENERGY MODELING SOFTWARE

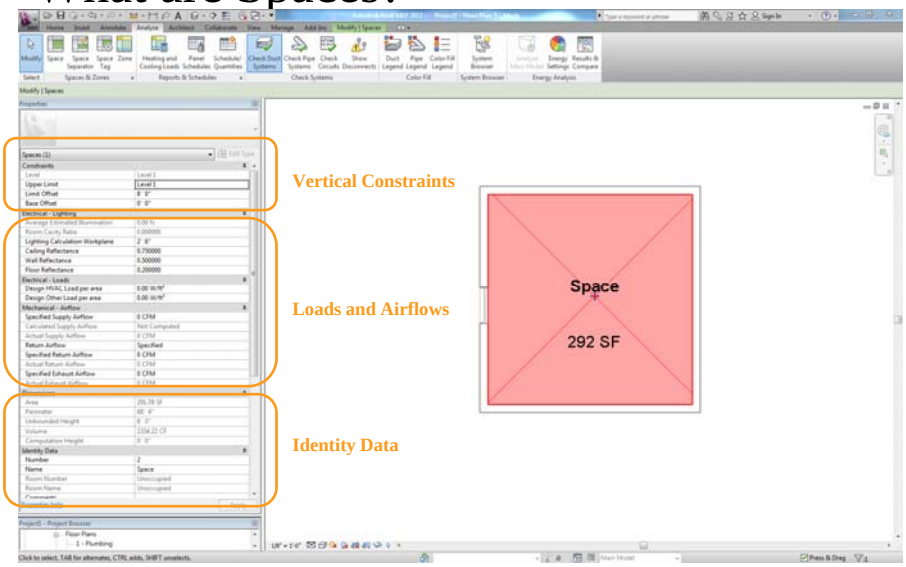
↓

IMPORT LOAD AND AIRFLOW DATA BACK INTO REVIT

77

ARUP

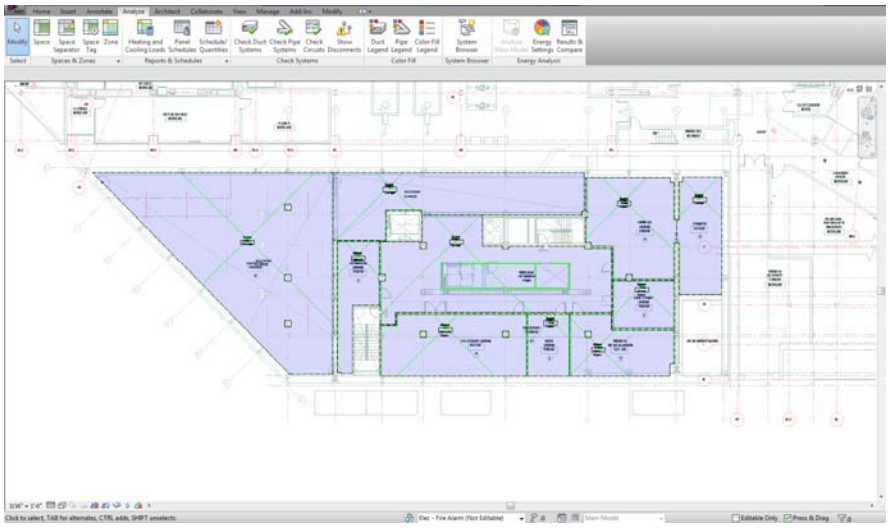
What are Spaces?



Data Management

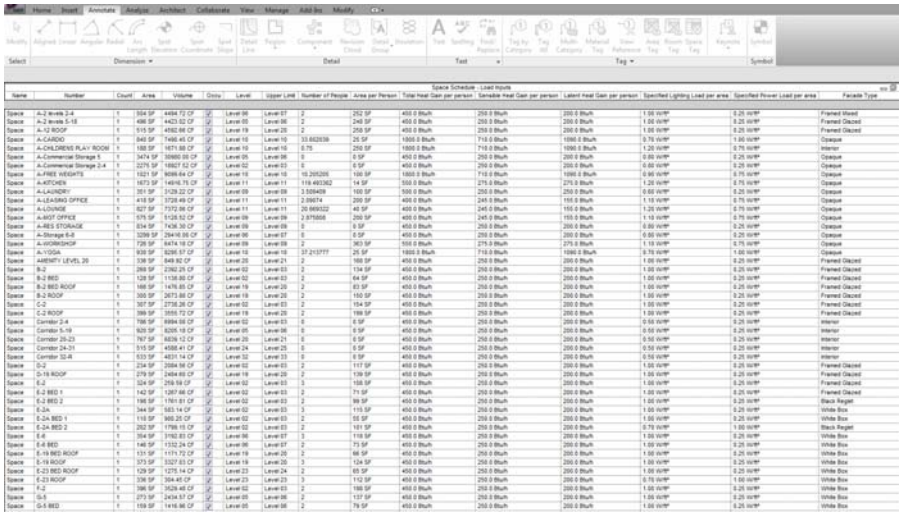
ARUP

Zoning Diagram in Revit MEP



Data Management ARUP

Space Schedule in Revit MEP



Data Management ARUP

Zones in Revit MEP

Revit Spaces:

