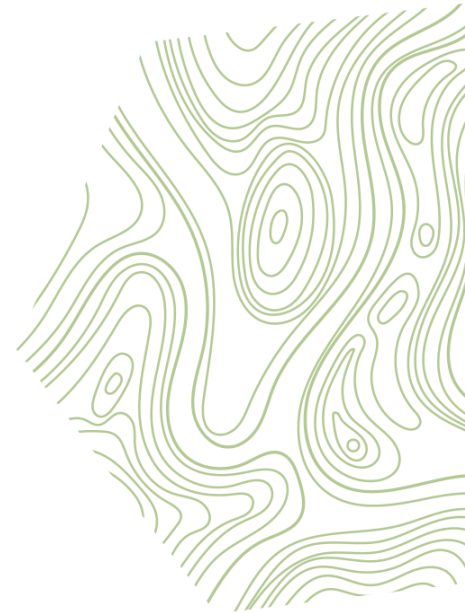


# DFMA Deployment at Scale



# Table of Contents

1. Introduction – Fortis & Techniques (5 Min)
2. The Obstacles – The Way (5 Min)
3. Procurement Strategy (5 Min)
4. Design Challenges (15 Min)
5. Prefab Deployment – From zero to hero (20 Min)
6. Lessons Learned (5 Min)
7. Q&A (10 Min)



# Team



**Todd Andersen**  
**Fortis – Sr. Project  
Manager**



**Hardarshan "Money" Singh**  
**Fortis – Sr. VDC  
Manager**



**Bobby Leong**  
**Techniques - Director**



**Paul Moss**  
**Techniques – Fab Shop  
Manager**

# About Fortis

Founded in  
**2003**

**Employee**  
owned

**600+**  
Full-Time  
Employees

**93%**  
work with  
repeat clients



Headquartered  
in Portland, OR

**BUILDING DESIGN  
+ CONSTRUCTION**

**Top-100 Firm: Airport, Data Center,  
Education, Healthcare, Workplace,  
Government, Science & Technology**

**\$2.5B**  
Annual Revenue

A decorative graphic in the bottom right corner consisting of light green, wavy, concentric lines that resemble a topographic map or contour lines.



Founded in  
**1983**

Mechanical  
Engineering  
& Installation

Accredited  
DfMA  
Fabricator  
(STAS)

**300+**  
Full Time  
Employees

Based in  
**Singapore**

## CASE STUDY

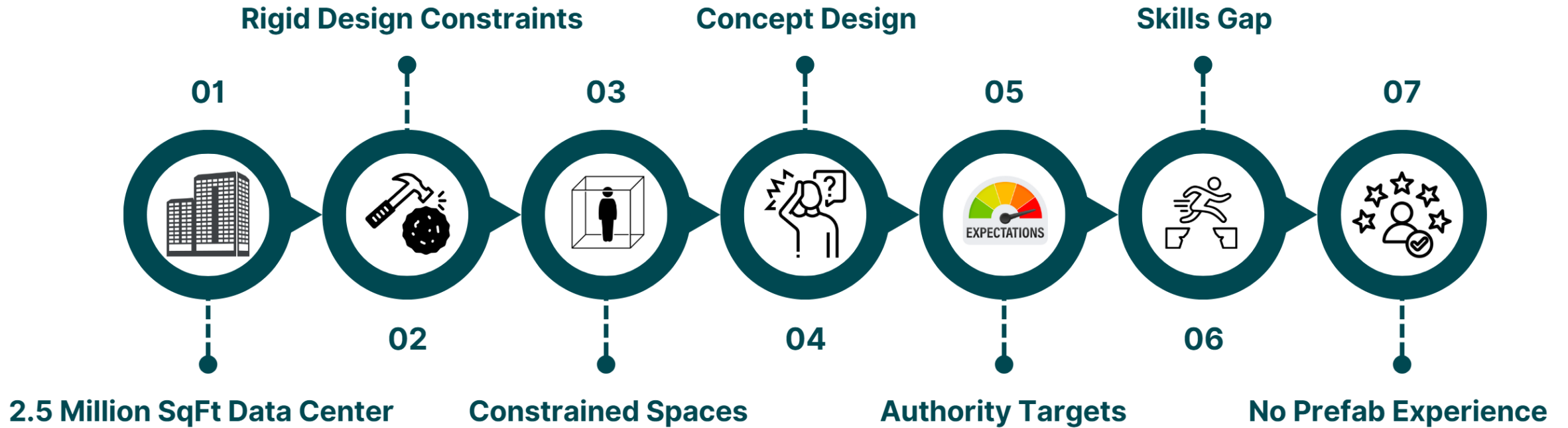
# Singapore Data Center



“Through Fortis’ foundation in Culture and Core Values, we assembled a team to build with skill and efficiency through prefabrication, DfMA, Virtual Design & Construction and many other lean strategies.”



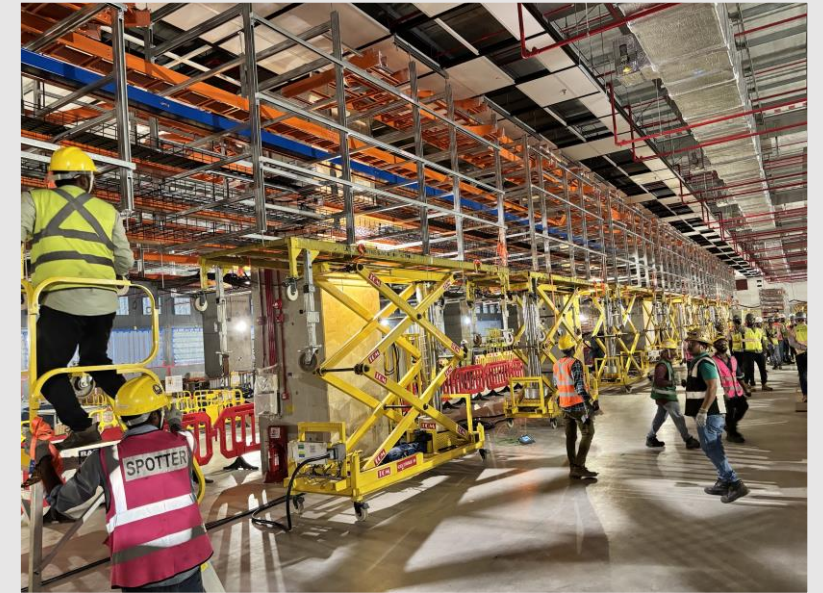
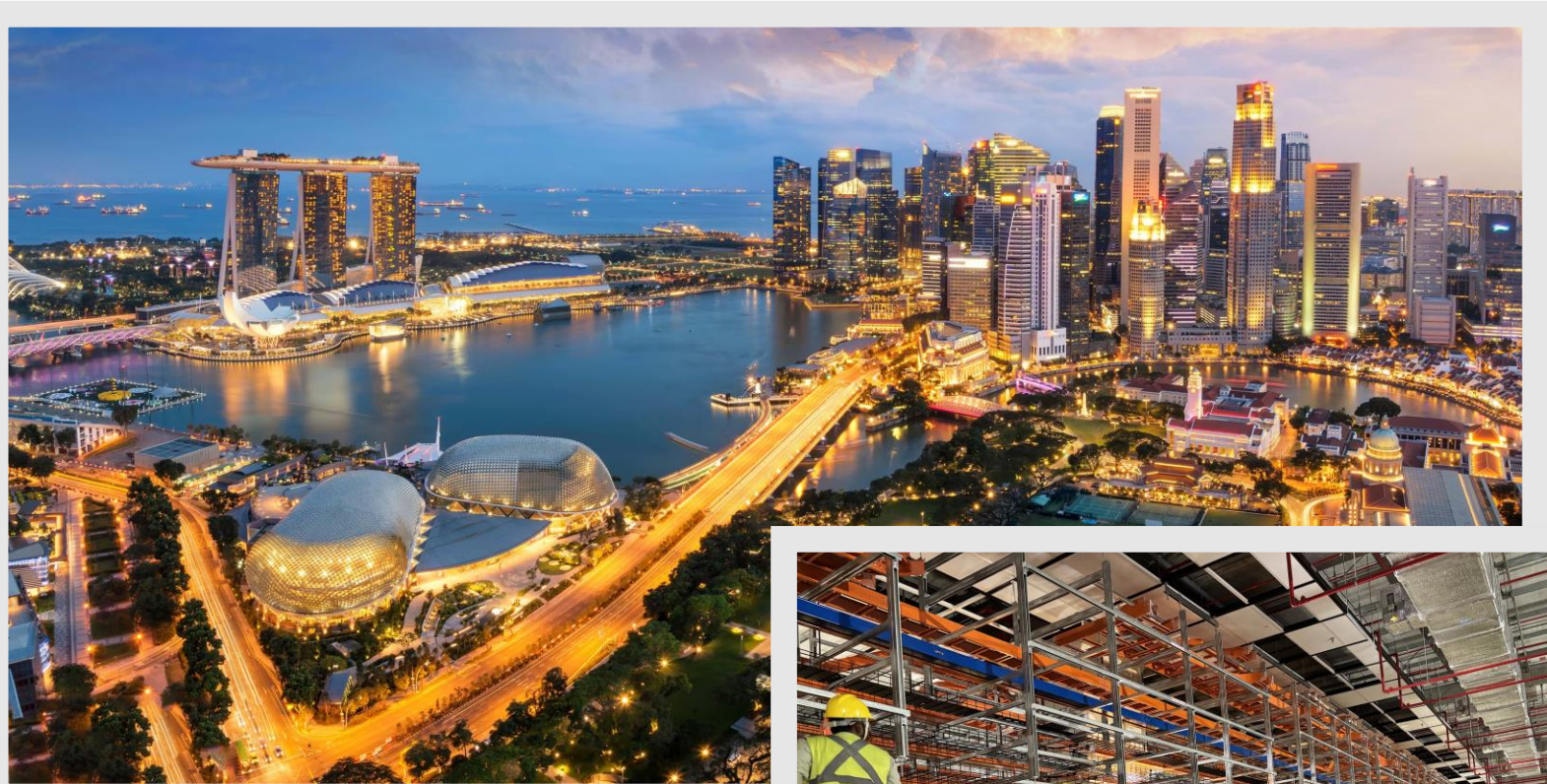
# The Obstacle



# Singapore Authority Targets

Building and Construction  Authority

- Initiative to reduce on-site labor
- Authority Target set for 70% of all MEP systems
- **Achieved 85%**





# Multi-Service Module Procurement

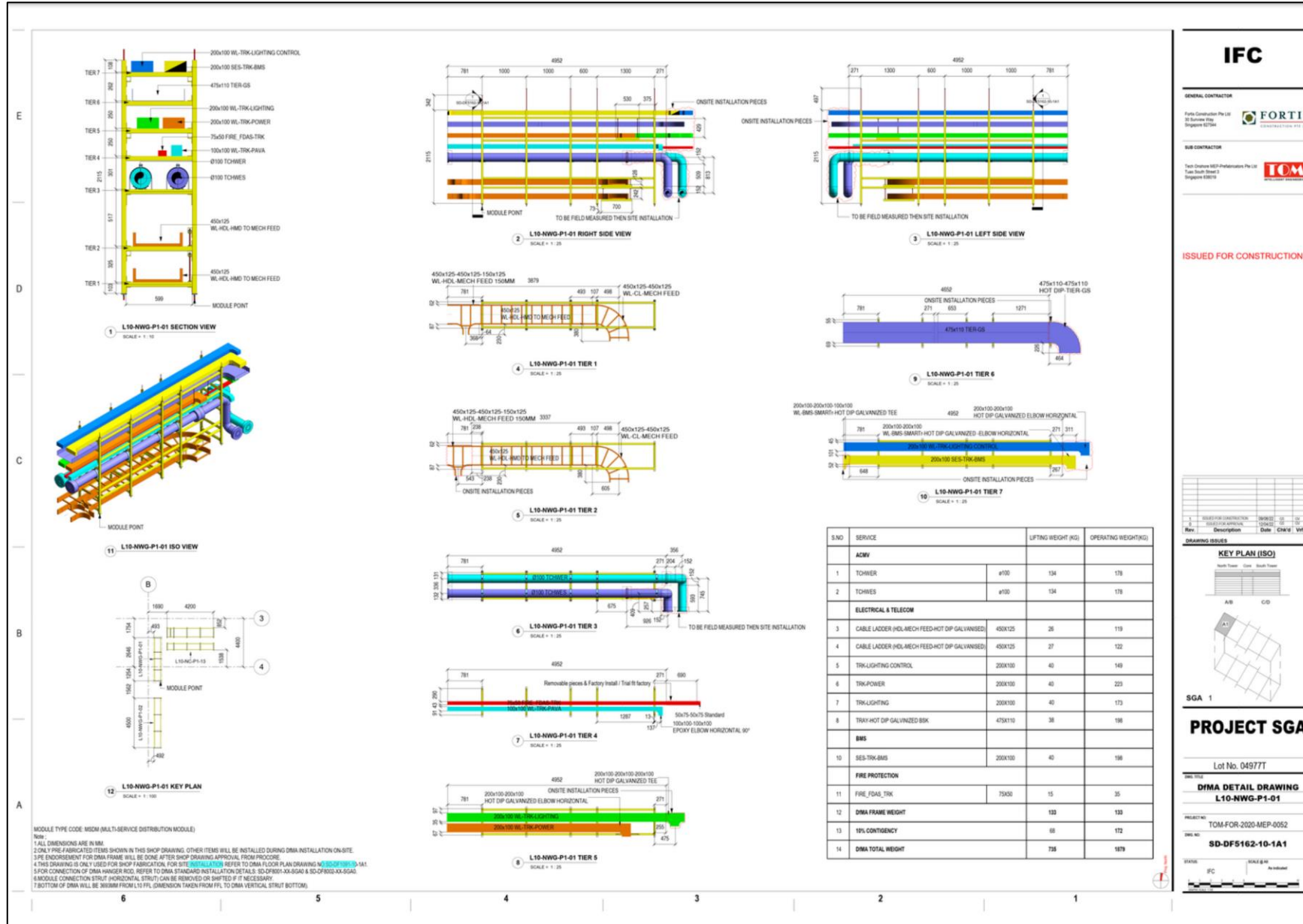
Scope	Responsible
Coordination	MEP Trades
Module Structural Design	Integrator
Frame Fabrication	Integrator
Services Installation (at Factory)	MEP Trades
Delivery & Site Logistics	Integrator
Module Connections (Ground Level)	MEP Trades
Lifting into position	Integrator



# Trade Specific Modules



# Multi-Service Module Coordination



**IFC**

GENERAL CONTRACTOR  
 Fortis Construction Pte Ltd  
 25 Sunway Way  
 Singapore 67206

SUB CONTRACTOR  
 Tech Design MEP Engineering Pte Ltd  
 Tech South Street 3  
 Singapore 088716

ISSUED FOR CONSTRUCTION

Rev	Description	Date	Chw's	Vrf's
1	ISSUED FOR CONSTRUCTION			
2	REVISIONS			

**KEY PLAN (ISO)**



SGA 1

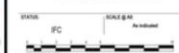
**PROJECT SGA**

Lot No. 04977T

**DIMA DETAIL DRAWING**  
**L10-NWG-P1-01**

PROJECT NO.  
 TOM-FOR-2020-MEP-0052

DWG NO.  
**SD-DFS162-10-1A1**



# Multi-Service Module Coordination



# Multi-Service Module Coordination

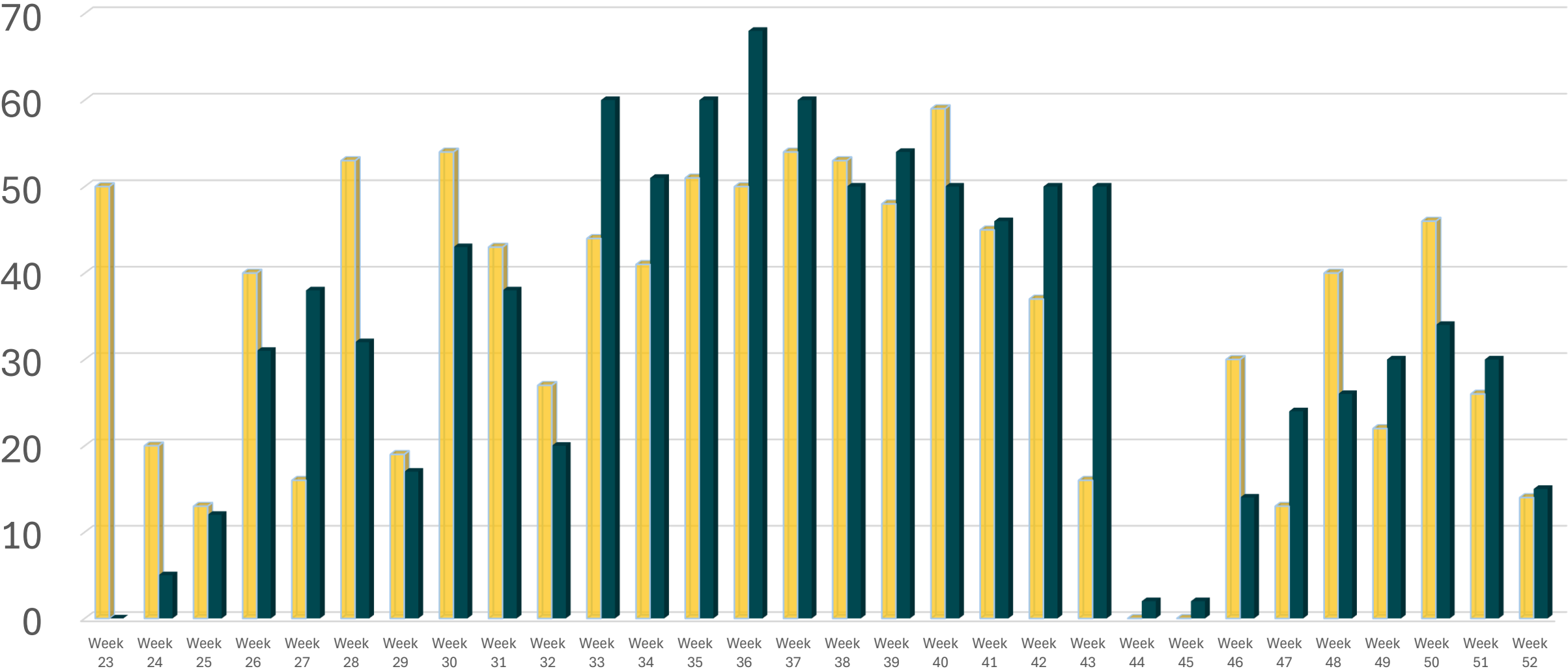


# Hoisting Process



# Fab Shop Production Rates – QAQC Improvement

## DFMA Module Fabrication & Installation



# DFMA Quantum

---

	<b>Total</b>
Total Modules	4819
Multi Service Modules	4199
Plant room Skids	217
Pipe Riser Modules	120
Pipe Rack Modules	88
Pump Skid Modules	40
Fire System Skids	55



# DFMA Design Deployment

---

SUBHEADER

FORTIS

# Design topics

1. Challenges
2. Implementation
3. Key Lessons Learned

**CW5 @ L2,4,6 & 8**  
 OPTION TO BONDCEK CEILING TO CREATE ACCESSIVE SPACE FOR T3/4

MAINTENANCE LOUND NO CUT NAK  
 1375mm  
 245mm  
 50mm 50mm  
 3200 AFFL  
 150mm BONDCEK  
 2000 AFFL  
 2450  
 280  
 4775mm  
 + AVOIDS LARGE BLUE MVA TO DH SAD

ACCESS FROM BOTH SIDES

**NETWORK CORE CORRIDORS**  
 T3/4 cable tray Provision in DFMA installed on site. FORTS BASED IN SGA1 T3/4 Req.

③ FORTS TO REVIEW SGA2-6 T3/4 BASKETS @ CW5. POSSIBLE TO DROP EVEL LADDERS EAST OF WBBY & RUN T3/4 IN PLACE. CREATES SMALL AREA OF TRAY ON LADDER AS A PINCH POINT. DOES NOT IMPACT CW5 SSL BUILD.

OPTIONS ① ② ③  
 OVER THE TOP HAS ACCESS ISSUES @ BIG BLUE SPD.

	EW5	WEL LIO W/PT/FRONT/BACK TO BULKHEAD	W/PT TO VERIFY	
L8	DITTO W/PT to cabinet	They connect in Bleed room over PDU! OK	✓	✓
L6	DITTO W/PT to cabinet	DITTO	✓	✓
L4	DITTO W/PT to cabinet	DITTO	✓	✓
L2	TELECOM GROUP AND TIME AND W/PT TO CONTROL	DITTO	✓	✓
	NNCE	NNCW	SNCE	SNCW

TELECOM GROUP MODEL AS SHOWN @ L2,4,6 & 8  
 THEREFORE TELECOM SGA2-6 MODEL INCOMPLETE

TELECOM MODEL LACKS T3/4 @ L2,4,6 & 8 IN 100% CB.

