Challenging the Status Quo in Coal Mining Ventilation

Cor Meyer & Karl du Plessis

FloEFD Conference 28 & 29 Nov 2017

Presented by

ESTEQ

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On behalf of

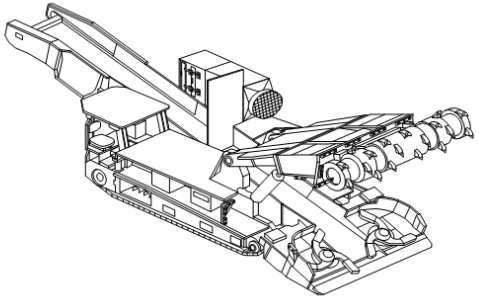
Coaltech

The Coaltech Research Association NPC

Coaltech Research Association

- Research Organisation for South African Coal Mining Industry
- Research across the industry – **Safety** one of those areas
- 1990s: COL518 Standard for continuous coal mining ventilation

SAFETY AROUND CONTINUOUS MINERS



FOCUSSING ON PREVENTING METHANE INCIDENTS

Imagine...

Continuous Coal Mining

Continuous Miners (CMs) – What are they?

Continuous Coal Mining

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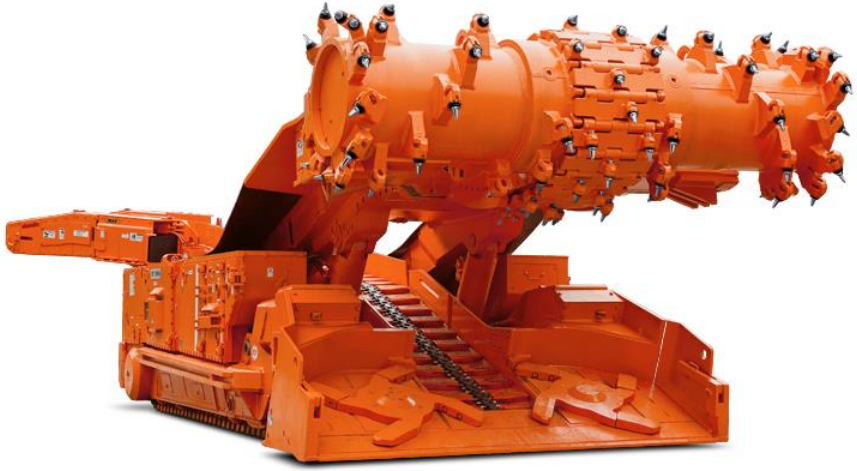
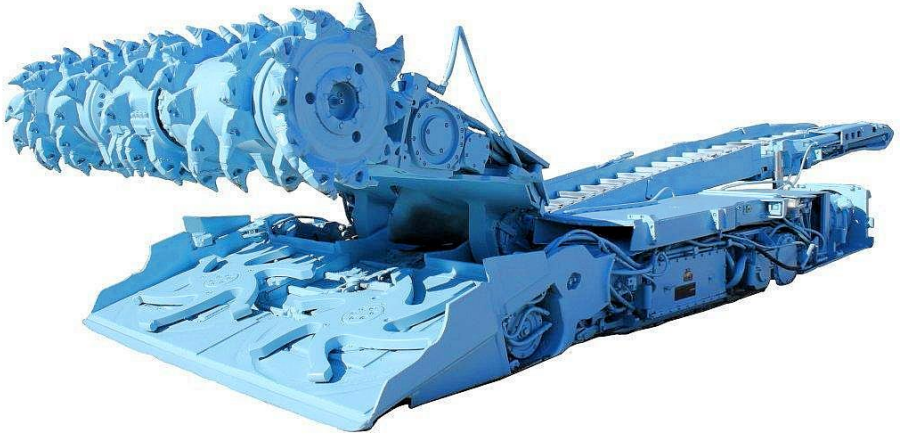
Continuous Miners (CMs) – What are they?