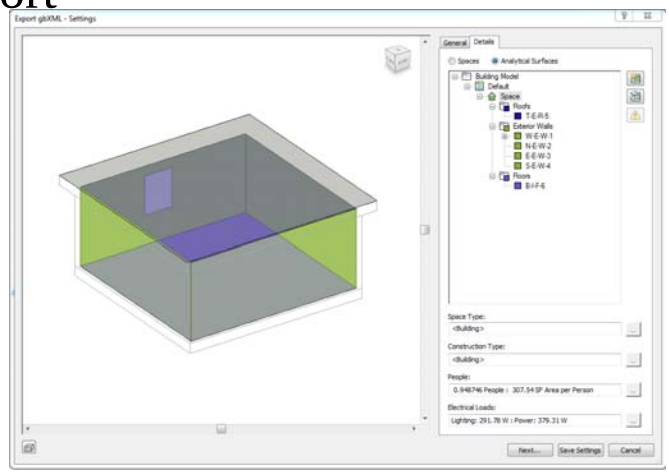
- Become thermal zones when imported into energy modeling software
- Store internal gains and schedules (lighting, occupancy, equipment)
- Store peak heating and cooling loads and airflows

Revit Zones:

- Used to sort Revit Spaces into HVAC systems
- Ability to store heating / cooling setpoints and outdoor airflow rates