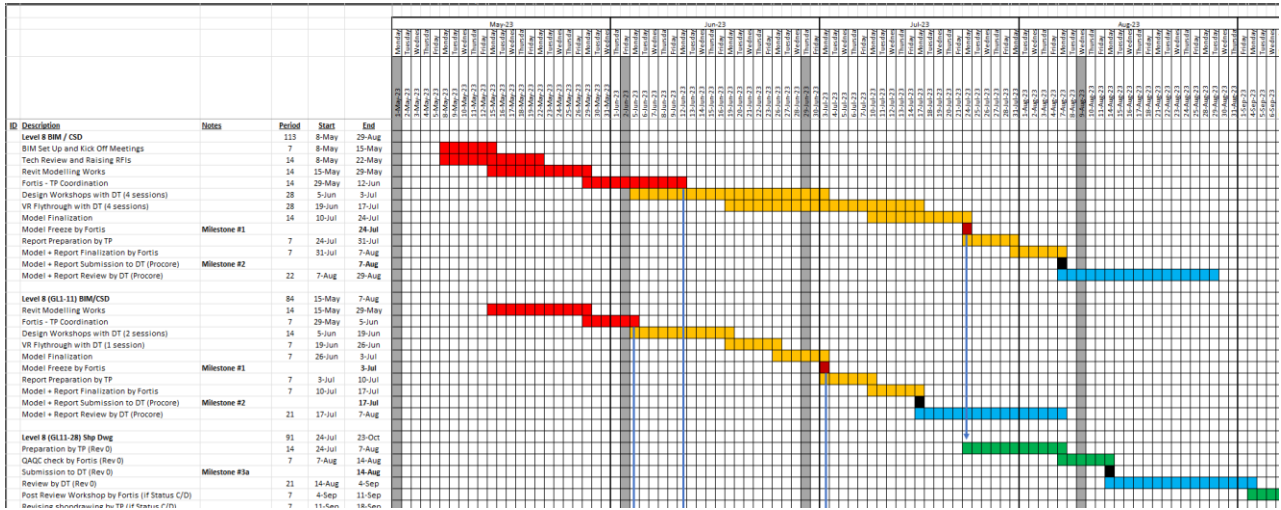
**ICT SUMMARY**

NETWORK AREA  
 IE P  
 CSD  
 CW5

NO ISSUES ON WEST CORRIDOR  
 CW5  
 IE P  
 SOUTH CORRIDOR NO ISSUES

# DFMA BIM General Challenges

- Early Completion of Coordination to allow for fabrication
- Reduced Timeline – need to manage upstream deliverables



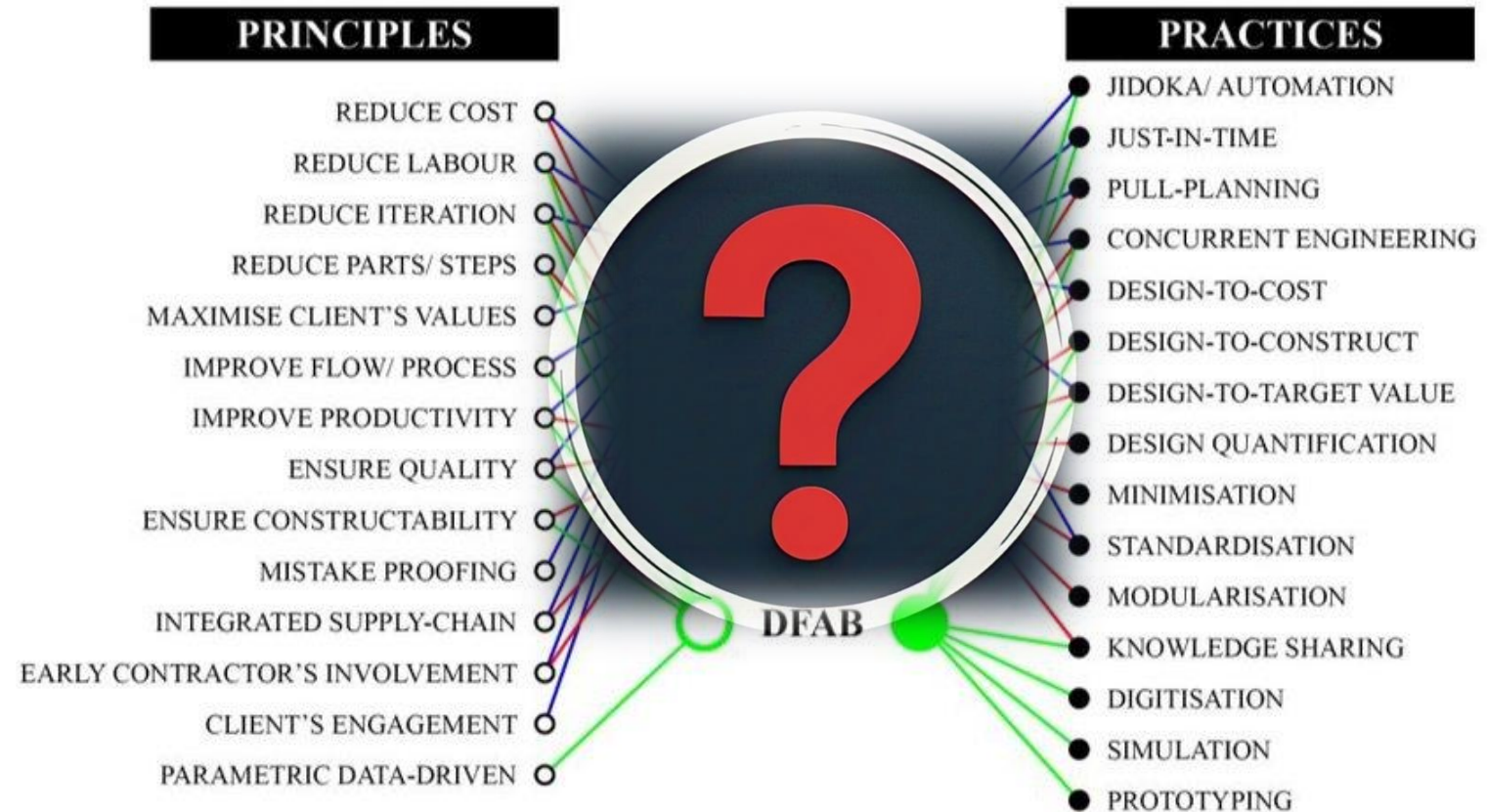
# BIM General Challenges

- Limited Collaboration and engagement
- Limited Interactivity
- Work Silos
- Inefficient Communication



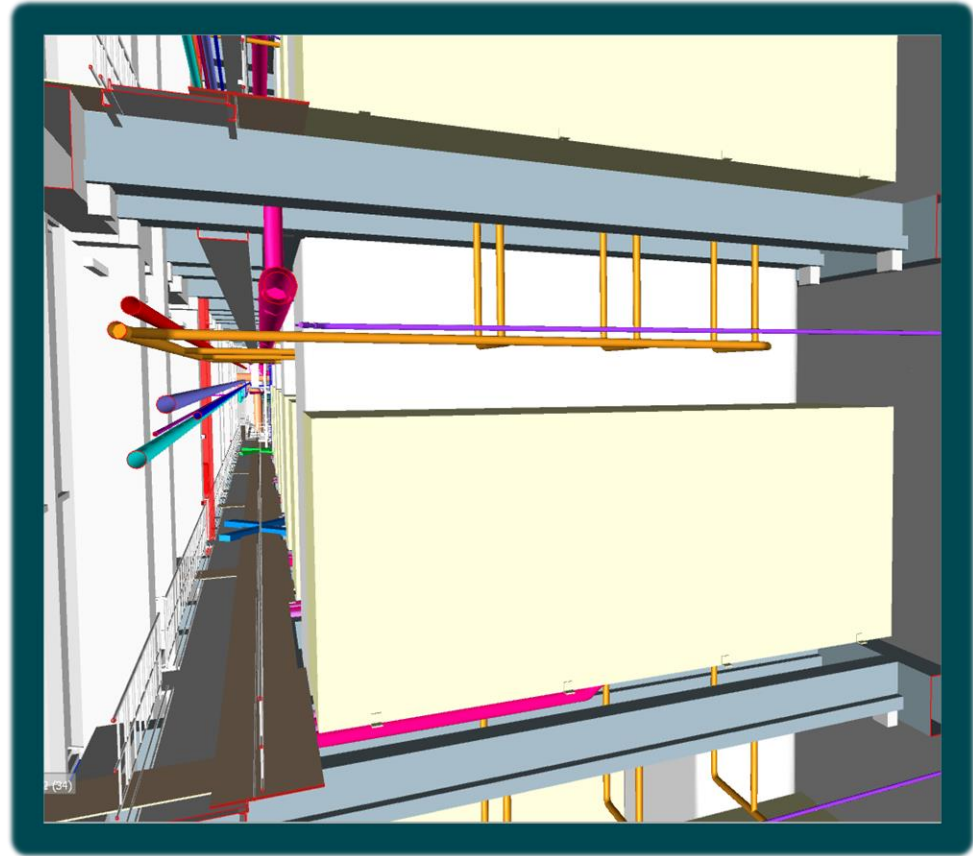
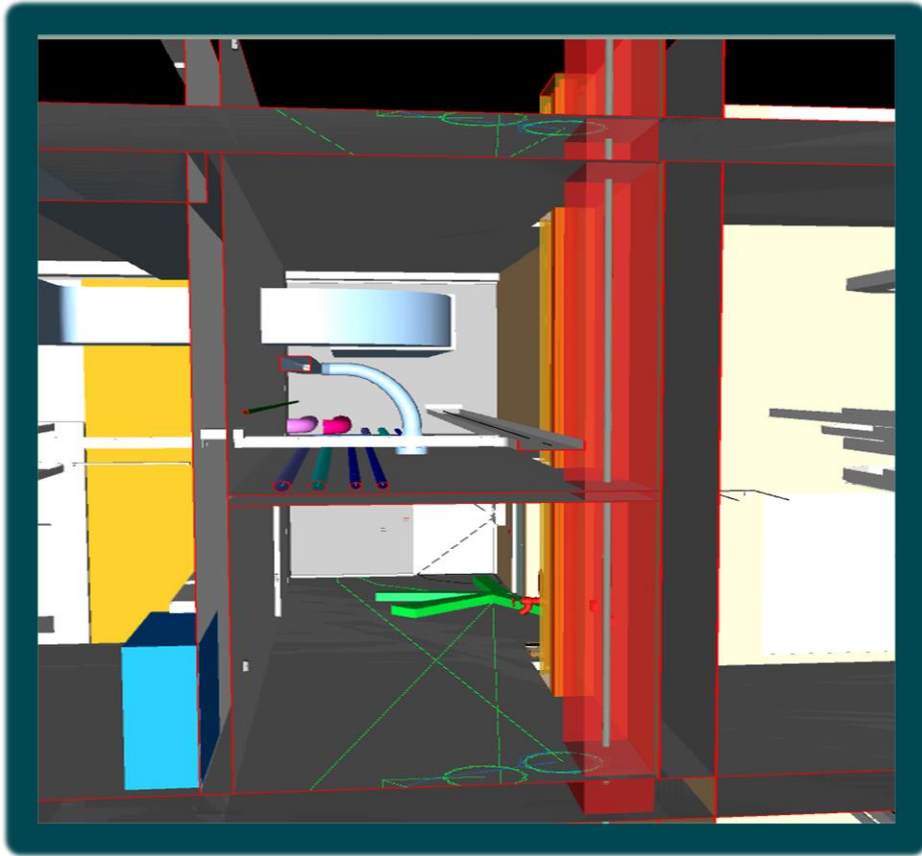
# BIM Knowledge Gaps

- Team Lacks DFMA & Prefab Knowledge



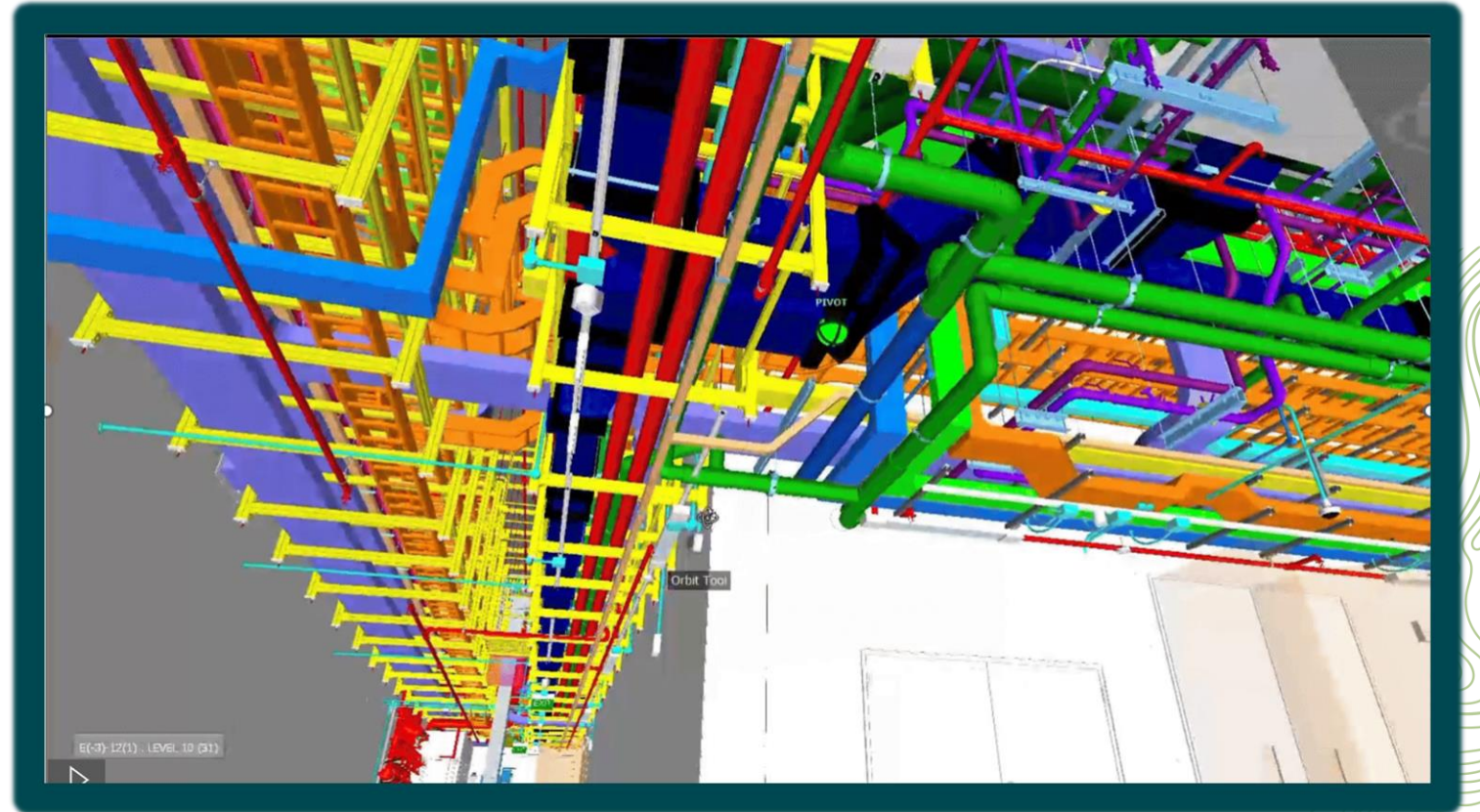
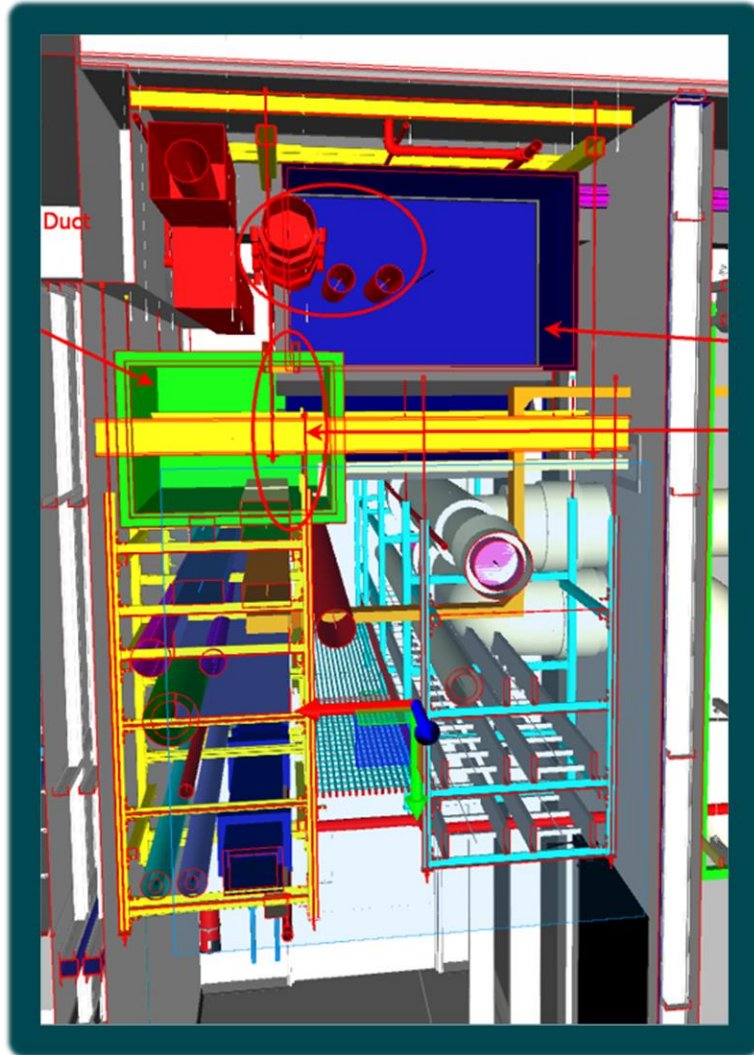
# Design Challenges