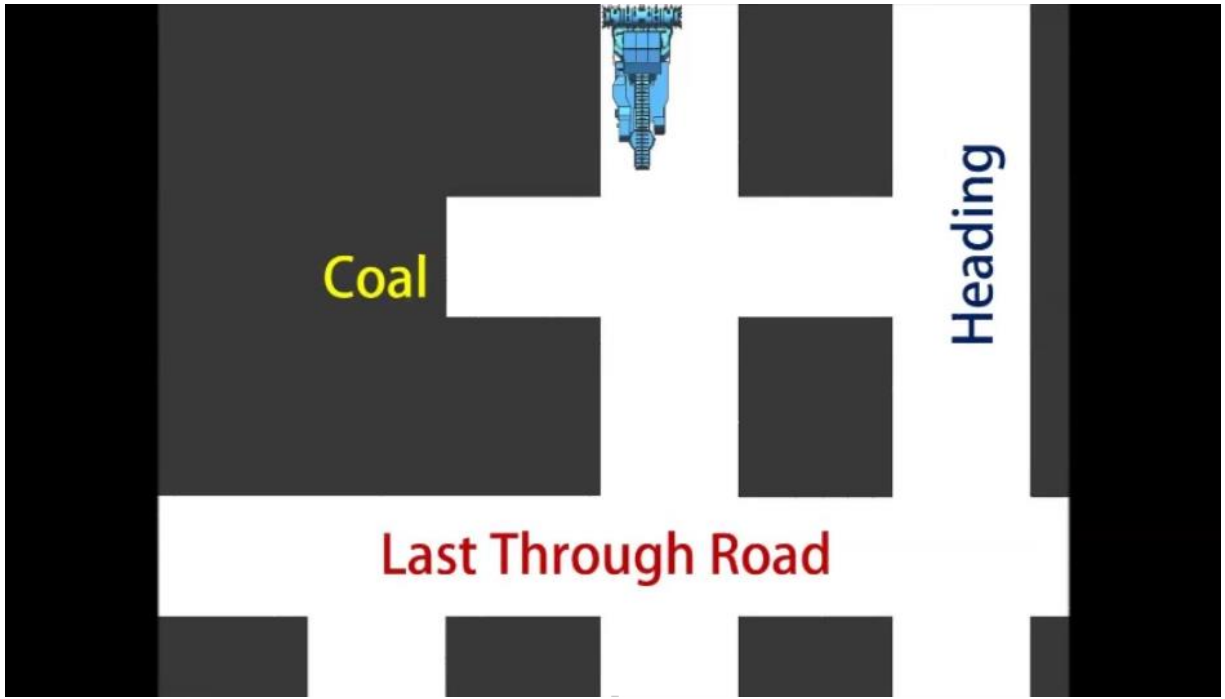


Continuous Coal Mining

Continuous Miners (CMs) – What do they do?

Continuous Coal Mining

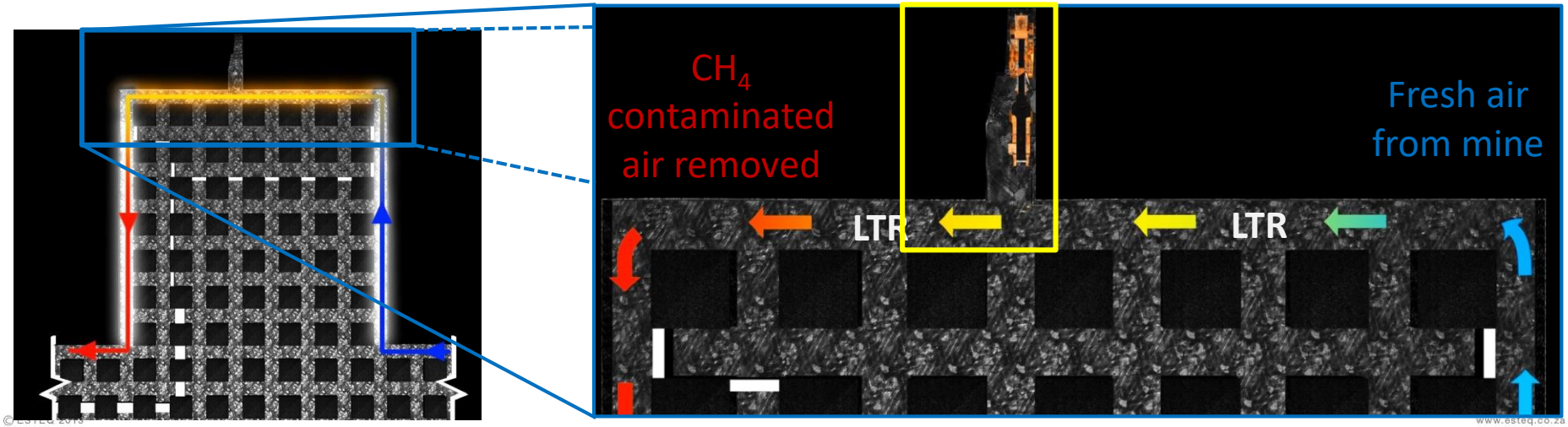
Continuous Miners (CMs) – What do they do?