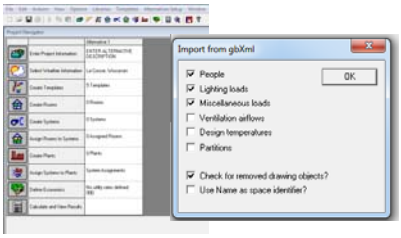
Data Management ARUP

gbXML Export

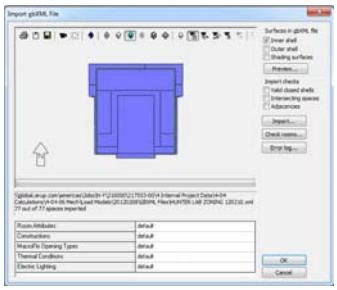


gbXML Export ARUP

Complete Analysis in Energy Modeling Software



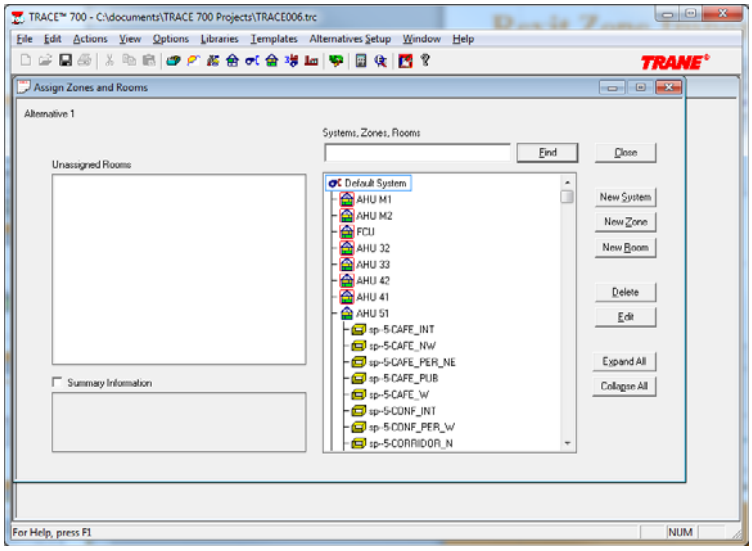
TRACE 700 gbXML Import Dialog



IES-VE gbXML Import Dialog

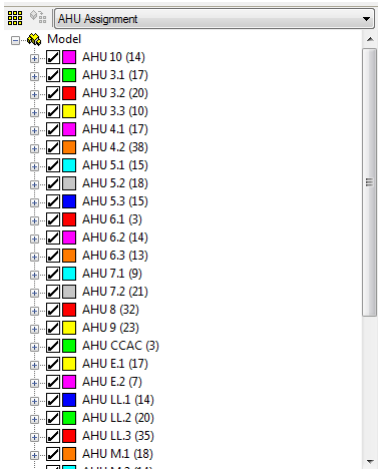
ARUP

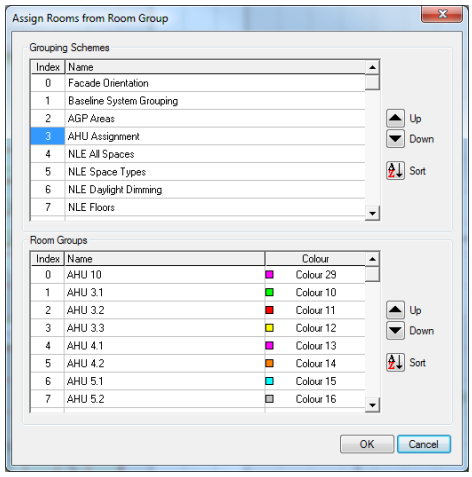
Revit Zone Imports in TRACE 700



ARUP

Revit Zone Imports in IES-VE

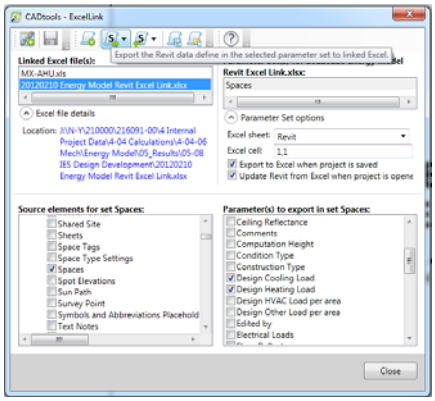




ARUP

BEM to BIM – Importing the analysis results back into Revit

- Currently no direct export from TRACE 700 or IES-VE to Revit MEP
  - ExcelLink can automate data transfer from spreadsheets
- Space parameters can store load model results
  - Design cooling load
  - Design heating load
  - Specified supply airflow



ARUP

Displaying information in BIM model

- BIM used for sharing information and aids design process
  - Dynamic space tags – displays information about space or zone
  - Colors schemes based on data – useful for checking and programming
  - Loads, airflows can be displayed to size equipment and systems
  - Compare “specified supply airflow” to “actual supply airflow” from Revit air terminals

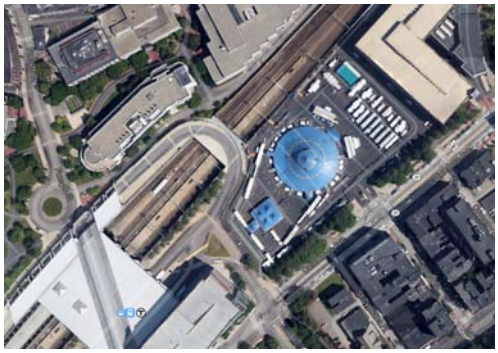
ARUP

Integrated Design of the Interdisciplinary Science and Engineering Complex (ISEC)

ARUP

ISEC @ Northeastern University

- 220,000 laboratory with Payette Associates
- 6 stories atrium
  - Core labs in basement
  - 2 level penthouse
- Construction documents Spring 2014
- Opening in 2016



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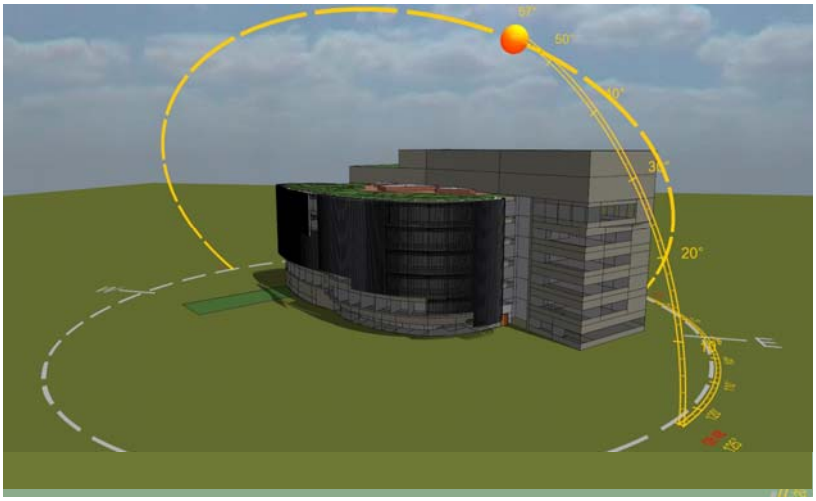
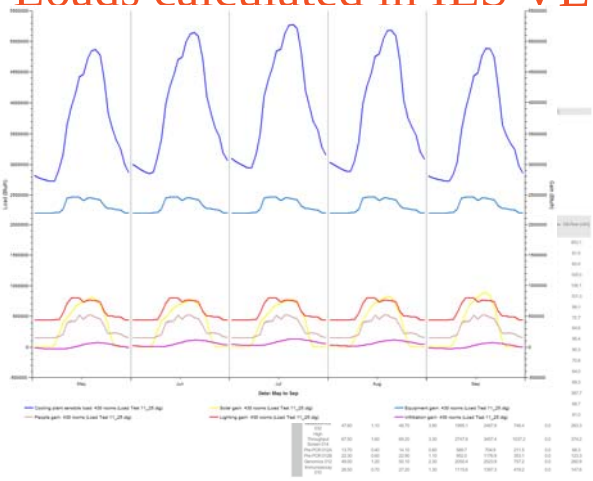
ARUP