- Incomplete Design



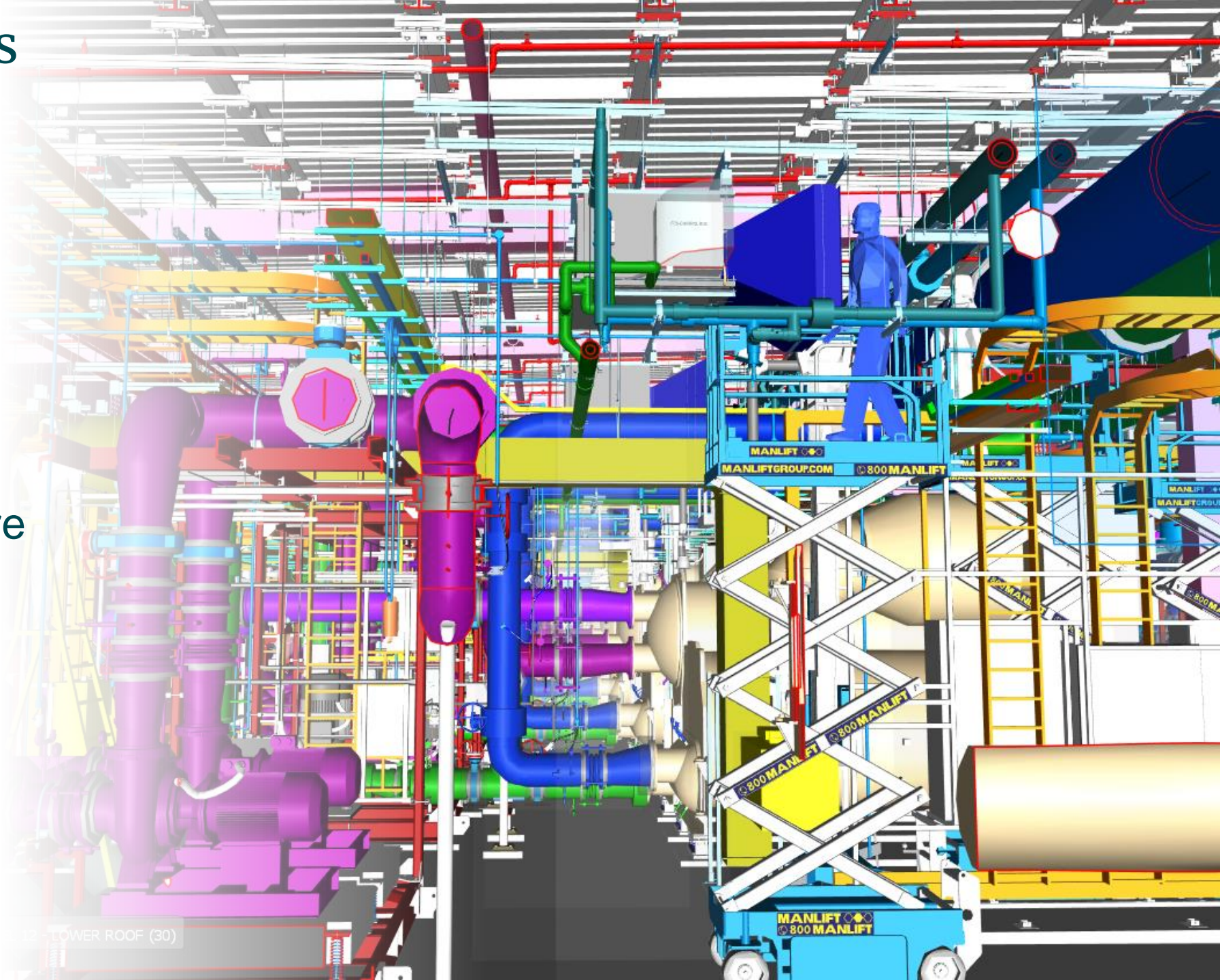
# Design Challenges

- Complexity & Congestion



# Design Challenges

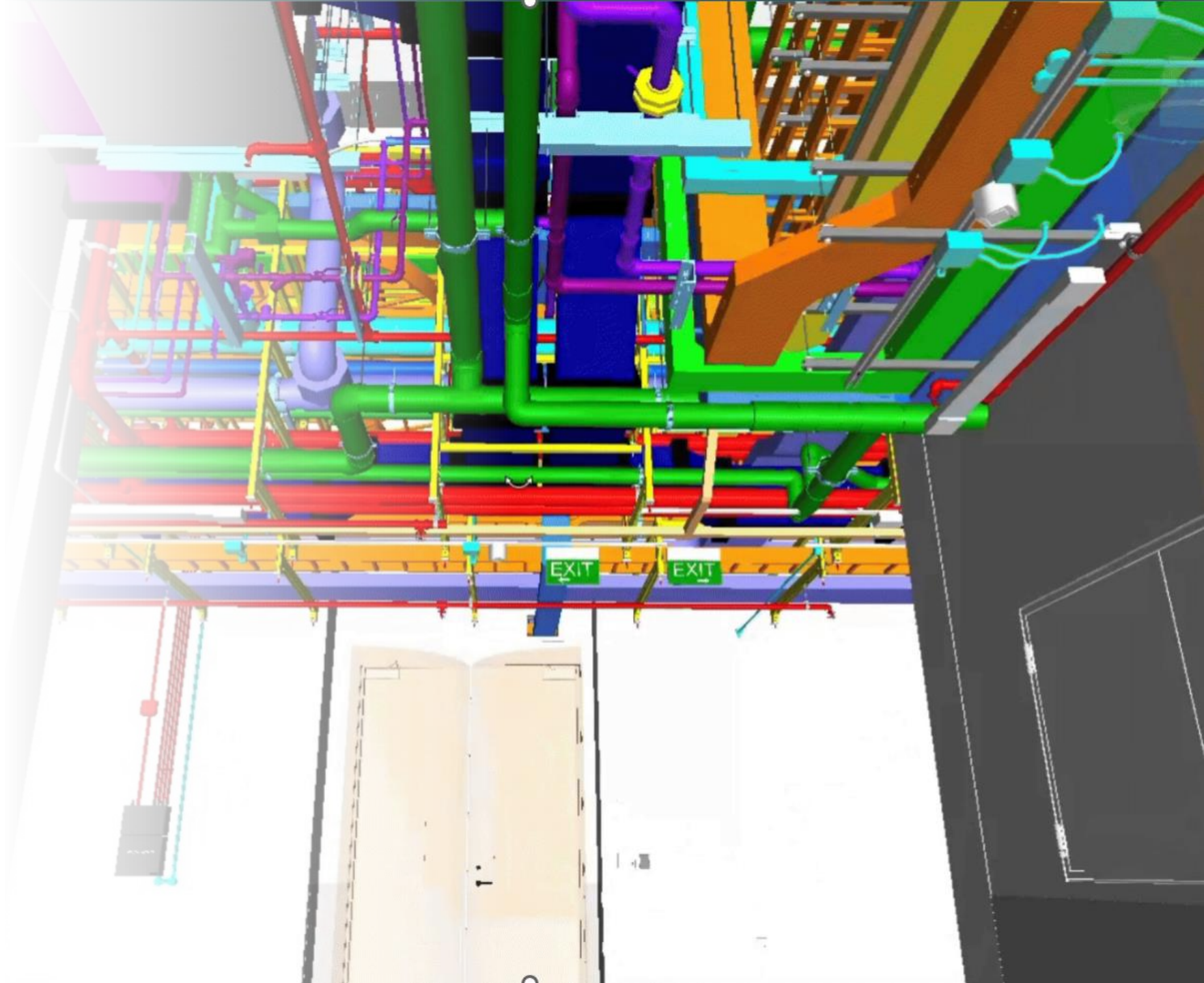
- Limited Space for Accessibility & Future Maintenance





# Design Challenges

- Maintaining Services Tolerances
- Negotiating No-Fly Zones



# Design Challenges

- Over 960 Design Changes
- Majority of changes were a result of incomplete design

# Design Challenges

- Design for Transport
- Strict Authority Regulations on Roads



# Singapore Data Center BIM Implementation

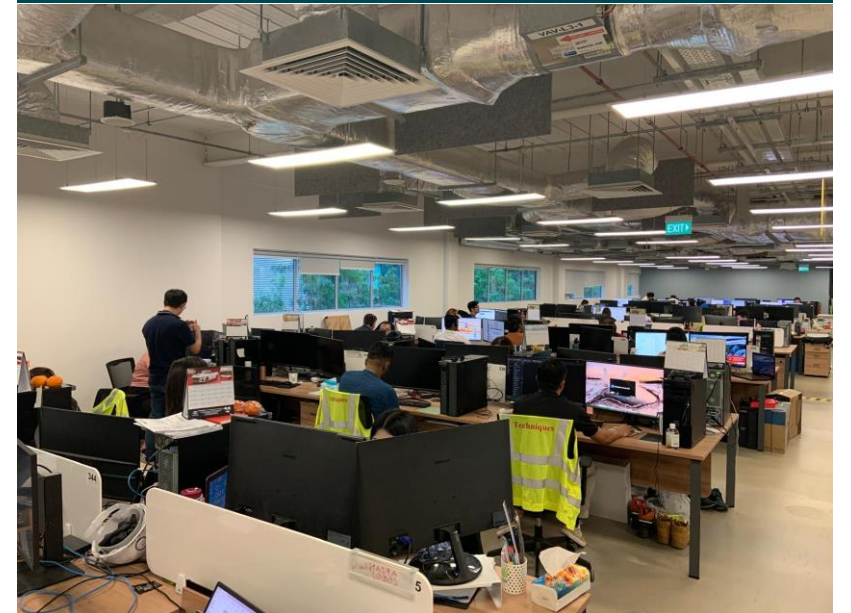
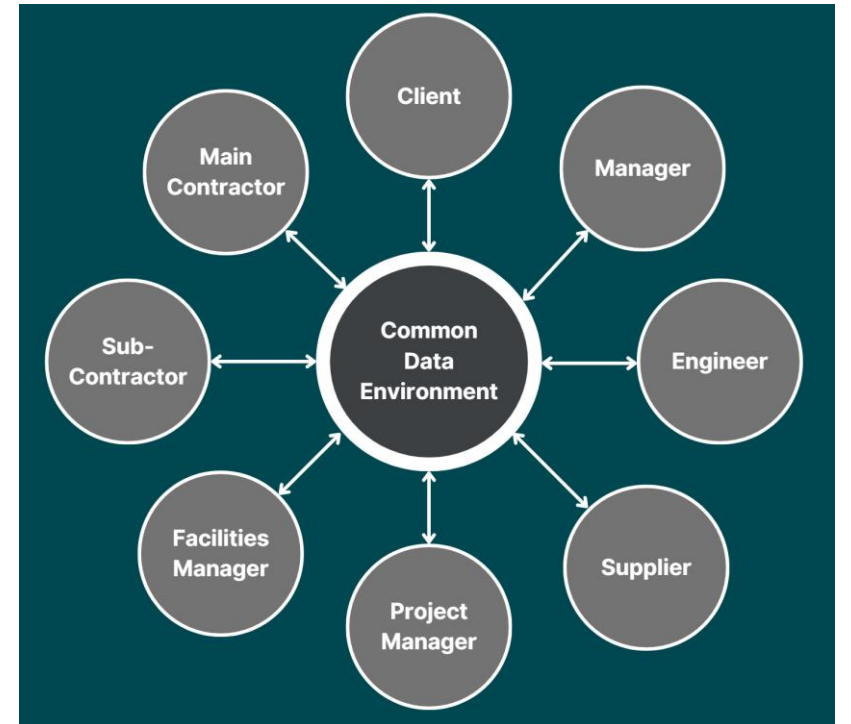
---

FORTIS

# BIM Implementation

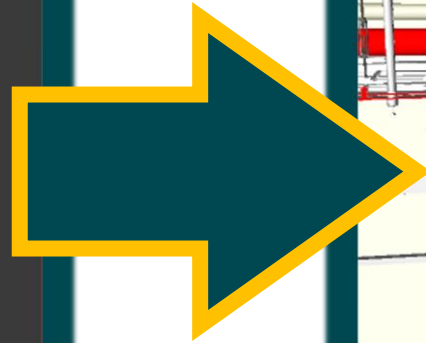
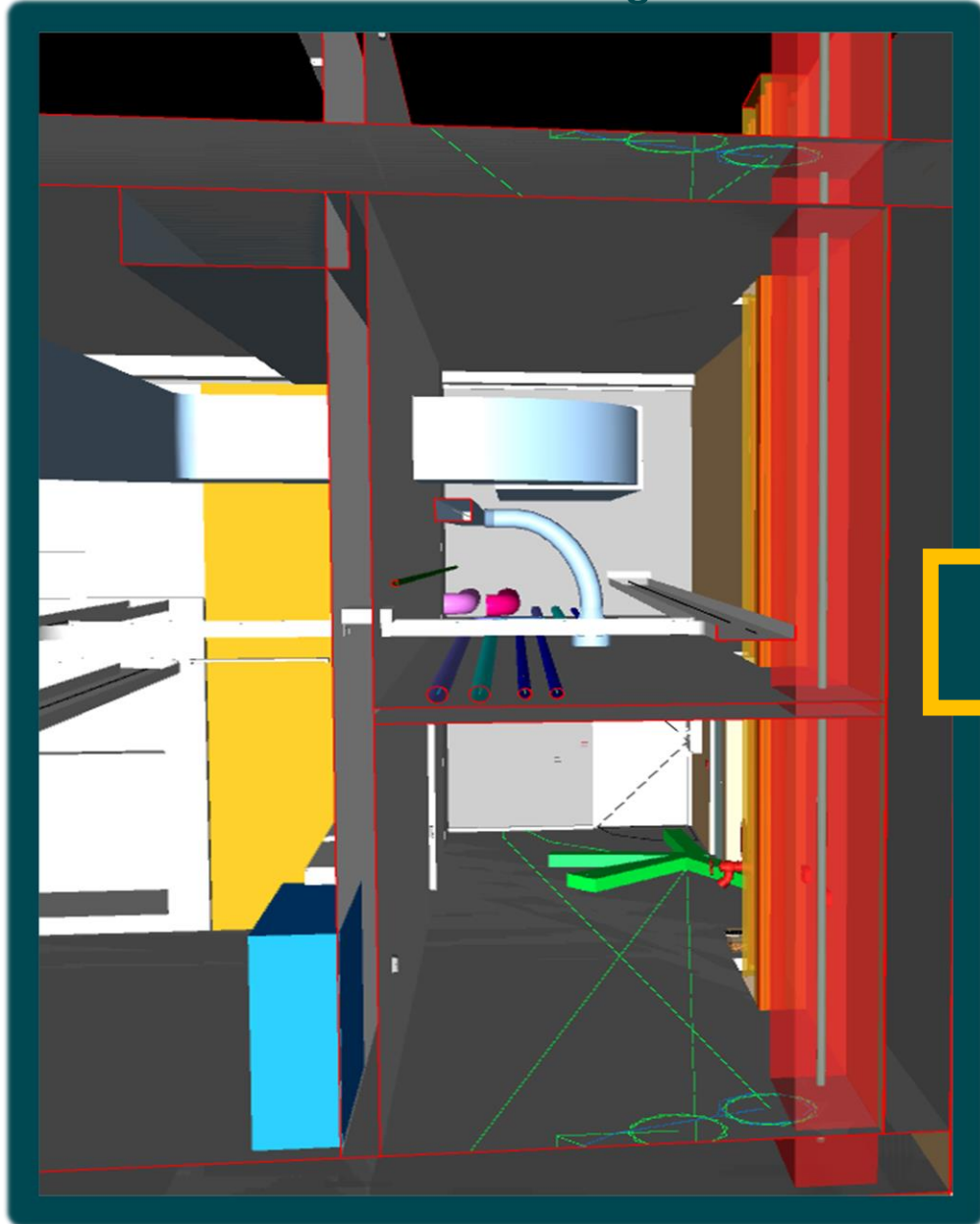
---

1. Common Data Environment
2. Design-Build Managers
3. Co-Locate Project Team
4. Daily Syncs
5. Twice Weekly External Stakeholder Coordination