Continuous Coal Mining

Continuous Miners (CMs) – Ventilation

- Cut coal releases Methane (CH_4)
- Methane explosive range: 5% < CH_4 < 15%
- Fresh Air from LTR onto the Work Face
- Dilute methane around CM: CH_4 < 1%



Continuous Coal Mining

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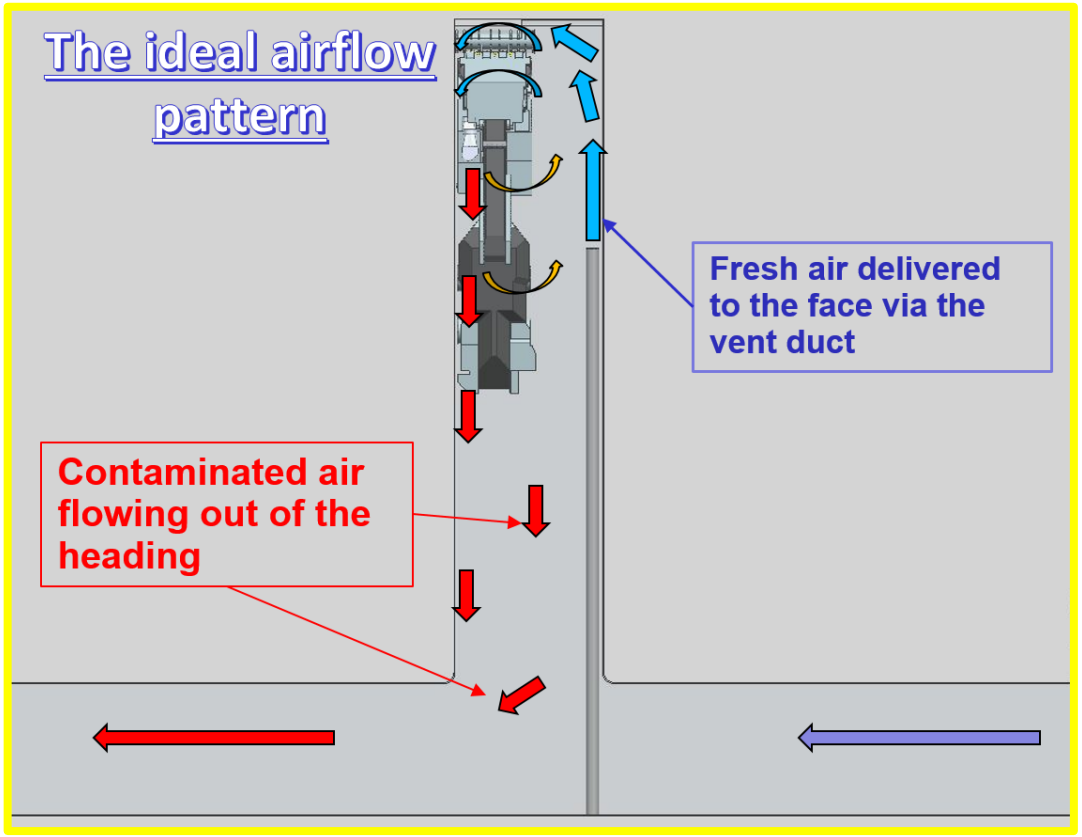
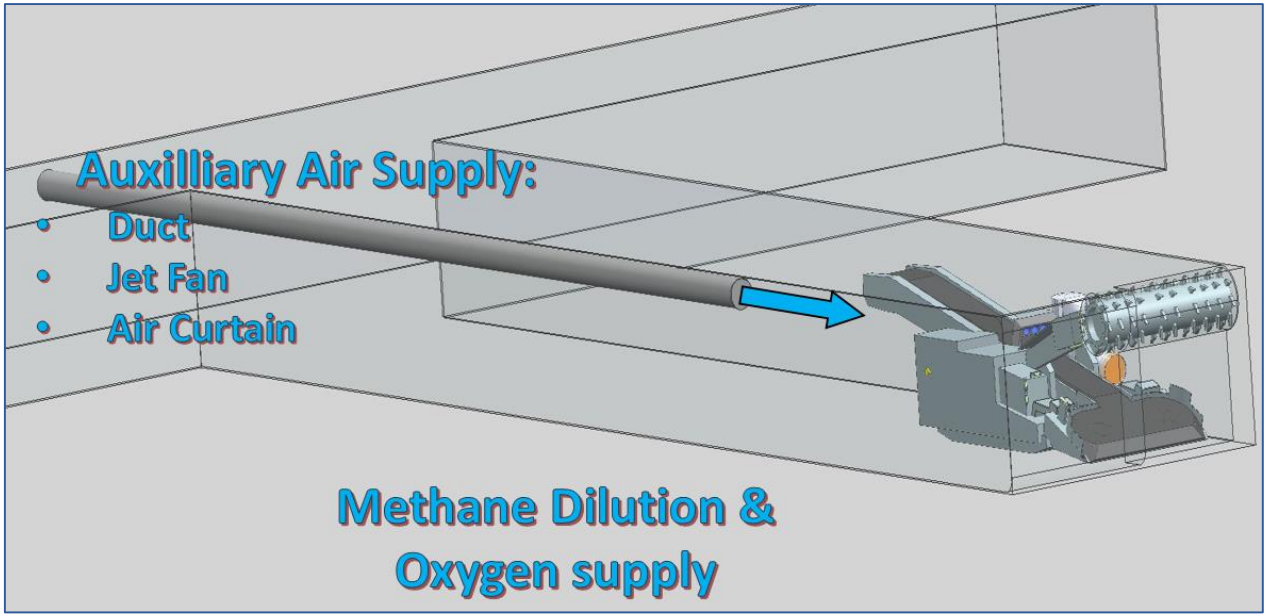