Building Energy Modeling (BEM)
IES VE



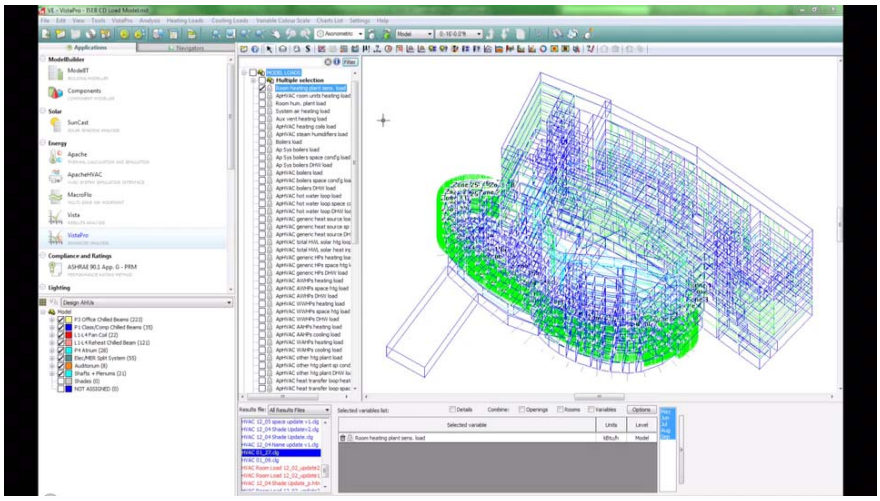
91 ARUP

Loads calculated in IES VE



92 ARUP

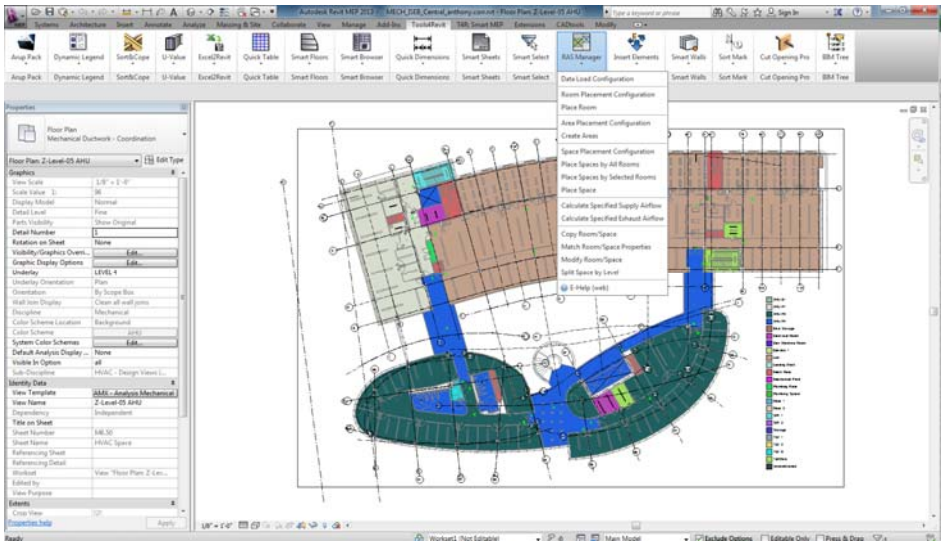
IES loads to Revit via Excel Link



BEM to BIM integration

ARUP

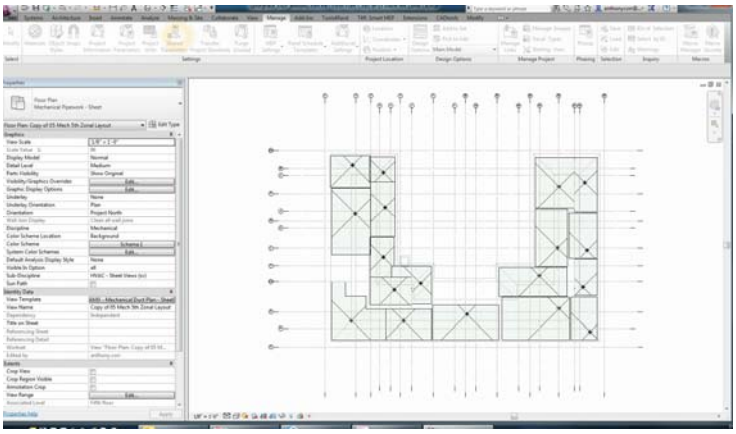
Spaces added from architects “Rooms”