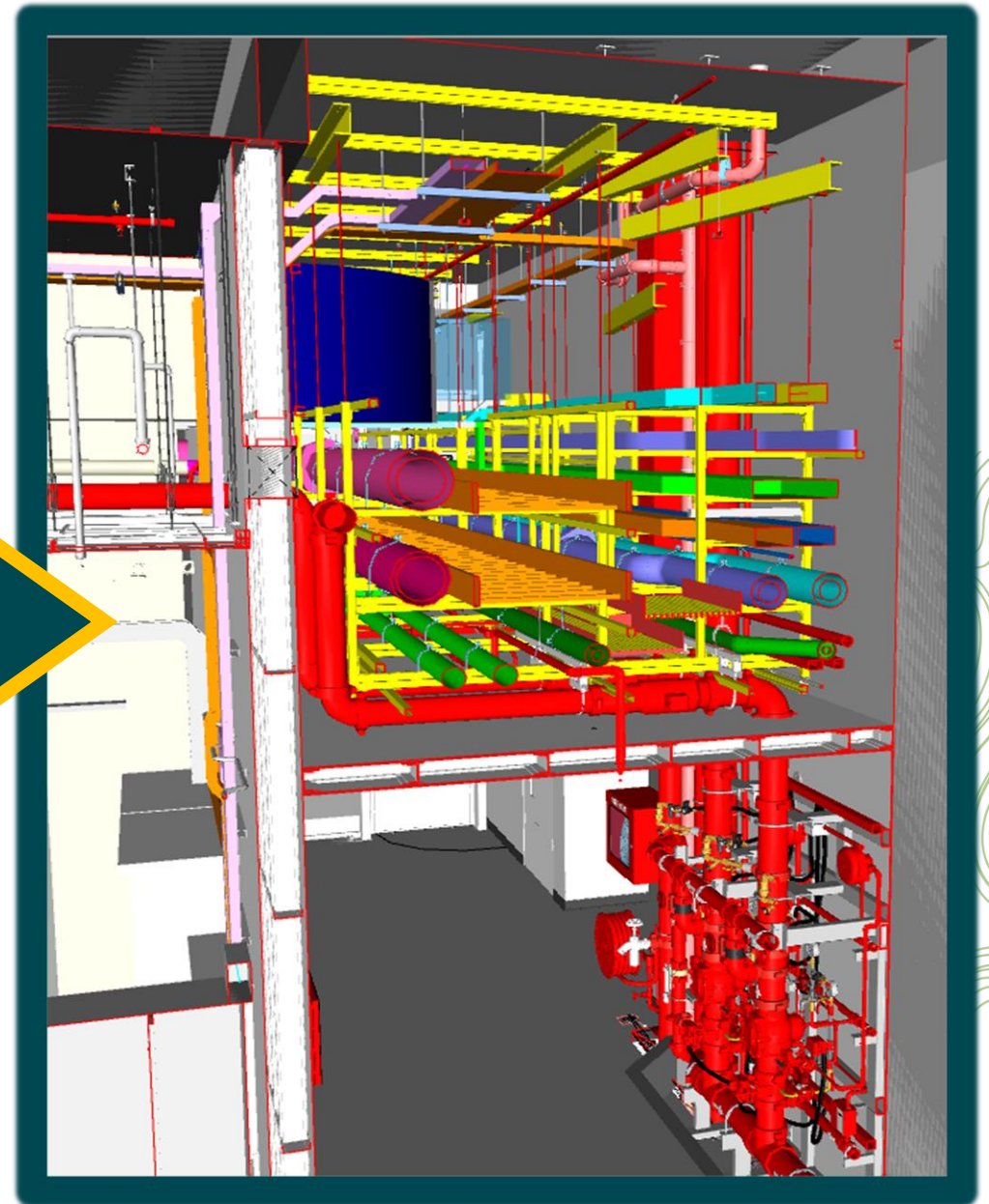


# Coordination Journey

Consultant Design

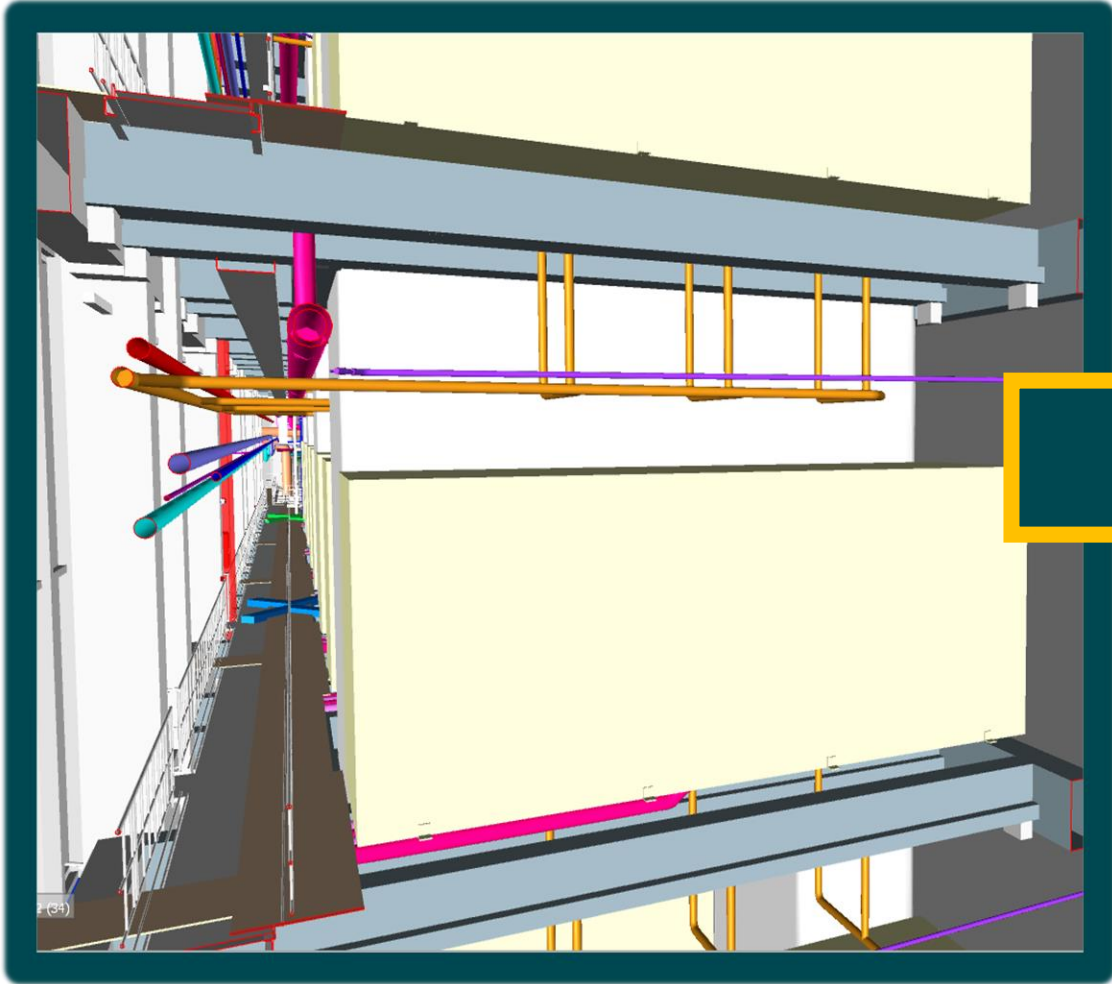


LOD 400 Coordination

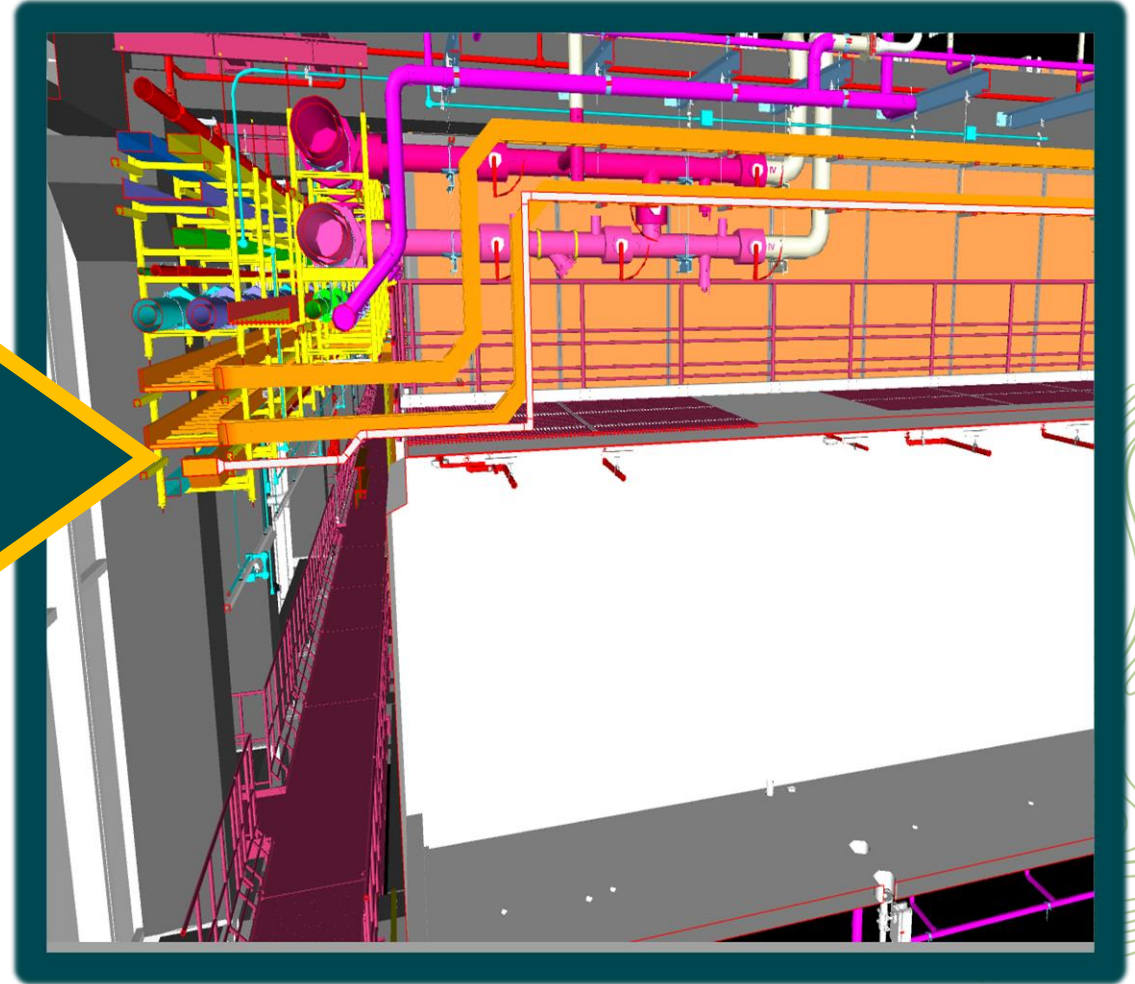


# Coordination Journey

Consultant Design

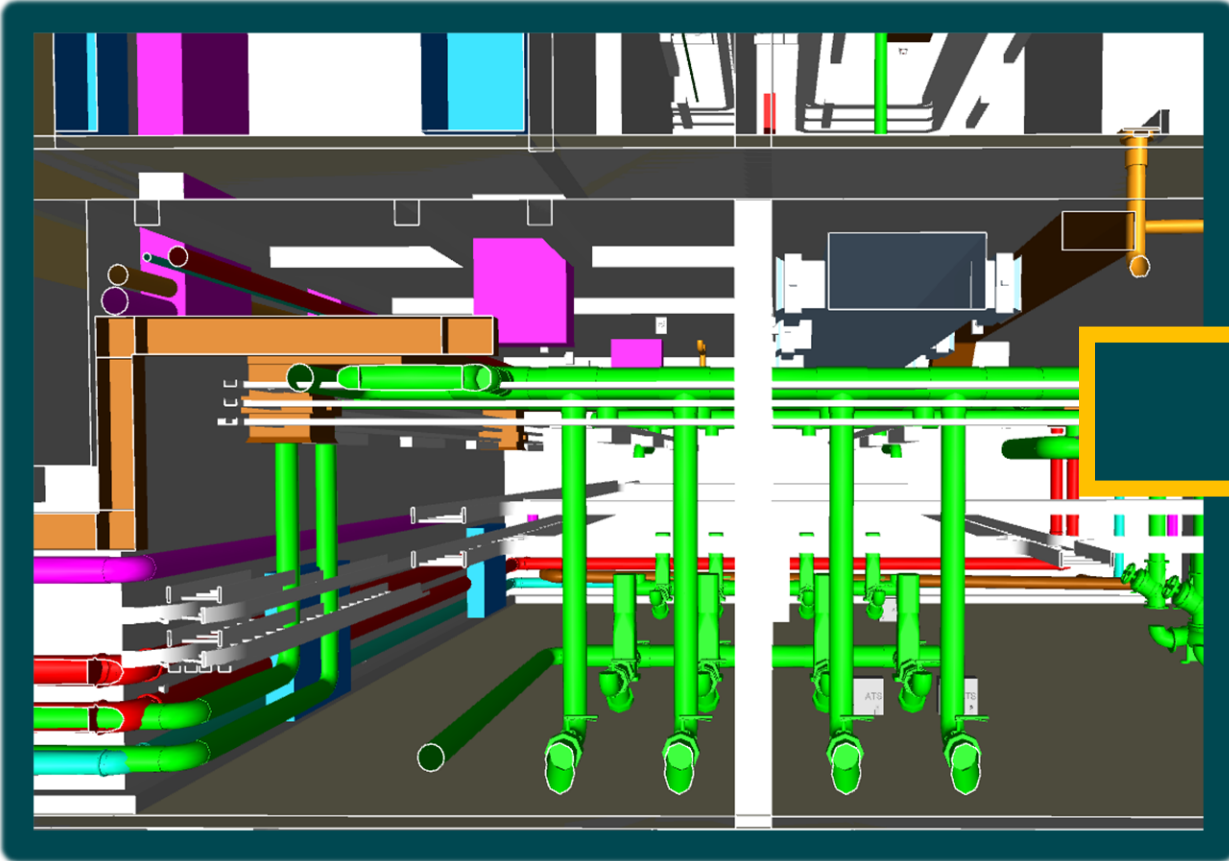


LOD 400 Coordination

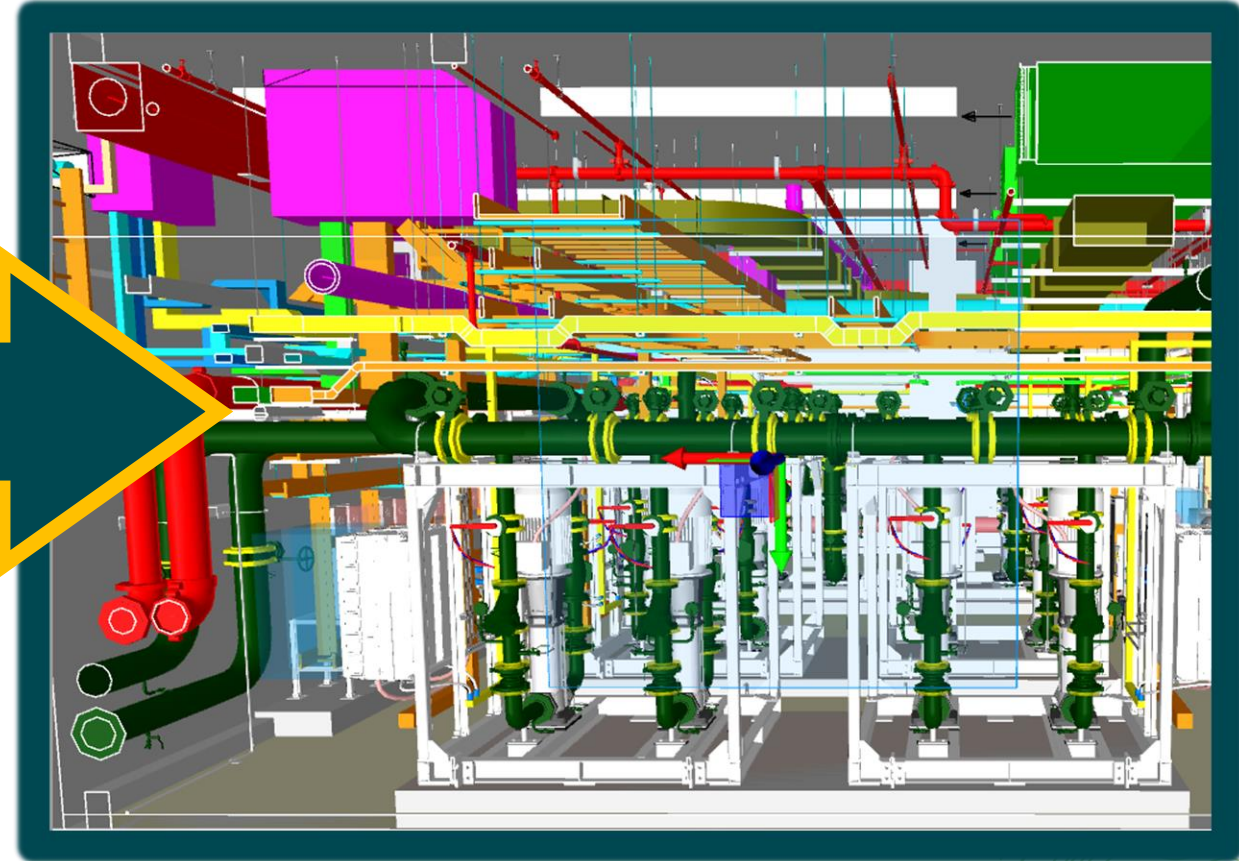


# Coordination Journey

## Consultant Design



## LOD 400 Coordination





# VR Implementation

## Conventional Design Review

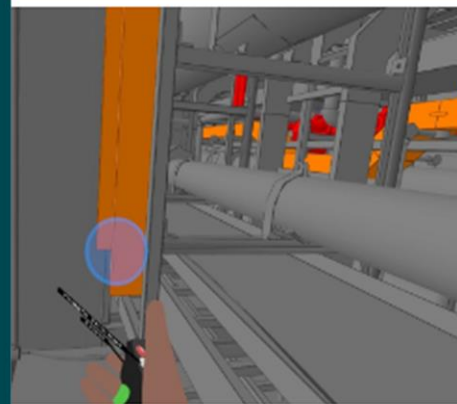


## Immersive Review



# VR Wins

## Issue Discovery: Accessibility, Constructability, and Future Maintenance.



#2450

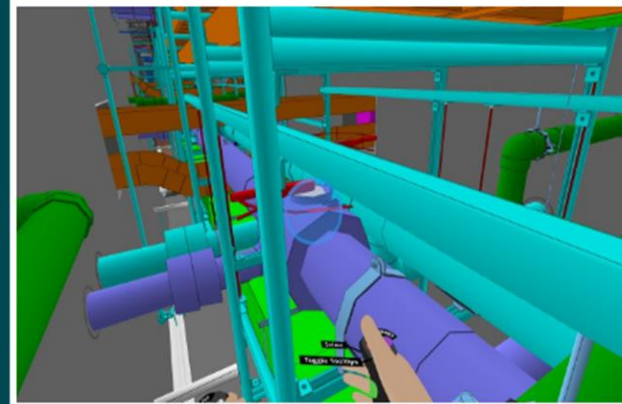
Status: ● Resolved | Tag: Accessibility

Added by: [REDACTED]

Element: [REDACTED] Orange

April 25th, 2024

"Accessibility issue : To check if enough space is available for ladder (maintenance/constructability) [REDACTED] ---> [REDACTED] confirmed Ph2 ladder can be accessed 1(Similar to how it was done in [REDACTED] at site)"



#2420

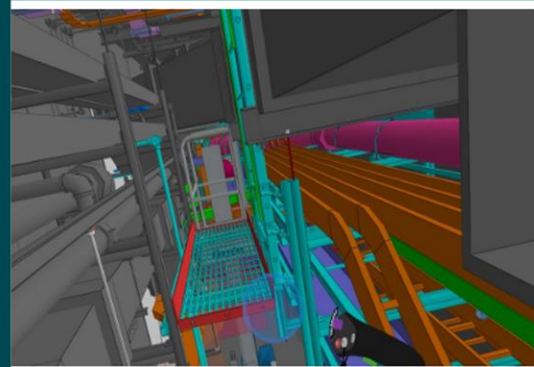
Status: ● Resolved | Tag: Accessibility

Added by: [REDACTED]

Element: Pipe CHWS (Tertiary)

April 25th, 2024

"Maintenance issue : To check accessibility of valve : ---> CHWP and CDP pipe swapped for better access to all valves"



#2437

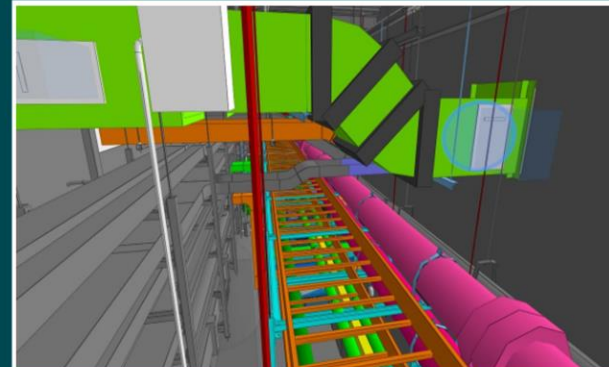
Status: ● Resolved | Tag: Design

Added by: [REDACTED]

Element: Type 1

April 25th, 2024

"Safety hazard ---> Toeboard updated by [REDACTED]"



#3072

Status: ● Resolved | Tag: Operations

Added by: [REDACTED]

Element: Solid

June 6th, 2024

"Access strategy? --->This FD to be accessed [REDACTED] [REDACTED] for FD access strategy)"

# VR Wins

## Fortis VR Design Review Sessions



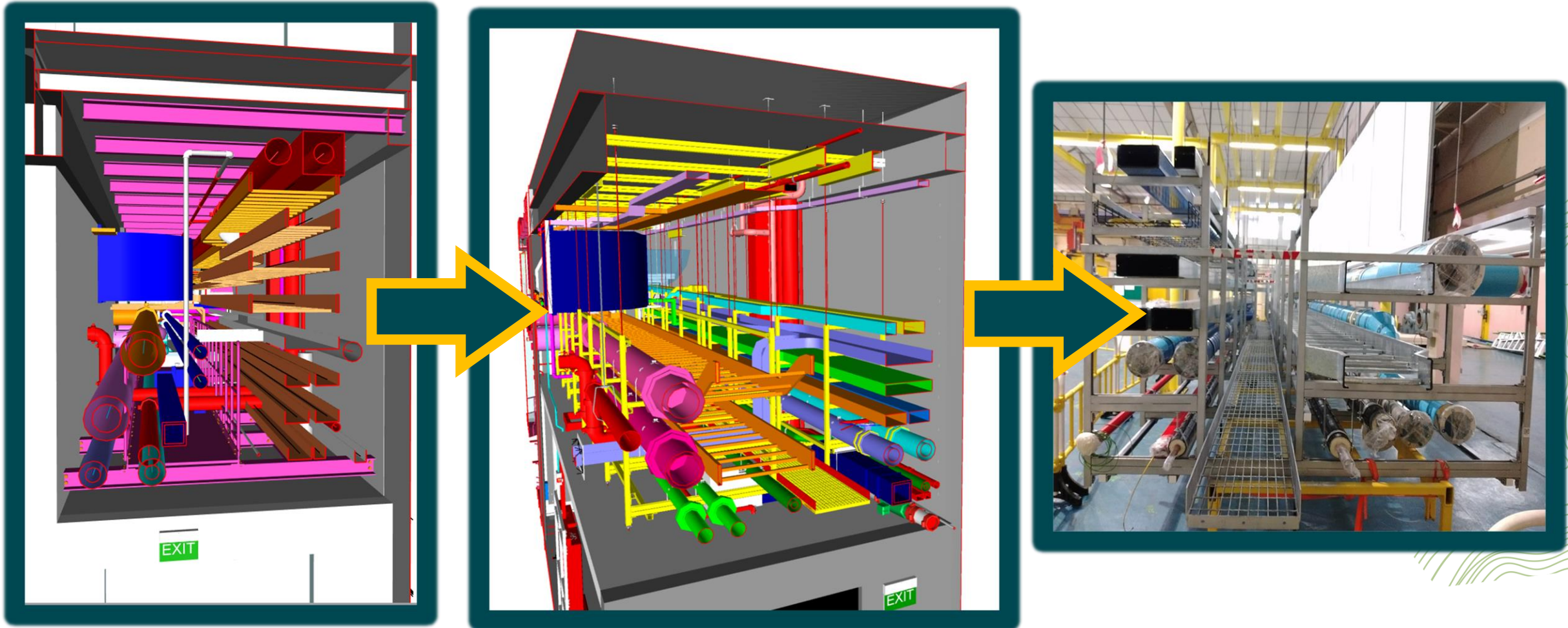
# 4D Sequencing

- Better Understanding of Accessibility
- Demonstration to Stakeholders
- Review Design For Safety Compliance
- Expedite Facility Operations Planning



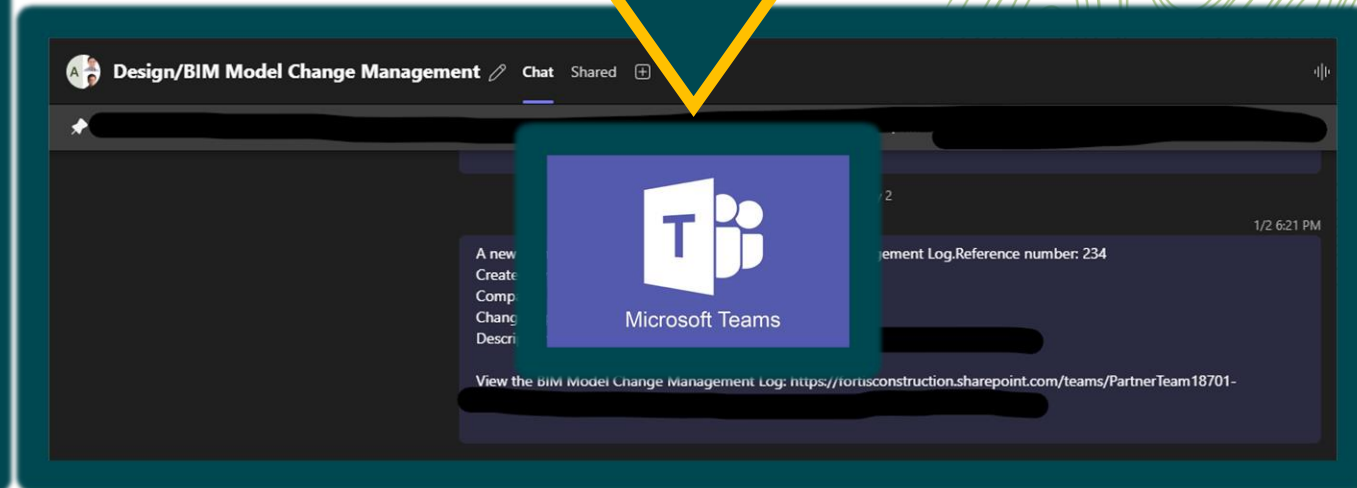
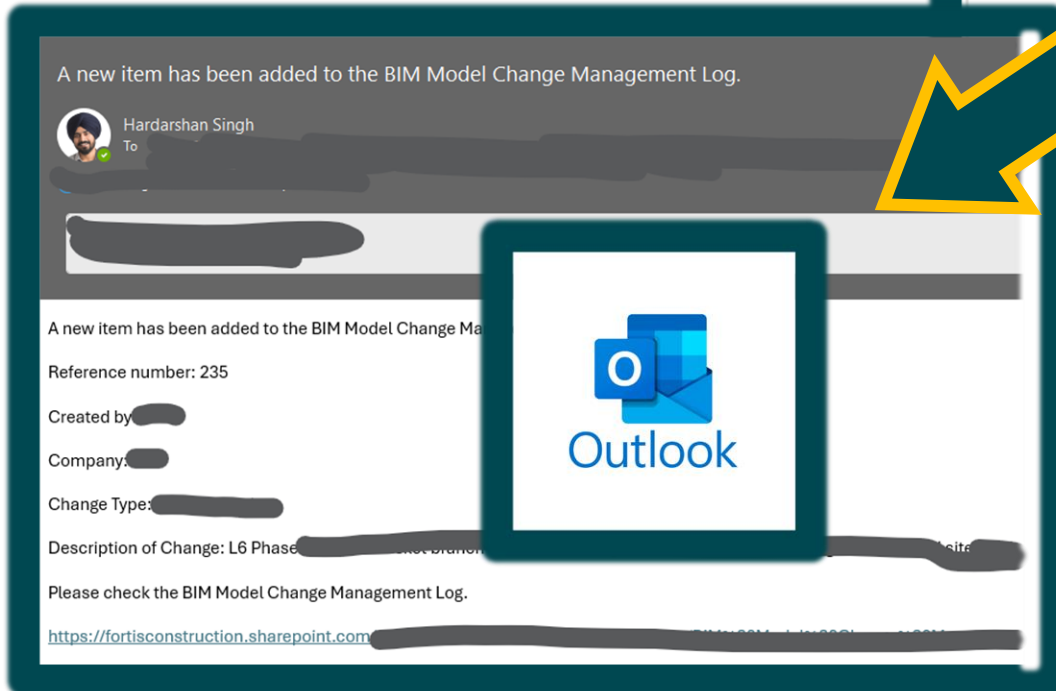
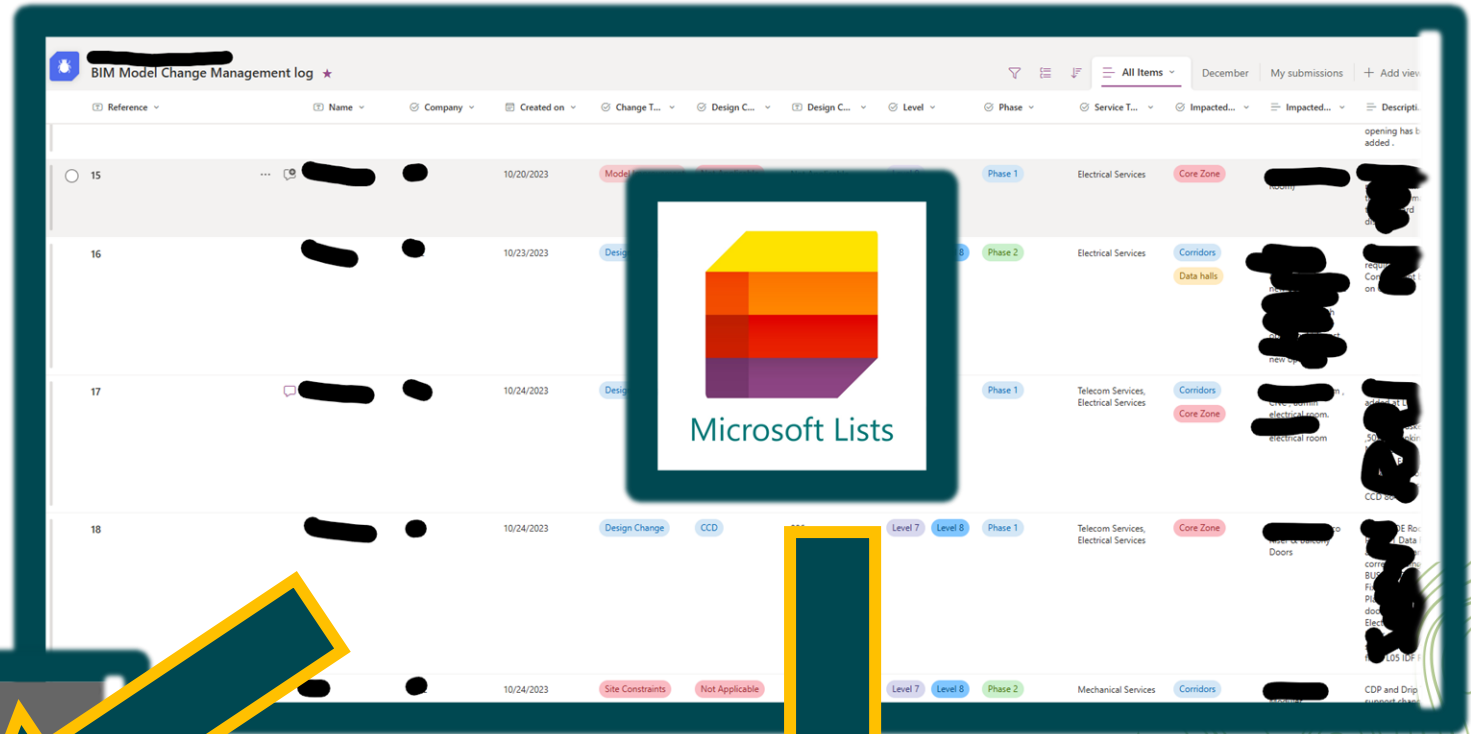
# Standardization

- Standardized & Simplified Modules to the greatest extent possible



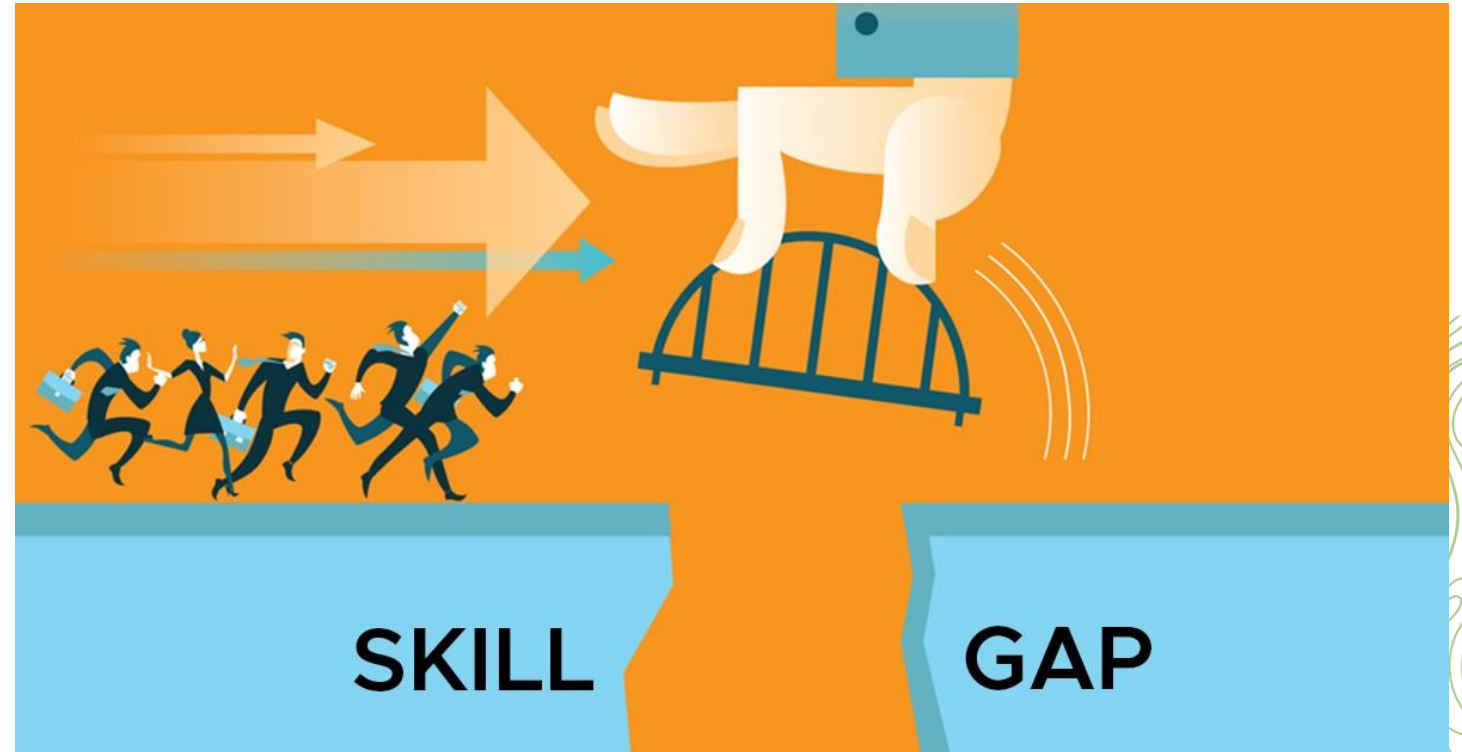
# Implementation

- BIM Model Change Management Log – Microsoft Lists
- Automate notifications for model changes - Power Automate
- Review all changes during daily meetings
- Address Changes Promptly



# Skills Gap

- Key hires to bridge the skills gap
- Relatable skill sets
- Manufacturing background



# Design Lessons Learned and Key Takeaways

FORTIS



# Design Lesson Learned and Key Takeaways

- CDE (Common Data Environment).
- Introduce DFMA intent in the design.
- Early engagement with stakeholders.
- Technology Integration – VR, AR, 4D, or other emerging technologies.
- Simplification, Standardization, and Repeatability.
- Sufficient tolerances & Design for transportation.
- Willpower





**WHY DID WE START  
ADOPTING DfMA?**





**CLIENT  
REQUIREMENT**

A worker wearing a blue protective suit, a white face mask, and a cap is working inside a large, circular industrial pipe. The worker is using a tool to work on the interior of the pipe. The background shows other pipes and industrial equipment. The image is overlaid with two blue rectangular boxes containing text.

**CLIENT  
REQUIREMENT**

**SCHEDULE  
REQUIREMENT**

A black and white photograph of a worker in a blue protective suit, cap, and mask, working inside a large industrial pipe. The worker is using a tool to work on the interior of the pipe. The scene is dimly lit, with light coming from the opening of the pipe. Three blue rectangular overlays are positioned horizontally across the middle of the image, each containing text.

**CLIENT  
REQUIREMENT**

**SCHEDULE  
REQUIREMENT**

**WE WANTED TO  
DO IT BETTER**



**HOW DID WE BEGIN?**



# INFRASTRUCTURE



## INFRASTRUCTURE

- Size
- Flow
- Facilities
  - Cranes
  - Gases
  - Electrical Requirement





**INFRASTRUCTURE**

**KNOWLEDGE  
BASE**



**INFRASTRUCTURE**

**KNOWLEDGE  
BASE**

- Bringing experts
- Previous experiences (Prefab)
- Knowledge shared
  - BCA
  - Write-ups
  - Articles



**INFRASTRUCTURE**

**KNOWLEDGE  
BASE**

**OPERATIONS**



**INFRASTRUCTURE**

**KNOWLEDGE  
BASE**

**OPERATIONS**

- New Processes & Protocols
- Educating existing stake-holders
- Procurement & Contracting
- Logistics
- Automation



**INFRASTRUCTURE**

**KNOWLEDGE  
BASE**

**OPERATIONS**

**INTEGRATION**



**INFRASTRUCTURE**

**KNOWLEDGE  
BASE**

**OPERATIONS**

**INTEGRATION**

- Design Coordination
- Revising traditional contracting models
- Introducing Multi-trade workflows
  - Off-site integration
- QAQC during fabrication
- Logistics partners role

TECHNIQUES MODULE FACILITY  
MEP PREFABRICATION FACILITY



 **Techniques**

 **EMERGENCY ASSEMBLY POINT**

 **Techniques Module Facility**  
7 Teas View Circuit

## 1. SPATIAL SETUP

- FABRICATION SPACES REQUIREMENT
- DIFFERENT ZONES TO FACILITATE FABRICATION PROCESS & SPACE
- MATERIALS HANDLING REQUIREMENT

## 2. CRANEAGE

- OVERHEAD CRANE WITH SUFFICIENT CAPACITY
- SUFFICIENT COVERAGE

## 3. AUTOMATION

- INTEGRATED DIGITAL DELIVERY
- BOOST EFFICIENCY
- CUTTING MACHINES
- WELDING MACHINES
- COLLARING MACHINES

## 4. STORAGE

- HOLDING AREAS FOR MATERIALS, INSPECTIONS
- POTENTIAL HOLDING AREAS FOR STORING PRIOR TO SITE READINESS



# TECHNIQUES MODULE FACILITY LAYOUT PLAN

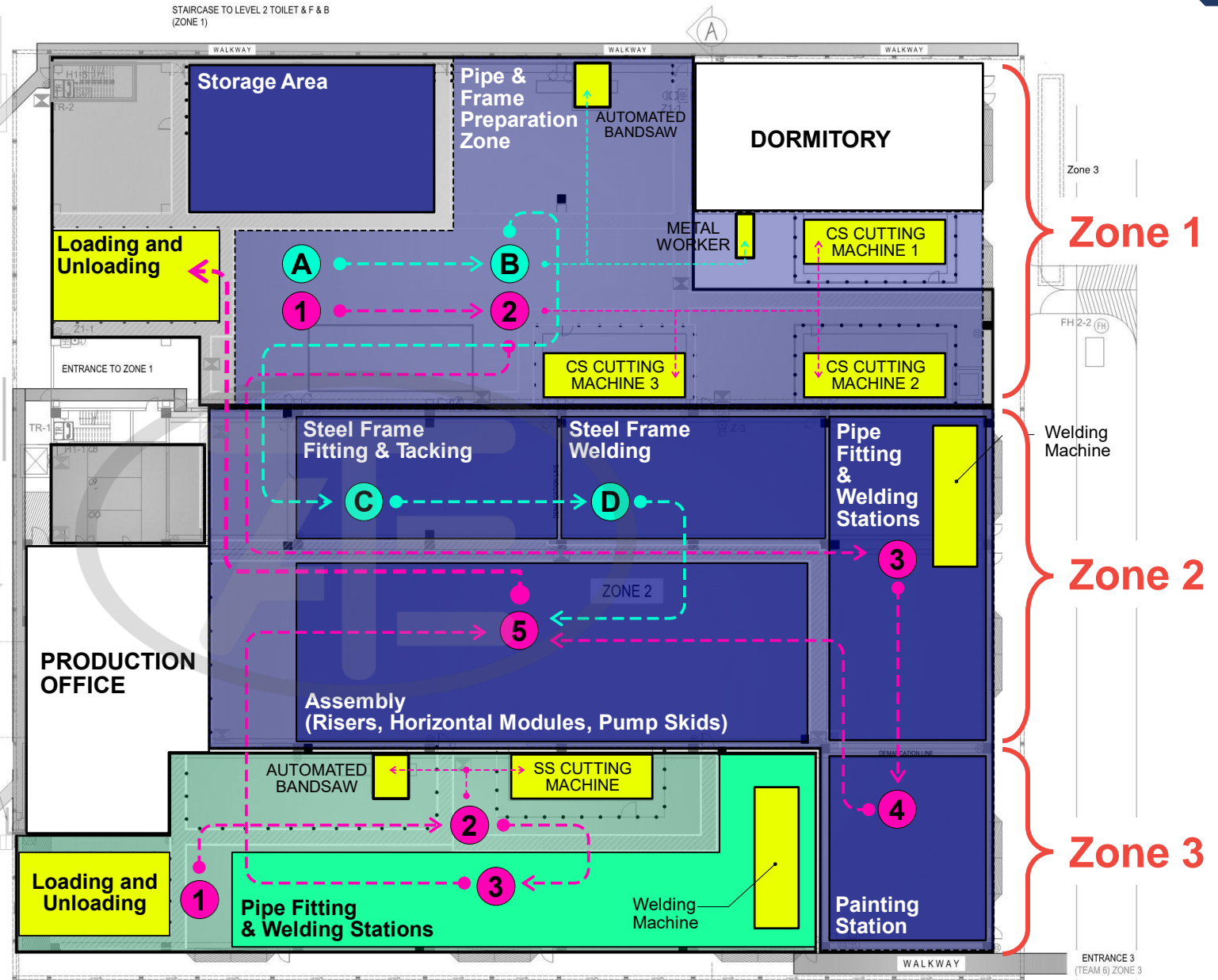
## STEELWORK SEQUENCE

- A** Incoming material
- B** Preparation / Cutting
- C** Fitting and Tacking
- D** Welding

## PIPEWORK SEQUENCE

- 1** Incoming material
- 2** Preparation / Cutting
- 3** Fitting and Welding
- 4** Painting and Insulation
- 5** Assembly & Inspection