94

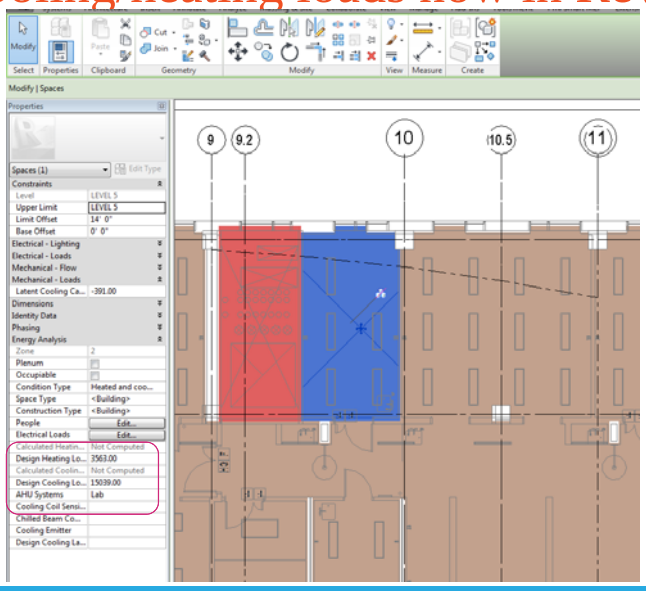
ARUP

Adding shared parameter to the spaces



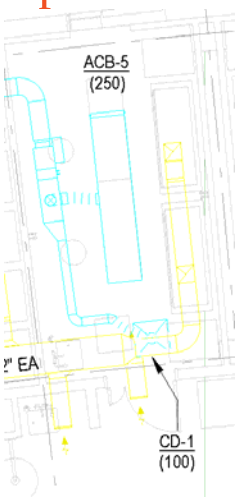
95 ARUP

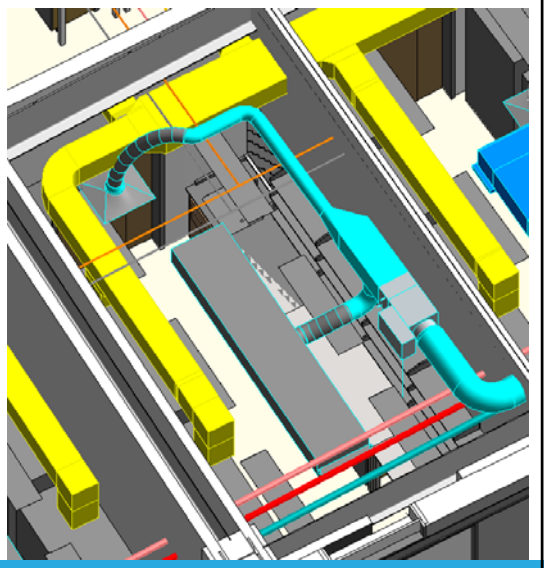
Cooling/heating loads now in Revit



96 ARUP

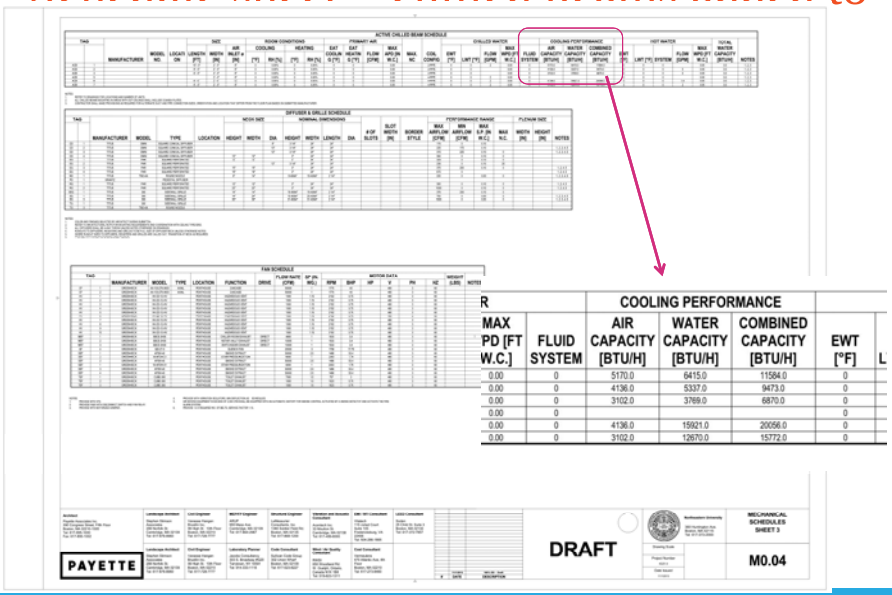
Chilled beam and diffuser added to space





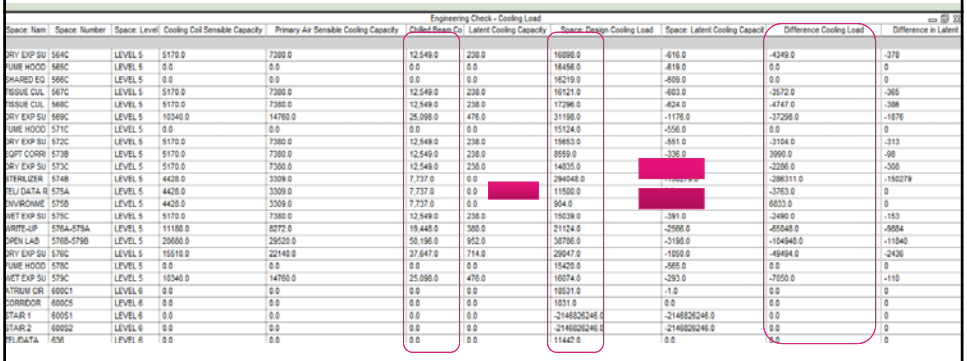
97 ARUP

Schedule sheet – chilled beams added to



98 ARUP

Cooling load schedule



Space: Nam	Space: Number	Space: Level	Cooling Coil Sensible Capacity	Primary Air Sensible Cooling Capacity	Chilled Beam Co	Latent Cooling Capacity	Space: Design Cooling Load	Space: Latent Cooling Capacit	Difference Cooling Load	Difference in Latent
DRY EXP SU	564C	LEVEL 5	5170.0	7380.0	12,549.0	238.0	16898.0	-616.0	-4249.0	-378
FUME HOOD	565C	LEVEL 5	0.0	0.0	0.0	0.0	16456.0	-619.0	0.0	0
SHARED EQ	566C	LEVEL 5	0.0	0.0	0.0	0.0	16219.0	-609.0	0.0	0
TISSUE CUL	567C	LEVEL 5	5170.0	7380.0	12,549.0	238.0	16121.0	-603.0	-3572.0	-365
TISSUE CUL	568C	LEVEL 5	5170.0	7380.0	12,549.0	238.0	17296.0	-624.0	-4747.0	-386
DRY EXP SU	569C	LEVEL 5	10340.0	14760.0	25,098.0	476.0	31198.0	-1176.0	-37298.0	-1876
FUME HOOD	571C	LEVEL 5	0.0	0.0	0.0	0.0	15124.0	-556.0	0.0	0
DRY EXP SU	572C	LEVEL 5	5170.0	7380.0	12,549.0	238.0	15653.0	-551.0	-3104.0	-313
EQPT CORR	573B	LEVEL 5	5170.0	7380.0	12,549.0	238.0	8659.0	-336.0	3990.0	-98
DRY EXP SU	573C	LEVEL 5	5170.0	7380.0	12,549.0	238.0	14035.0	[redacted]	-2256.0	-308
STERILIZER	574B	LEVEL 5	4428.0	3309.0	7,737.0	0.0	294048.0	[redacted]	-286311.0	-150279
TEL/ DATA R	575A	LEVEL 5	4428.0	3309.0	7,737.0	0.0	11500.0	[redacted]	-3763.0	0
ENVIRONME	575B	LEVEL 5	4428.0	3309.0	7,737.0	0.0	904.0	[redacted]	6833.0	0
WET EXP SU	575C	LEVEL 5	5170.0	7380.0	12,549.0	238.0	15039.0	-391.0	-2490.0	-153
WRITE-UP	576A-579A	LEVEL 5	11180.0	8272.0	19,448.0	380.0	21124.0	-2566.0	-85048.0	-5884
OPEN LAB	576B-579B	LEVEL 5	20680.0	29520.0	50,196.0	952.0	38706.0	-3196.0	-104948.0	-11840
DRY EXP SU	576C	LEVEL 5	15510.0	22140.0	37,647.0	714.0	29047.0	-1050.0	-49494.0	-2436
FUME HOOD	578C	LEVEL 5	0.0	0.0	0.0	0.0	15420.0	-565.0	0.0	0
WET EXP SU	579C	LEVEL 5	10340.0	14760.0	25,098.0	476.0	16074.0	-293.0	-7050.0	-110
ATRIUM CR	600C1	LEVEL 6	0.0	0.0	0.0	0.0	18531.0	-1.0	0.0	0
CORRIDOR	600C5	LEVEL 6	0.0	0.0	0.0	0.0	1031.0	0.0	0.0	0
STAIR 1	600S1	LEVEL 6	0.0	0.0	0.0	0.0	-2146826246.0	-2146826246.0	0.0	0
STAIR 2	600S2	LEVEL 6	0.0	0.0	0.0	0.0	-2146826246.0	-2146826246.0	0.0	0
TEL/DATA	656	LEVEL 6	0.0	0.0	0.0	0.0	11443.0	0.0	0.0	0