Mild Steel Zone  
Stainless Steel Zone





# ZONE 1

Safety Always Success  
Accidents Always Failure

ABUS 20t



OVERHEAD  
CRANE

CS CUTTING  
MACHINE 1

AUTOWELDING  
MACHINE

AUTO BAND SAW

CS CUTTING  
MACHINE 2

CS CUTTING  
MACHINE 3

CNC PLATE  
CUTTING

Safety  
Accid

Success  
Fail

**ZONE 1**  
PREPARATION WORKS

TECHNIQUES MODULE FACILITY  
2 - PREPARATION OF PIPE SPOOL



HGG CUTTING MACHINE  
CS CUTTING MACHINE 1

TECHNIQUES MODULE FACILITY  
2 - PREPARATION OF PIPE SPOOL



HGG CUTTING MACHINE  
CS CUTTING MACHINE 2 & 3

TECHNIQUES MODULE FACILITY  
2 - PREPARATION OF PIPE SPOOL



Carbon Steel  
Cut Samples



CAPABILITY DEVELOPMENT  
HGG Video

TECHNIQUES MODULE FACILITY  
2 - PREPARATION OF STEEL WORKS



**MACHINE CUTTING**  
AUTO BAND SAW MACHINE

TECHNIQUES MODULE FACILITY  
2 - PREPARATION OF STEEL WORKS



PLATE CUTTING  
CNC CUTTING MACHINE



TECHNIQUES MODULE FACILITY  
B - PREPARATION OF STEELWORKS



**GEKA METAL WORKER**  
BRACKET PUNCH PIECES

TECHNIQUES MODULE FACILITY  
B – AUTO WELDING



AUTO WELDING MACHINE  
FLANGE WELDING

# ZONE 2

Through the Quality of our People  
We Seal Everyone Home Safe and Sound

ING STATION  
6

TECHNIQUES MODULE FACILITY  
5 – ASSEMBLY

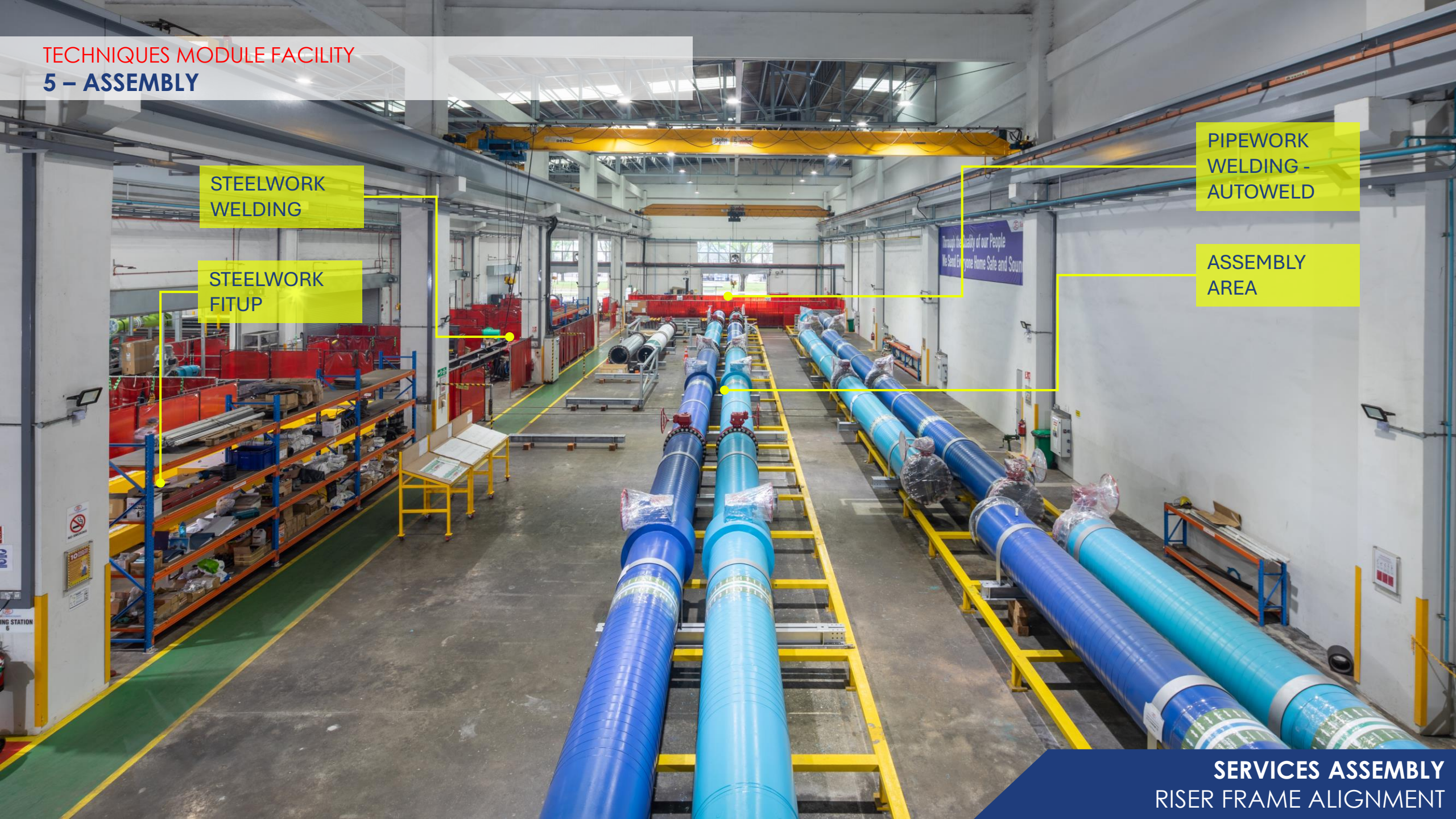
STEELWORK  
WELDING

STEELWORK  
FITUP

PIPEWORK  
WELDING -  
AUTOWELD

ASSEMBLY  
AREA

SERVICES ASSEMBLY  
RISER FRAME ALIGNMENT



TECHNIQUES MODULE FACILITY  
3 – PIPE WELDING



TECHNIQUES MODULE FACILITY  
3 – PIPE WELDING



Set-up of Carbon Steel  
Welding Machine



# ZONE 3



**TECHNIQUES MODULE FACILITY**  
**LAYOUT PLAN**

SS CUTTING  
MACHINE 4

AUTOMATED  
BAND SAW

MATERIAL  
STORAGE

WELDING MACHINE  
HERE

PIPE FAB &  
WELDING AREA

**ZONE 3**

SS CUT / FAB / WELDING



TECHNIQUES MODULE FACILITY  
3 – SS PIPE CUTTING

28 Tuas South Avenue 8  
Tuas 637648  
Singapore

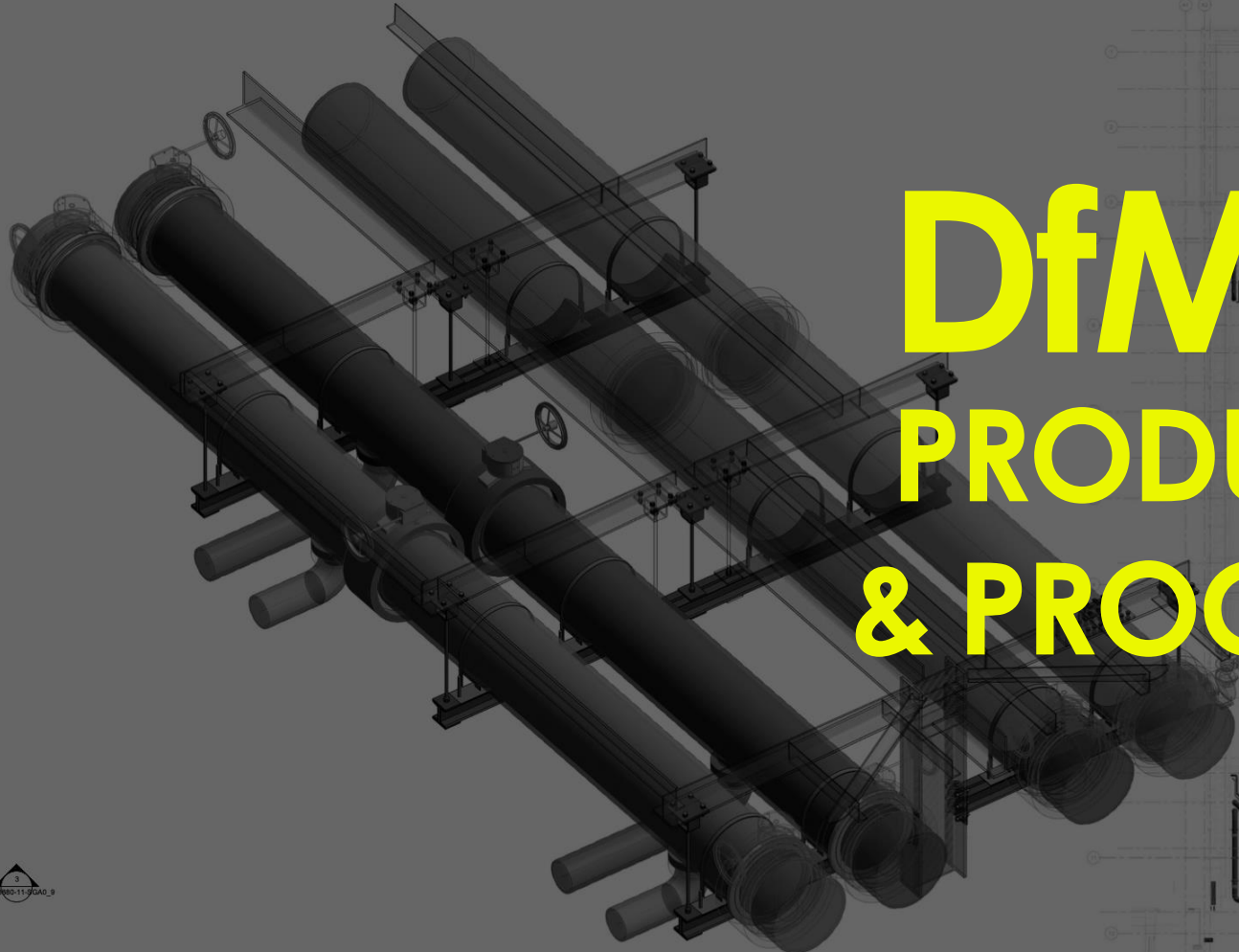


PIPE CUTTING  
HGG SS CUTTING MACHINE

TECHNIQUES MODULE FACILITY  
3 – SS PIPE WELDING

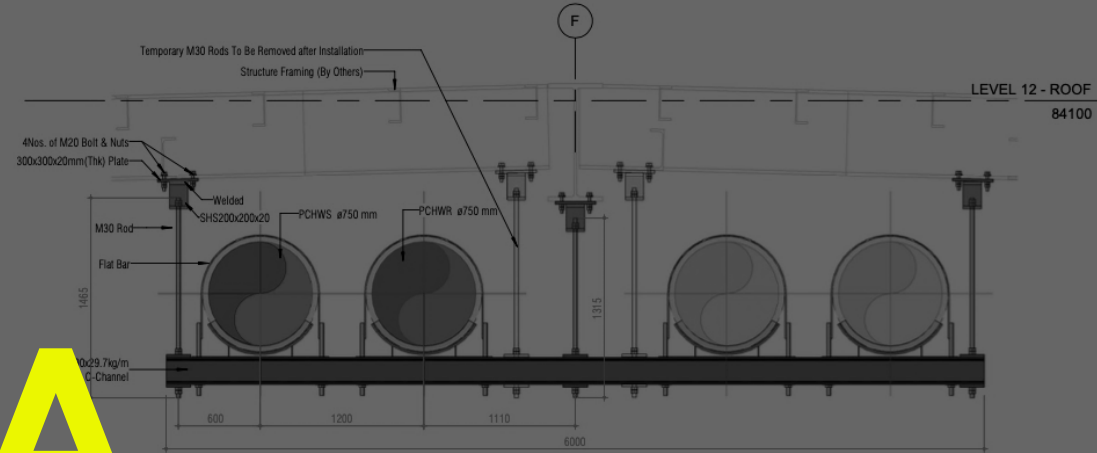


PIPE WELDING  
AUTOMATED SS WELDING MACHINE



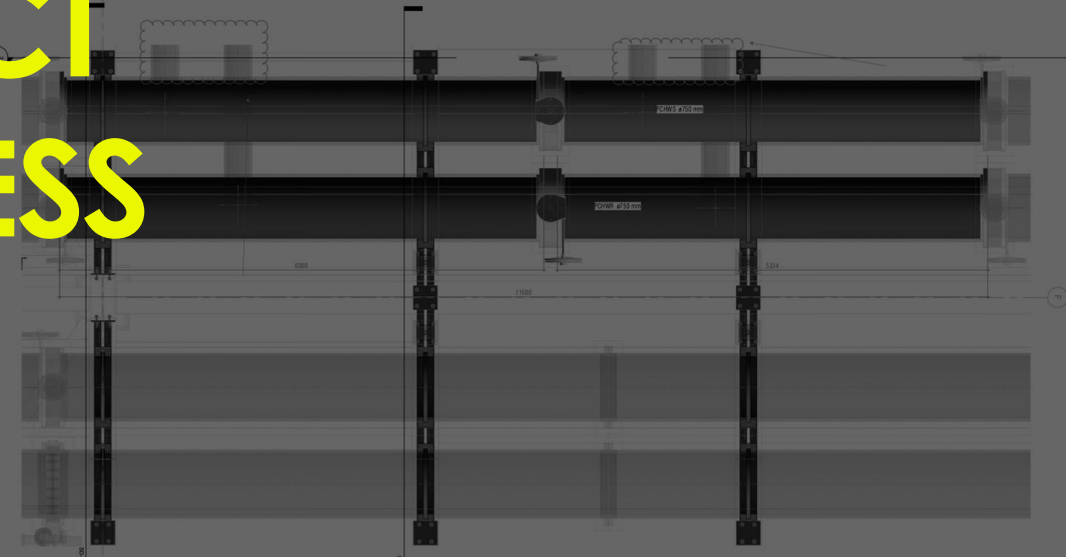
3D VIEW OF CHWP (PRIMARY) MODULE 9  
SCALE

# DfMA PRODUCT & PROCESS

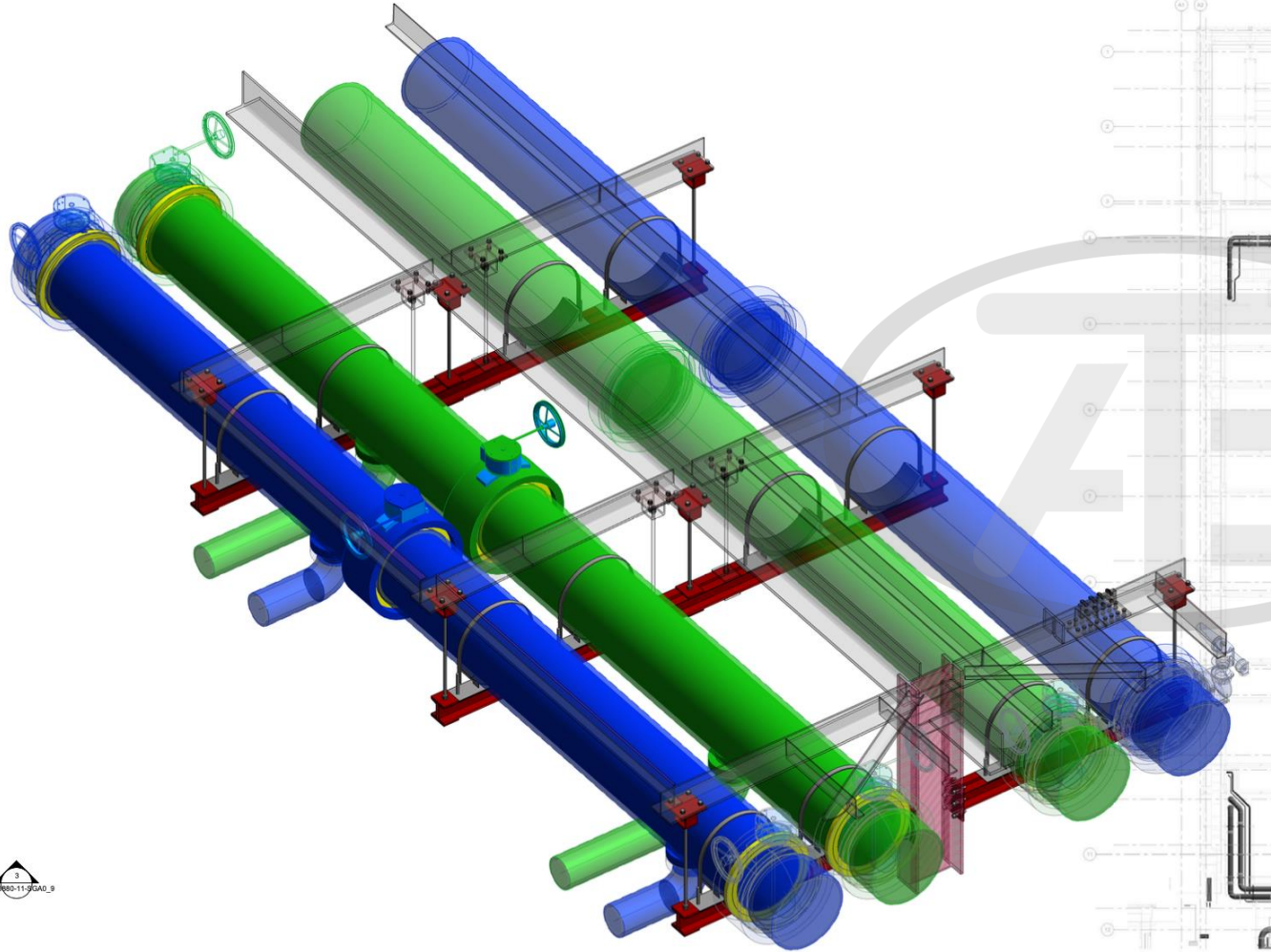


3 Section B - CHILLED WATER PIPE (PRIMARY) MODULE 9  
SCALE 1:25

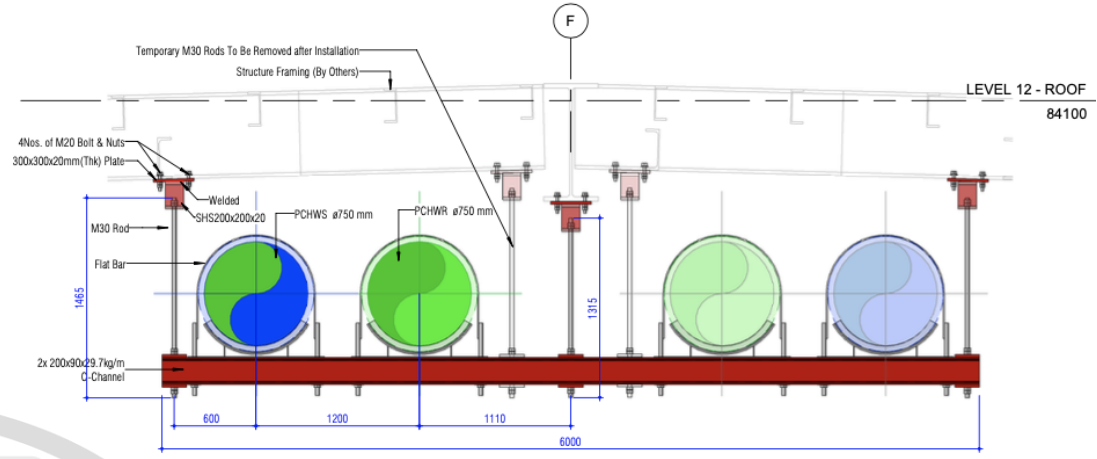
1 CHILLED WATER HEADER PIPE MODULE 9  
SCALE 1:25



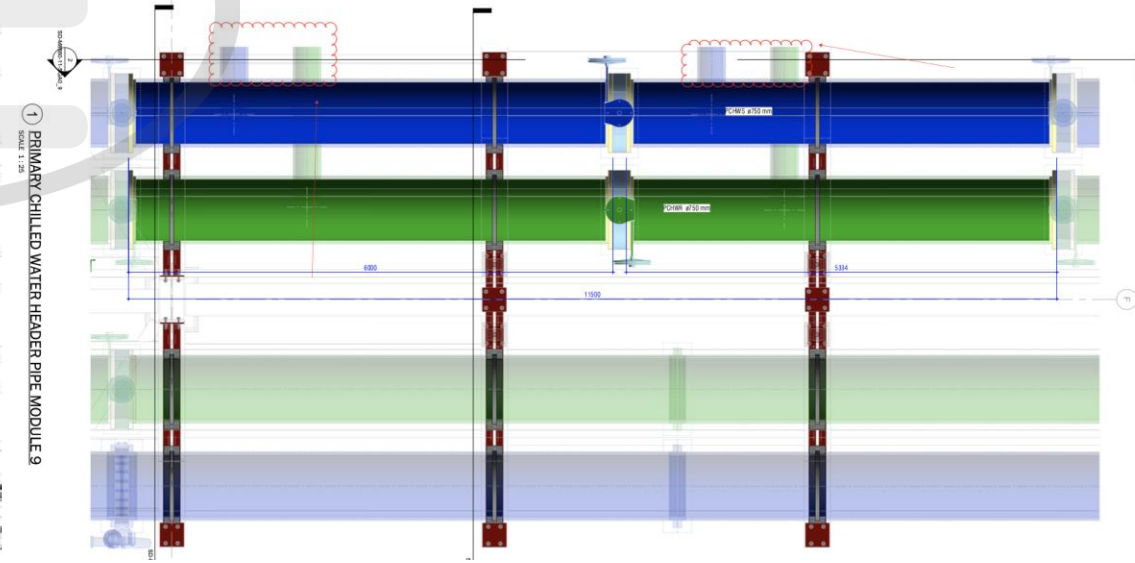
**PREFABRICATION**  
**PREFAB: HORIZONTAL PIPING MODULE**



3D VIEW OF CHWP (PRIMARY) MODULE 9  
 SCALE



3 Section B - CHILLED WATER PIPE (PRIMARY) MODULE 9  
 SCALE 1 : 25



1 PRIMARY CHILLED WATER HEADER PIPE MODULE 9  
 SCALE 1 : 25

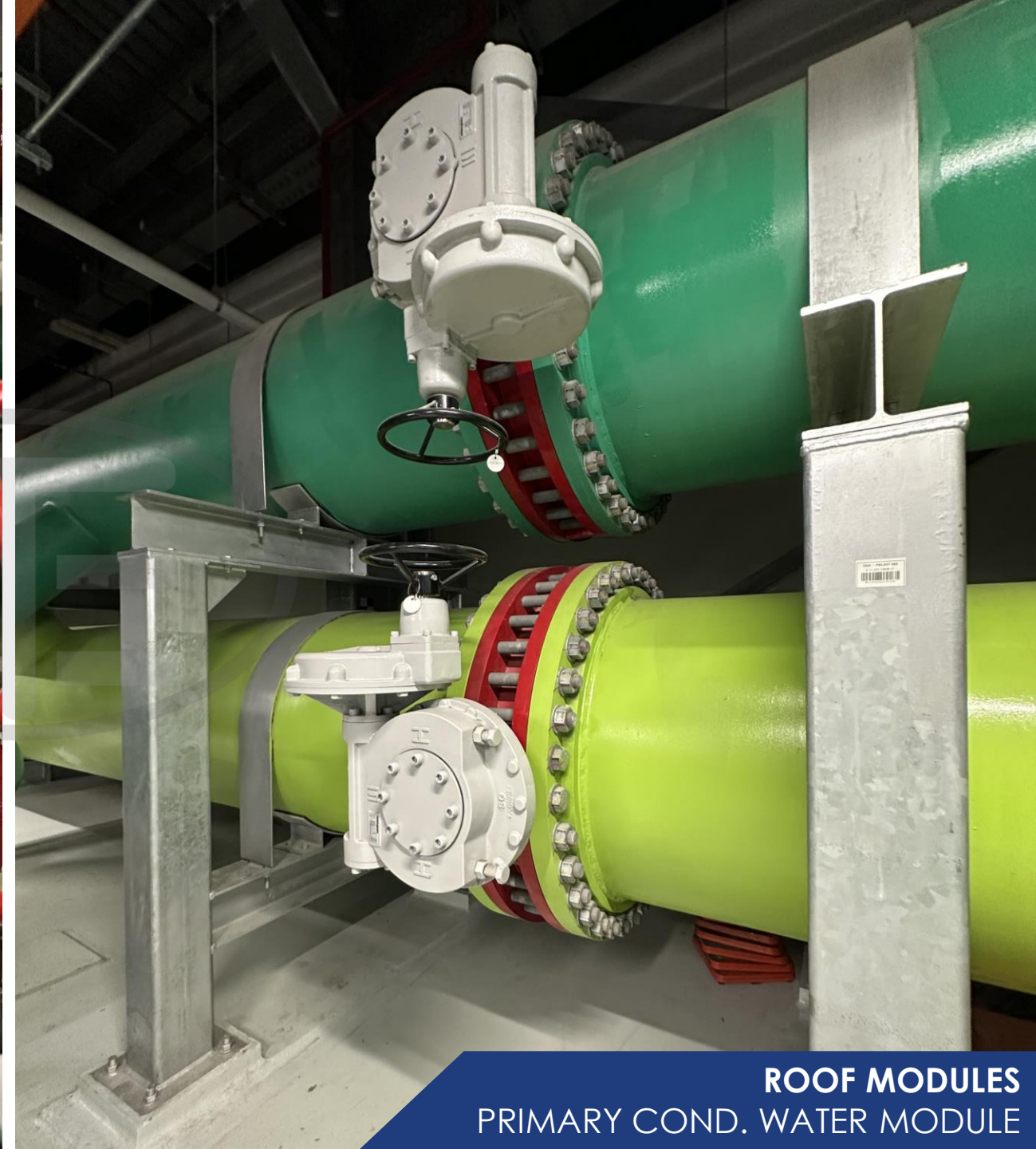


MODULE FACILITY  
PREFAB: HORIZONTAL PIPING MODULE



**ROOF MODULES**  
PRIMARY CHILLED WATER MODULE

**MODULE FACILITY**  
**PREFAB: HORIZONTAL PIPING MODULE**



**ROOF MODULES**  
**PRIMARY COND. WATER MODULE**

**MODULE FACILITY**  
**PREFAB: HORIZONTAL PIPING MODULE**

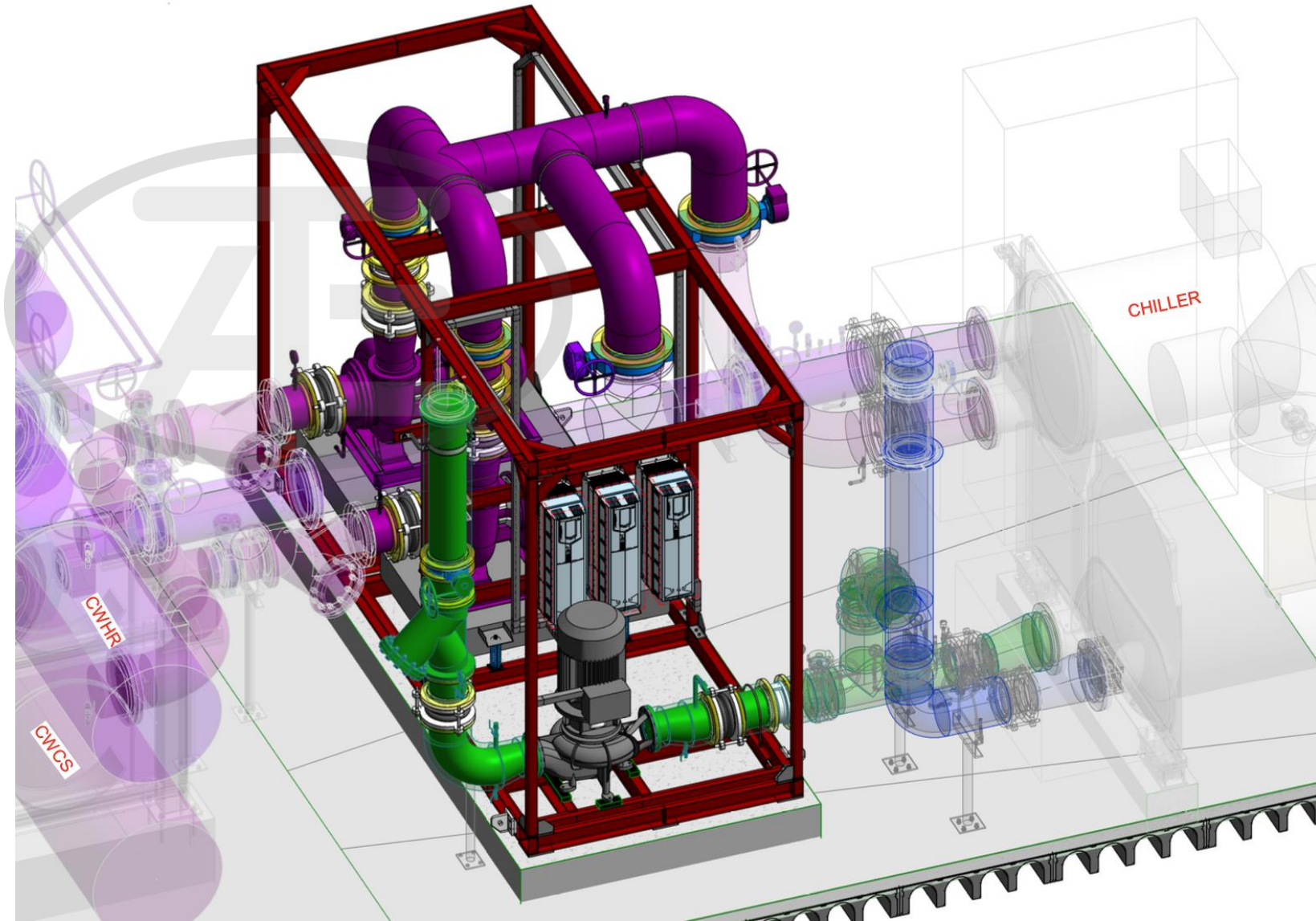


**ROOF MODULES**  
**PRIMARY COND. WATER MODULE**

PREFABRICATION  
PREFAB: SKID MODULES

## PREFABRICATED SKID MODULES

- EQUIPMENT PRE-INSTALLED AND TESTED
- PIPE HEADERS FABRICATED TOGETHER WITH EQUIPMENT
- MINIMIZE ON SITE WELDING AND HIGHER QUALITY CONTROL IN FACILITY ENVIRONMENT