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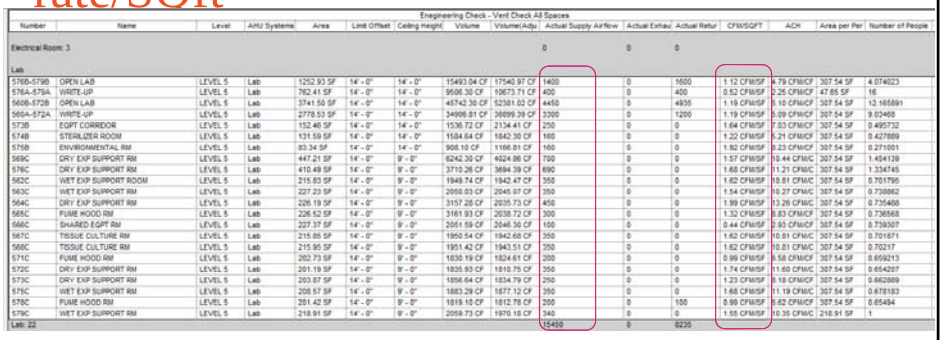
Vent check schedule volume flow rate/SOft



Number	Name	Level	ARU Systems	Area	Limit Offset	Ceiling Height	Volume	Volume(Adju	Actual Supply Airflow	Actual Exhau	Actual Retur	CFM/SQFT	ACH	Area per Per	Number of People
Electrical Room: 3									0	0	0				
Lab															
576B-579B	OPEN LAB	LEVEL 5	Lab	1252.93 SF	14' - 0"	14' - 0"	15493.04 CF	17540.97 CF	1400	0	1600	1.12 CFM/SF	4.79 CFM/CF	307.54 SF	4.074023
576A-579A	WRITE-UP	LEVEL 5	Lab	762.41 SF	14' - 0"	14' - 0"	9606.30 CF	10673.71 CF	400	0	400	0.52 CFM/SF	2.25 CFM/CF	47.65 SF	16
560B-572B	OPEN LAB	LEVEL 5	Lab	3741.50 SF	14' - 0"	14' - 0"	45742.30 CF	52581.02 CF	4450	0	4935	1.19 CFM/SF	5.10 CFM/CF	307.54 SF	12.165891
560A-572A	WRITE-UP	LEVEL 5	Lab	2778.53 SF	14' - 0"	14' - 0"	34906.81 CF	36099.39 CF	3300	0	1200	1.19 CFM/SF	5.09 CFM/CF	307.54 SF	9.03468
573B	EQPT CORRIDOR	LEVEL 5	Lab	152.46 SF	14' - 0"	14' - 0"	1536.72 CF	2134.41 CF	250	0	0	1.64 CFM/SF	7.03 CFM/CF	307.54 SF	0.495732
574B	STERILIZER ROOM	LEVEL 5	Lab	131.59 SF	14' - 0"	14' - 0"	1584.64 CF	1842.30 CF	160	0	0	1.22 CFM/SF	5.21 CFM/CF	307.54 SF	0.427889
575B	ENVIRONMENTAL RM	LEVEL 5	Lab	83.34 SF	14' - 0"	14' - 0"	908.10 CF	1166.81 CF	160	0	0	1.92 CFM/SF	8.23 CFM/CF	307.54 SF	0.271001
569C	DRY EXP SUPPORT RM	LEVEL 5	Lab	447.21 SF	14' - 0"	9' - 0"	6242.39 CF	4024.86 CF	700	0	0	1.57 CFM/SF	10.44 CFM/C	307.54 SF	1.454139
576C	DRY EXP SUPPORT RM	LEVEL 5	Lab	410.49 SF	14' - 0"	9' - 0"	3710.26 CF	3694.39 CF	690	0	0	1.68 CFM/SF	11.21 CFM/C	307.54 SF	1.334745
563C	WET EXP SUPPORT ROOM	LEVEL 5	Lab	215.83 SF	14' - 0"	9' - 0"	1949.74 CF	1942.47 CF	350	0	0	1.62 CFM/SF	10.81 CFM/C	307.54 SF	0.701795
563C	WET EXP SUPPORT RM	LEVEL 5	Lab	227.23 SF	14' - 0"	9' - 0"	2050.03 CF	2045.97 CF	350	0	0	1.54 CFM/SF	10.27 CFM/C	307.54 SF	0.738862
564C	DRY EXP SUPPORT RM	LEVEL 5	Lab	226.19 SF	14' - 0"	9' - 0"	3157.28 CF	2035.73 CF	450	0	0	1.99 CFM/SF	13.26 CFM/C	307.54 SF	0.735488
565C	FUME HOOD RM	LEVEL 5	Lab	226.52 SF	14' - 0"	9' - 0"	3161.93 CF	2038.72 CF	300	0	0	1.32 CFM/SF	8.83 CFM/CF	307.54 SF	0.736568
566C	SHARED EQPT RM	LEVEL 5	Lab	227.37 SF	14' - 0"	9' - 0"	2051.59 CF	2046.30 CF	100	0	0	0.44 CFM/SF	2.93 CFM/CF	307.54 SF	0.739307
567C	TISSUE CULTURE RM	LEVEL 5	Lab	215.85 SF	14' - 0"	9' - 0"	1950.54 CF	1942.68 CF	350	0	0	1.62 CFM/SF	10.81 CFM/C	307.54 SF	0.701871
568C	TISSUE CULTURE RM	LEVEL 5	Lab	215.95 SF	14' - 0"	9' - 0"	1951.42 CF	1943.51 CF	350	0	0	1.62 CFM/SF	10.81 CFM/C	307.54 SF	0.70217
571C	FUME HOOD RM	LEVEL 5	Lab	202.73 SF	14' - 0"	9' - 0"	1830.19 CF	1824.61 CF	200	0	0	0.99 CFM/SF	6.58 CFM/CF	307.54 SF	0.659213
572C	DRY EXP SUPPORT RM	LEVEL 5	Lab	201.19 SF	14' - 0"	9' - 0"	1835.93 CF	1810.75 CF	350	0	0	1.74 CFM/SF	11.60 CFM/C	307.54 SF	0.654207
573C	DRY EXP SUPPORT RM	LEVEL 5	Lab	203.87 SF	14' - 0"	9' - 0"	1856.64 CF	1834.79 CF	250	0	0	1.23 CFM/SF	8.18 CFM/CF	307.54 SF	0.662689
575C	WET EXP SUPPORT RM	LEVEL 5	Lab	208.57 SF	14' - 0"	9' - 0"	1883.29 CF	1877.12 CF	350	0	0	1.68 CFM/SF	11.19 CFM/C	307.54 SF	0.678183
578C	FUME HOOD RM	LEVEL 5	Lab	201.42 SF	14' - 0"	9' - 0"	1819.15 CF	1812.79 CF	200	0	100	0.99 CFM/SF	6.62 CFM/CF	307.54 SF	0.65494
579C	WET EXP SUPPORT RM	LEVEL 5	Lab	218.91 SF	14' - 0"	9' - 0"	2059.73 CF	1970.18 CF	340	0	0	1.55 CFM/SF	10.35 CFM/C	218.91 SF	1
Lab: 22									15450	0	6235				

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Duct velocities

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VAV schedule

ITEM TYPE	NO.	MANUFACTURER	MODEL NO.	Space Name	Space Number	AREA SERVED	INLET DIAMETER [IN]	INLET HEIGHT [IN]	INLET WIDTH [IN]	Actual Air Flow	AIRFLOW DESIGN MAX AIRFLOW	AIRFLOW CLG MIN AIRFLOW	AIRFLOW HTG AIRFLOW	MAXIMUM PRESSURE DROP [IN	HEATING COI ROWS	HEATING COI TOTAL HEATING	HEATING COI EWT [°F]	HEA LV
VAV	1	TITUS		COMPUTATIONAL LAB	555		16"			660	4000	0		0.00				
VAV	1	TITUS		COMPUTATIONAL LAB	555		16"			750	4000	0		0.00				
VAV	1	TITUS		CONFAB	669B		16"			1050	2000	1200		0.02				
VAV	1	TITUS		COMPUTATIONAL LAB	660-674		16"			1515	2000	1200		0.02				
VAV	1	TITUS		COMPUTATIONAL LAB	660-674		16"			750	2000	1200		0.02				
VAV	1	TITUS		CLASSROOM	137		16"			950	4000	0		0.00				
VAV	1	TITUS		CLASSROOM	139		16"			1000	4000	0		0.00				
VAV	1	TITUS		CLASSROOM	141		16"			1000	4000	0		0.00				
VAV	1	TITUS		CLASSROOM	143		16"			1000	4000	0		0.00				
VAV	1			OFFICE	017		16"			750	2000	0	1200	0.00	3	0.004396	120	
VAV	1			GENOMICS	012		16"			1375	2000	0	1200	0.00	3	0.004396	120	
VAV	1			GENOMICS	012		16"			950	2000	1200	1200	0.03	3	0.000733	120	
VAV	1			SHELL SPACE	004		16"			2000	2000	1200	1200	0.03	3	0.000733	120	
VAV	1			TELDATA RM	145		16"			3960	2000	1200	1200	0.03	3	0.000733	120	
VAV	1			VENDING	103		16"			3080	2000	1200	1200	0.03	3	0.000733	120	
VAV	1	TITUS		INSTRUCTION LAB (24 SEAT)	148		16"			2675	4000	0		0.00				

Air flow read from ductwork

Spaces and numbers populated automatically

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Who is responsible for modelling spaces?

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BIM is about "sharing structured information"

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Future Challenges

- Clear specifications for model build if others are to rely on the model for their own tasks
- This has implications on contracts & PI
- Validation of design & simulation
- Dissemination through the industry
- IPR of the design processes that may get embedded into the model
- Closing the project lifecycle and getting as-built building performance data.
- Real-time optimisation (power of the cloud)

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