TECHNIQUES MODULE FACILITY  
PREFAB: PLANT ROOM PUMP SKIDS



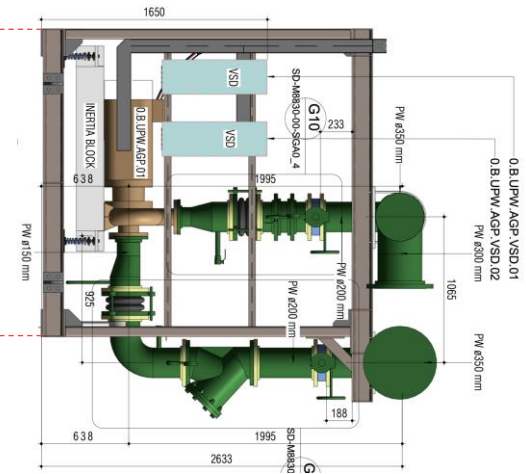
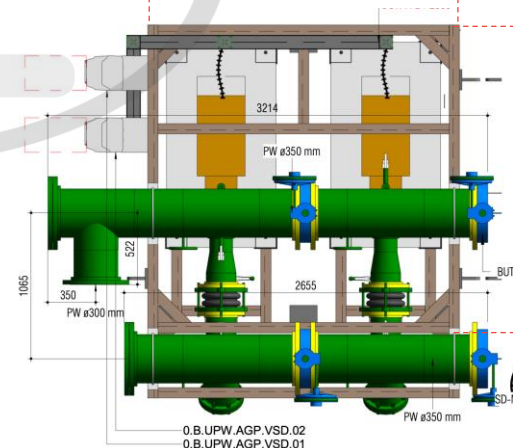
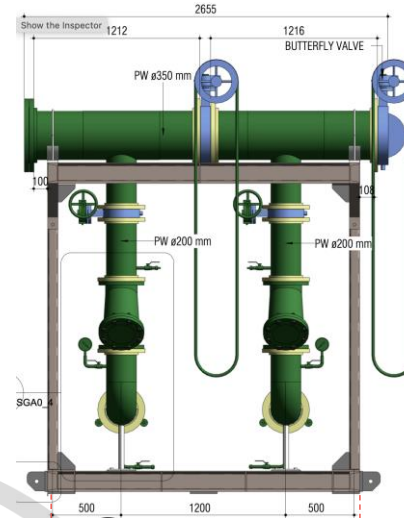
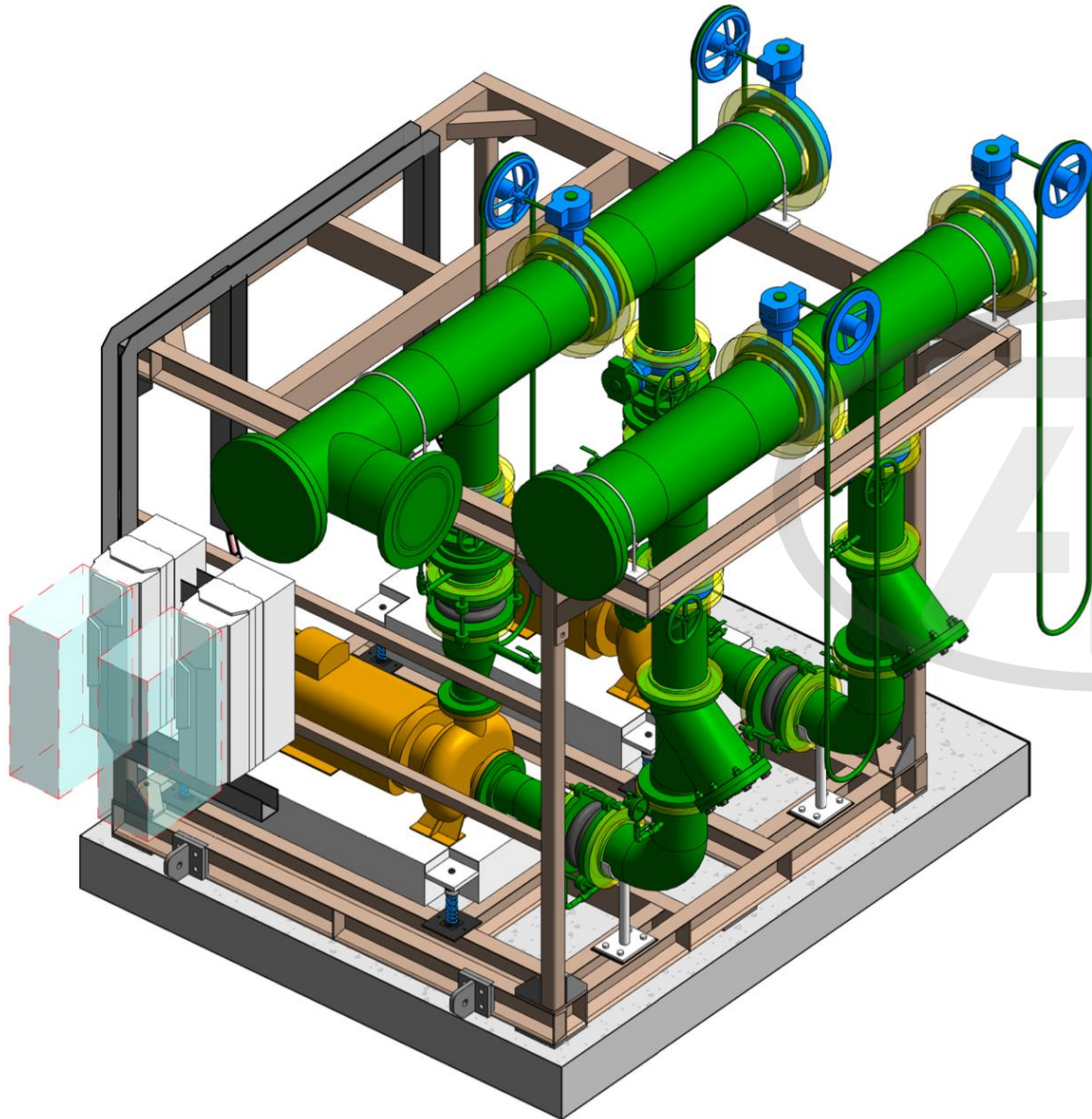
SKID MODULES  
PRE-TESTING

TECHNIQUES MODULE FACILITY  
PREFAB: PLANT ROOM PUMP SKIDS



SKID MODULES  
SITE INSTALLATION

PREFABRICATION  
**PREFAB: PROCESS WATER PUMP SKID**

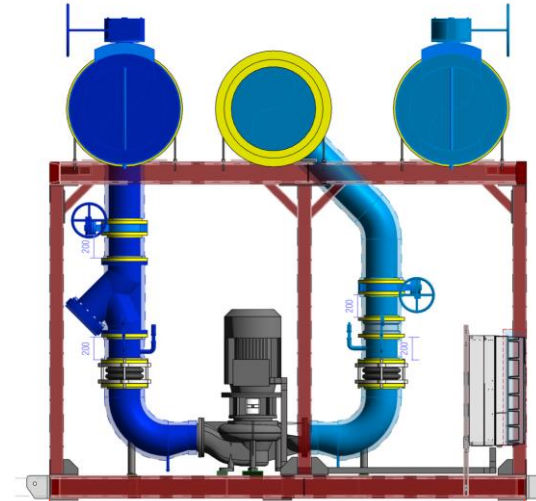
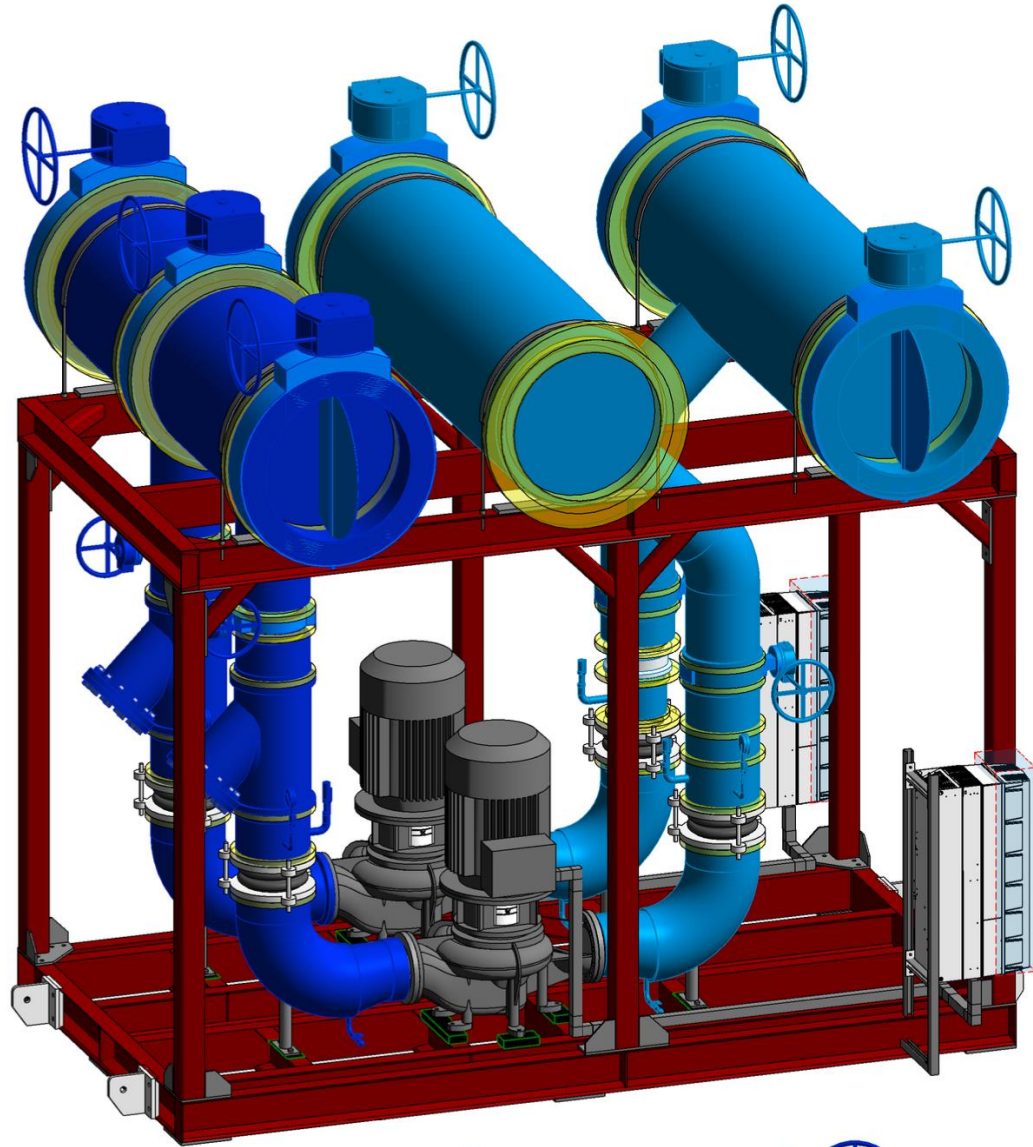


TECHNIQUES MODULE FACILITY  
PREFAB: PROCESS WATER PUMP SKIDS

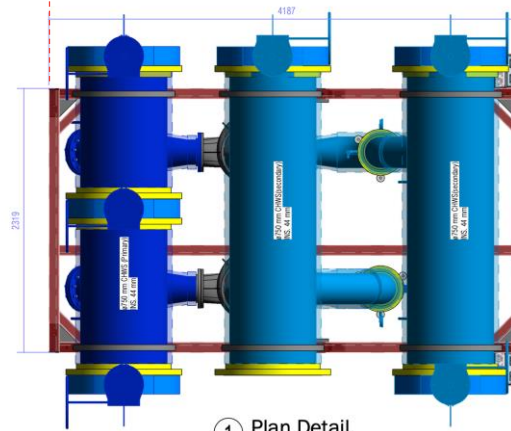


SKID MODULES  
PRE-TESTING

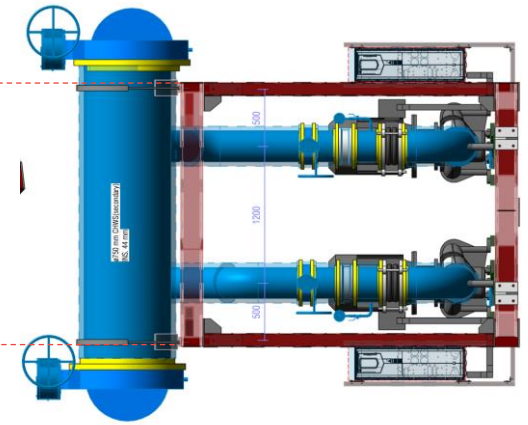
PREFABRICATION  
PREFAB: SECONDARY CHILLED WATER PUMP SKID



② Elevation Front  
SCALE 1:25



① Plan Detail  
SCALE 1:25



MODULE FACILITY

PREFAB: SECONDARY CHILLED WATER PUMP SKIDS



SKID MODULES  
PUMP AND PLANTROOM SKIDS

MODULE FACILITY

PREFAB: SECONDARY CHILLED WATER PUMP SKIDS



SKID MODULES  
PUMP AND PLANTROOM SKIDS

MODULE FACILITY  
PREFAB: SECONDARY CHILLED WATER PUMP SKIDS



SKID MODULES  
PUMP AND PLANTROOM SKIDS



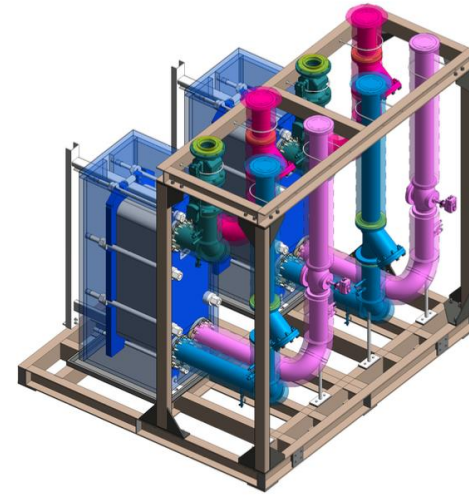
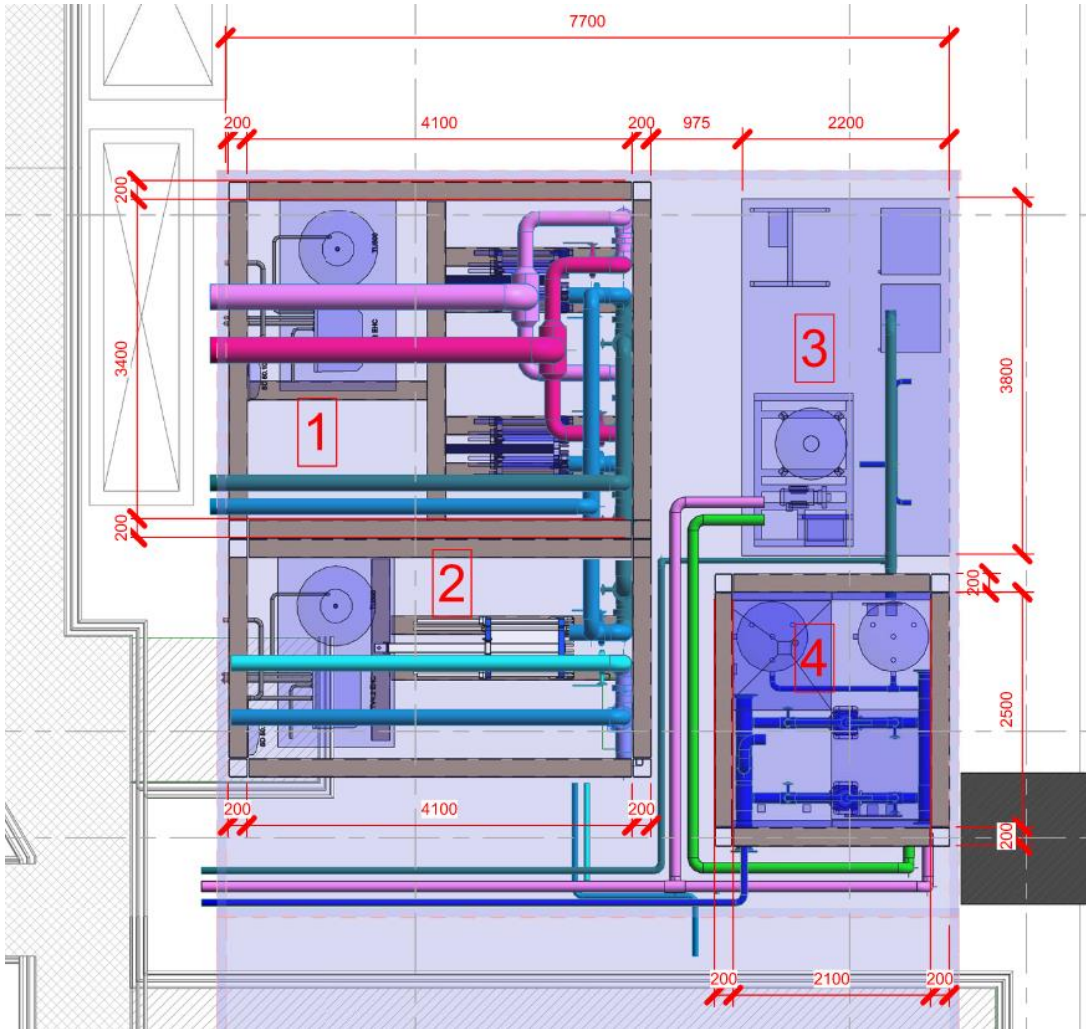
MODULE FACILITY  
PREFAB: SECONDARY CHILLED WATER PUMP SKIDS



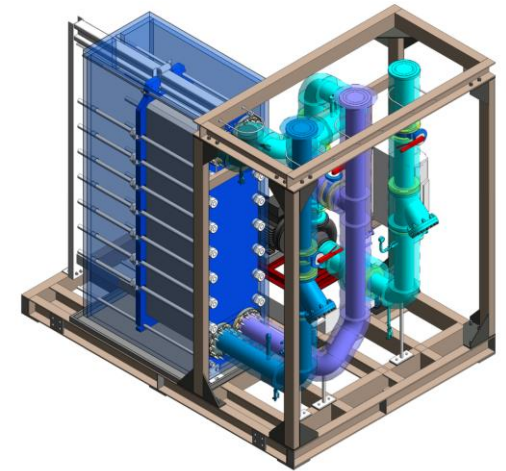
MSB TO SCHWP

SKID MODULES  
PUMP AND PLANTROOM SKIDS

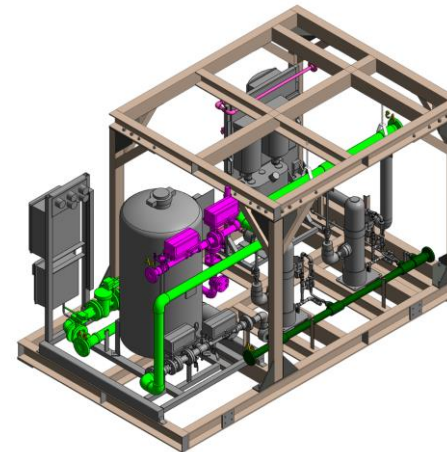
# PREFABRICATION MECHANICAL PACKAGE PLANT MODULE



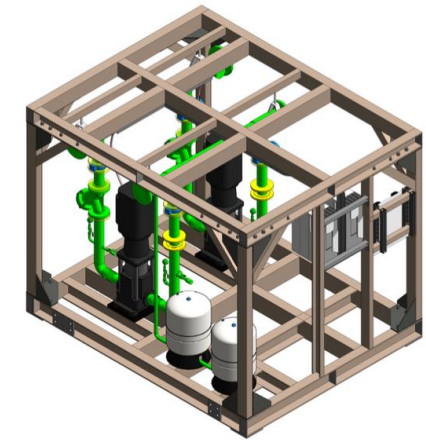
**1. HEAT EXCHANGER  
MODULE 1**



**2. HEAT EXCHANGER  
MODULE 2**



**3. CHEMICAL  
TREATMENT**



**4. MAKE UP PUMP SKID  
CRAH HEAT EXCHANGER SKID  
SKID 3D VIEW**

TECHNIQUES MODULE FACILITY  
PREFAB: PPR HEAT EXCHANGER SKIDS



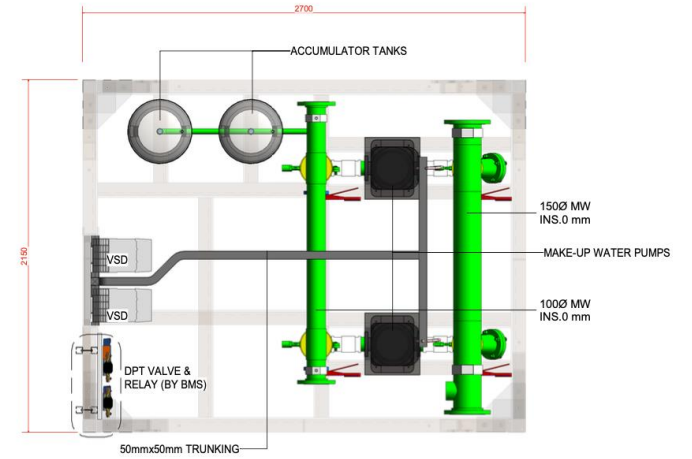
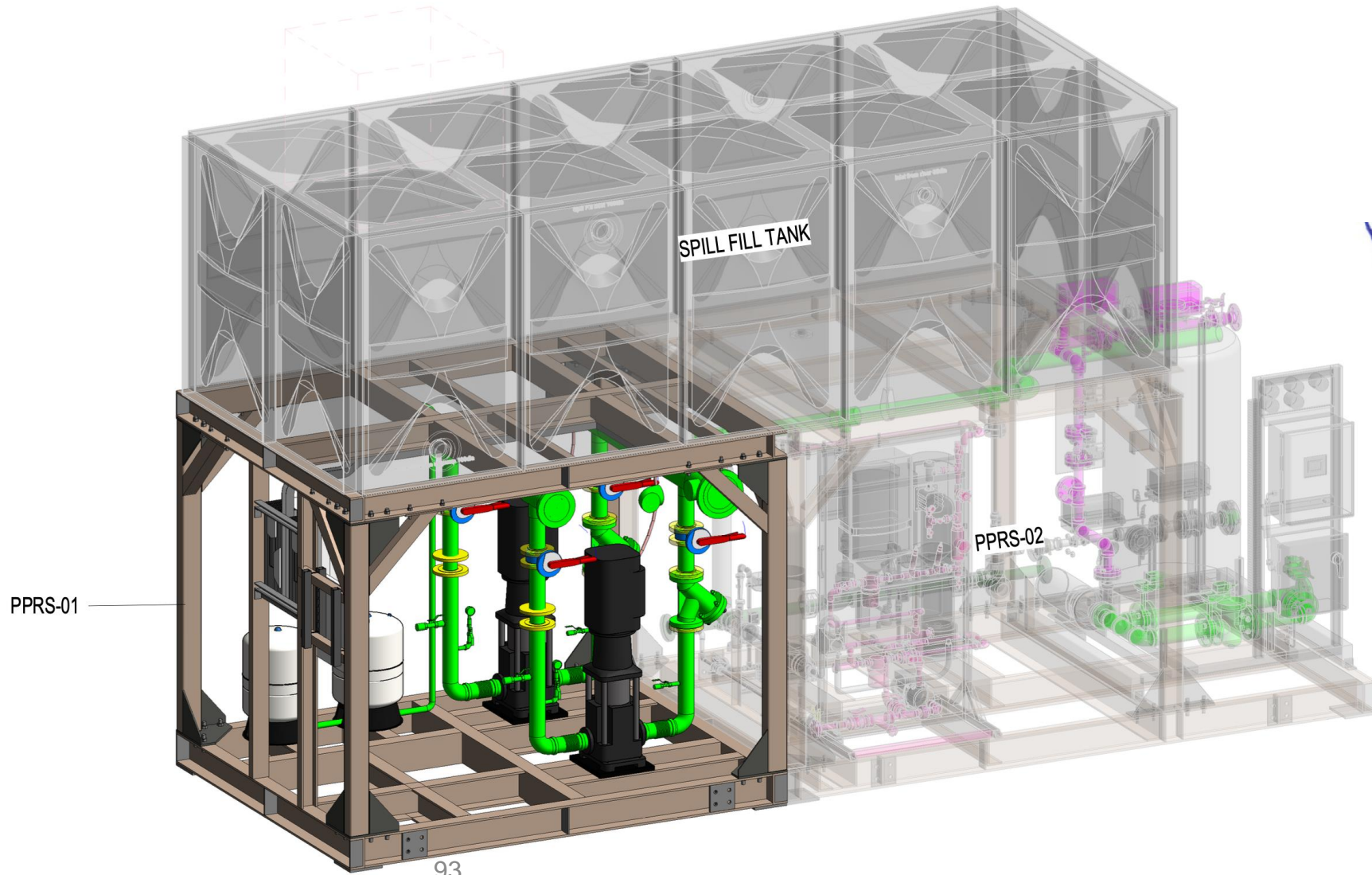
SKID MODULES  
PUMP AND PLANTROOM SKIDS

TECHNIQUES MODULE FACILITY  
PREFAB: PPR HEAT EXCHANGER SKIDS

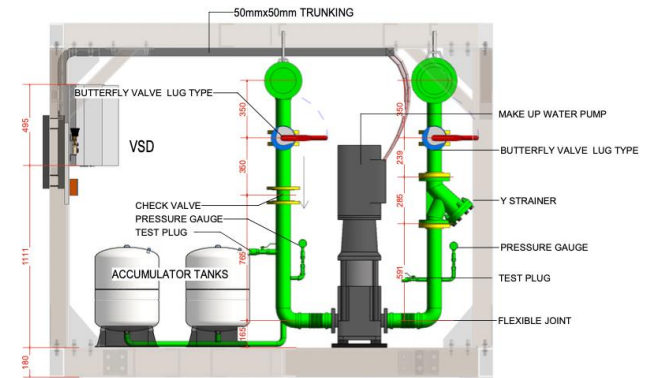


SKID MODULES  
PUMP AND PLANTROOM SKIDS

# PREFABRICATION MECHANICAL PACKAGE PLANT



3 PLAN VIEW  
SD-M8810-XX-SGAX\_1 1 : 20



6 FRONT ELEVATION  
SD-M8810-XX-SGAX\_1 1 : 20

**PREFABRICATION  
MECHANICAL PACKAGE PLANT**



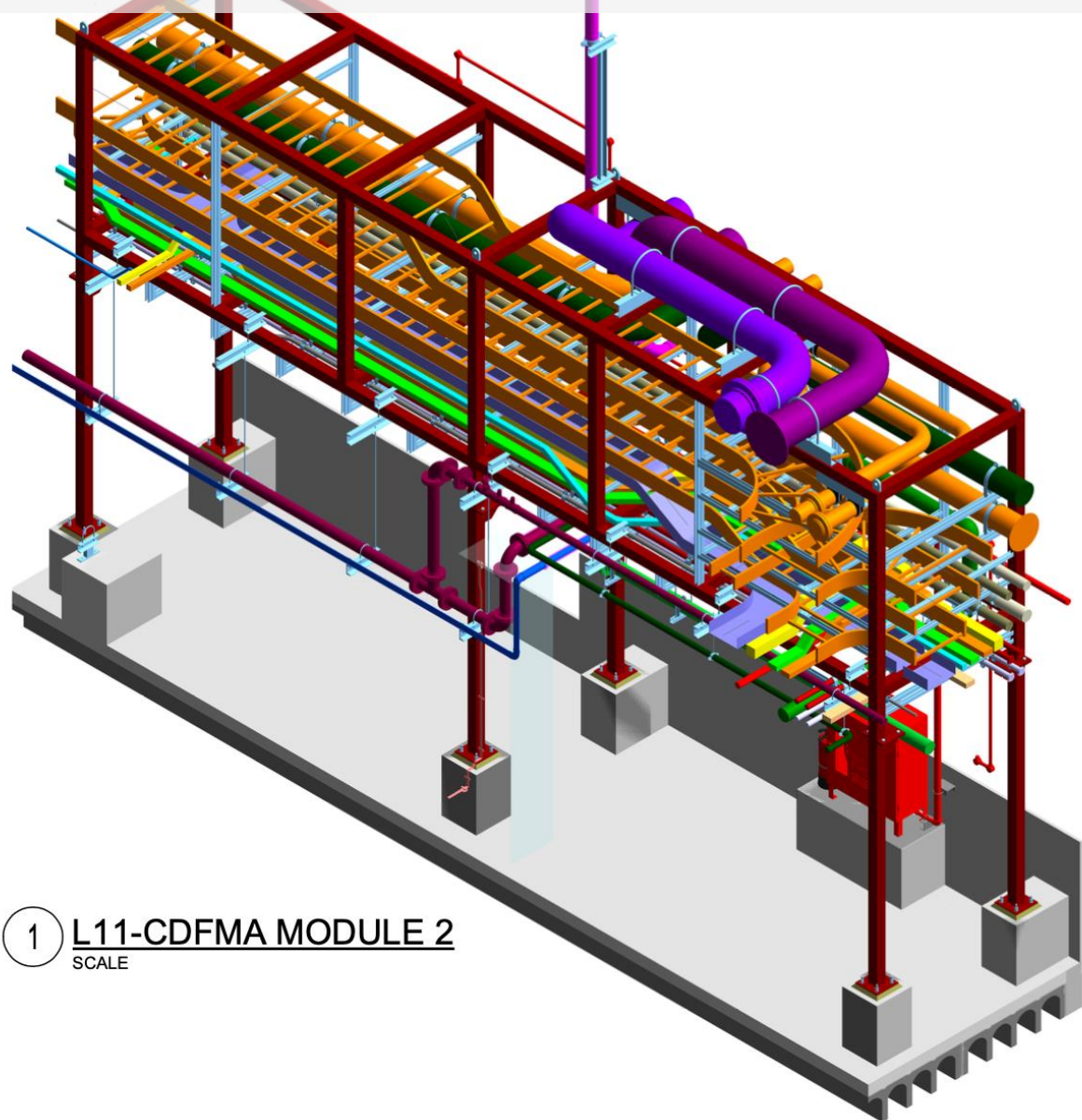
**WATER TANK SKID  
SKID DETAILS**



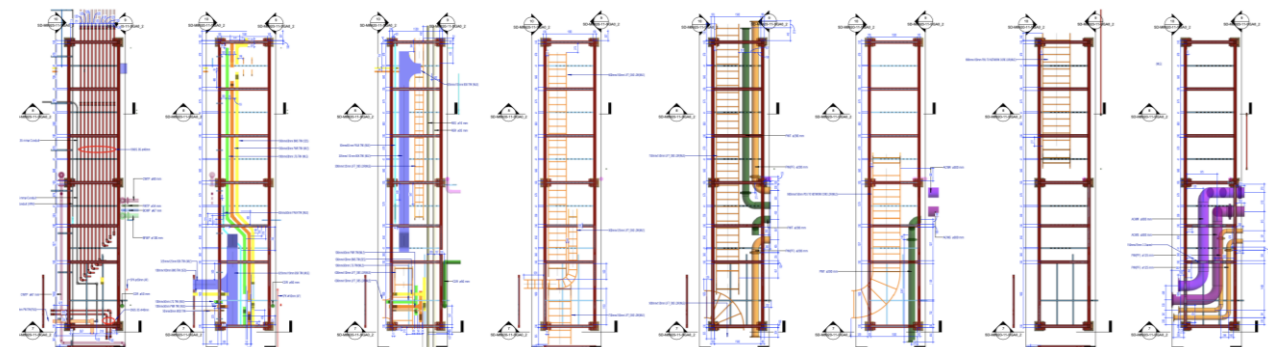
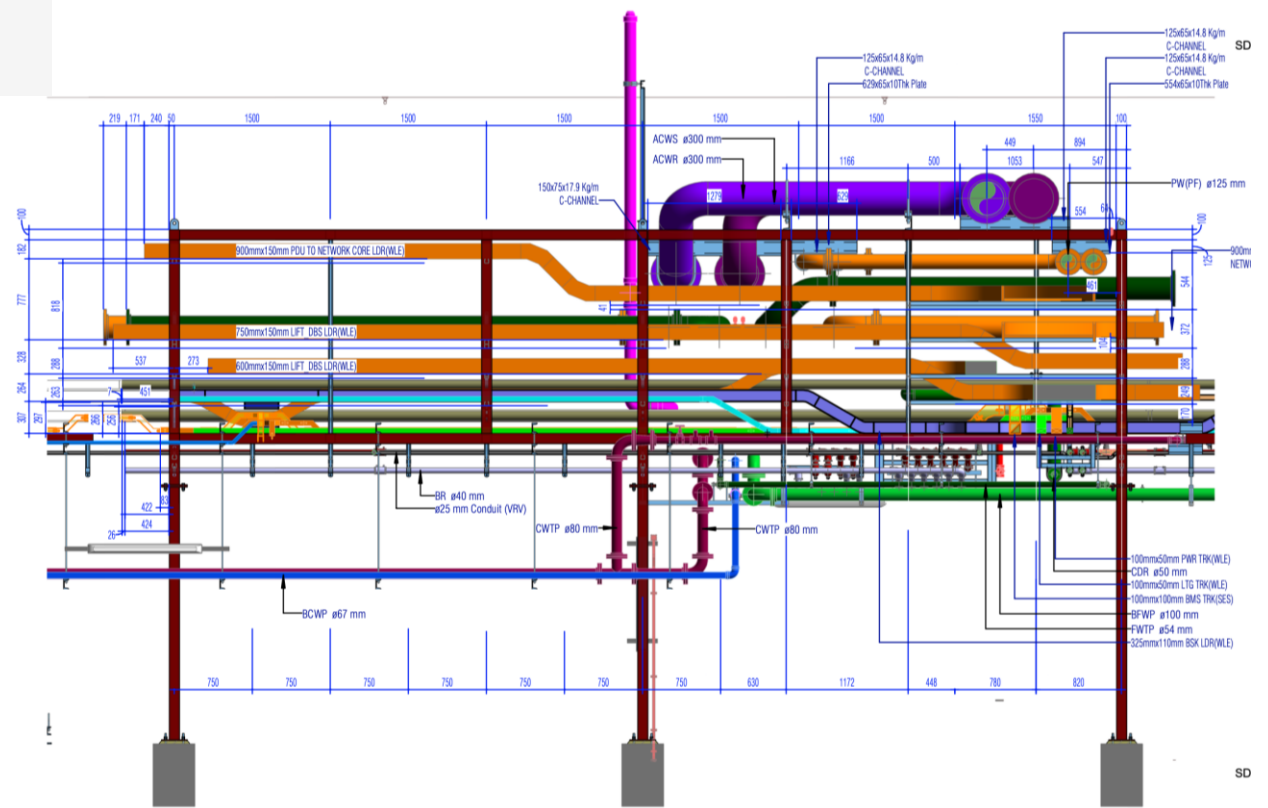
**RISER MODULES**  
SKID DETAILS

PREFABRICATION

PREFAB: MULTI-SERVICE HORIZONTAL MODULES



1 L11-CDFMA MODULE 2  
SCALE



1) L11 - CDFMA MODULE 2-TIER.2 SCALE 1:10  
 2) L11 - CDFMA MODULE 2-TIER.3 SCALE 1:10  
 3) L11 - CDFMA MODULE 2-TIER.4 SCALE 1:10  
 4) L11 - CDFMA MODULE 2-TIER.5 SCALE 1:10  
 5) L11 - CDFMA MODULE 2-TIER.6 SCALE 1:10  
 6) L11 - CDFMA MODULE 2-TIER.7 SCALE 1:10  
 7) L11 - CDFMA MODULE 2-TIER.8 SCALE 1:10  
 8) L11 - CDFMA MODULE 2-TIER.9 SCALE 1:10



Safety is the Priority  
Quality is the Standard

**PREFABRICATION**

## **PREFAB: MULTI-SERVICE HORIZONTAL MODULES**



**MULTI-SERVICE MODULE  
CORRIDOR MODULES**

PREFABRICATION

PREFAB: MULTI-SERVICE HORIZONTAL MODULES



**MULTI-SERVICE MODULE**  
CORRIDOR MODULES

A black and white photograph of a large industrial facility, possibly a refinery or chemical plant. The scene is filled with complex machinery, including large cylindrical tanks, pipes, and structural steel frameworks. The lighting is dramatic, with bright spots from overhead lights and deep shadows. The word "CHALLENGES" is superimposed in the center in a bold, bright yellow font. The overall atmosphere is one of scale and complexity.

# CHALLENGES

## BREAKING CONVENTION

- Re-educate methodologies
- Logistics centric operation
- Multi-trade co-work

## TEAM COMMUNICATION

- Being on the same page
- Information flow, or lack of
- Updates and tracking

## OPERATIONS PLANNING

- Module / Space planning
- Inflow / Outflow

## CONTRACTING

- Aligning with sub-trades
- Expectations & risks

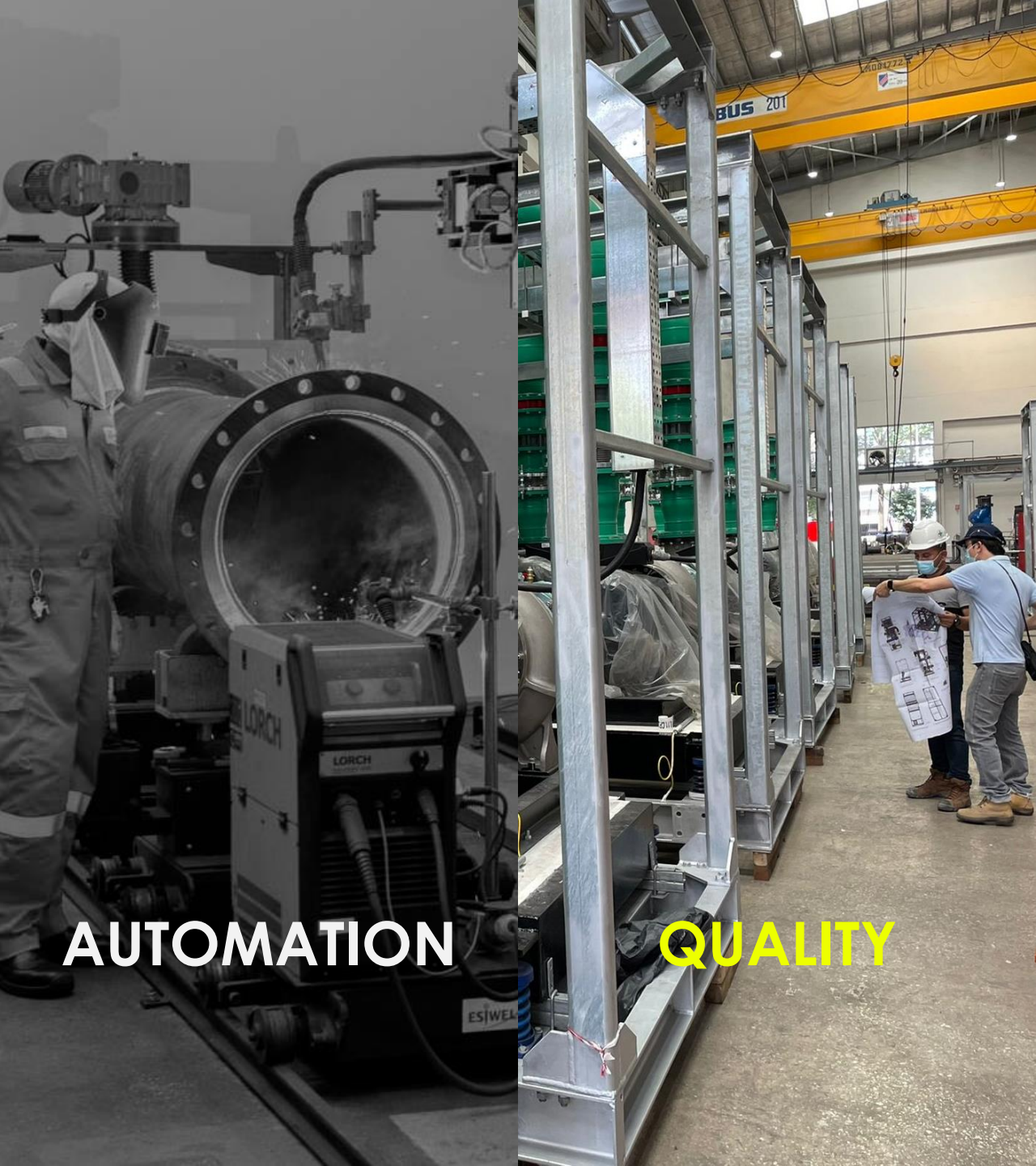


# KEY SUCCESSES



**AUTOMATION**





**AUTOMATION**

**QUALITY**





**AUTOMATION**

**QUALITY**



**REDUCED RISK  
ON SITE**







**AUTOMATION**

**QUALITY**



**REDUCED RISK  
ON SITE**



**CLEAN & SAFE  
WORKING  
ENVIRONMENT**

# The Obstacle is the Way

## Rigid Design Constraints

Generally repeatable design

## Concept Design

Freedom to adjust the design to suit  
DFMA deployment

## Skills Gap

Eager to learn new skills

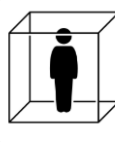
01



02



03



04



05



06



07



## 2.5 Million SqFt Data Center

Opportunity to deploy at Scale

## Constrained Spaces

Forced to compress services

## Authority Targets

Mandate to deliver

## No Prefab Experience

No old ways to unlearn



**FORTIS**  
CONSTRUCTION INC.

WE MAKE AN

**IMPACT**

THAT'S WHY WE EXIST.