Continuous Coal Mining

Continuous Miners (CMs) – Ventilation

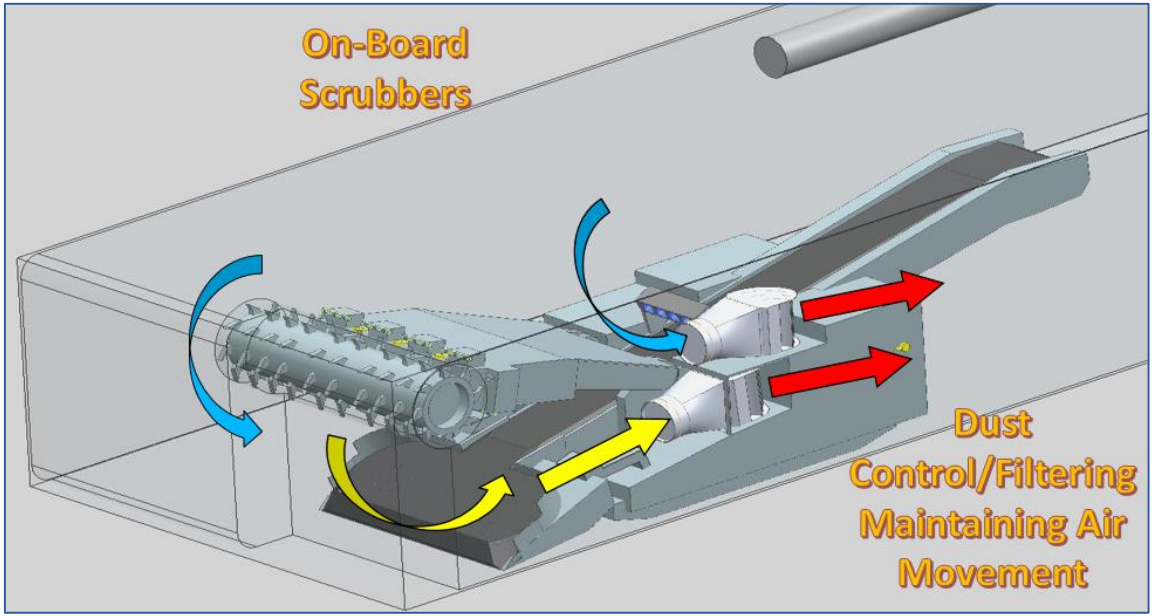
1.Auxilliary/Fresh Air



Continuous Coal Mining

Continuous Miners (CMs) – Ventilation

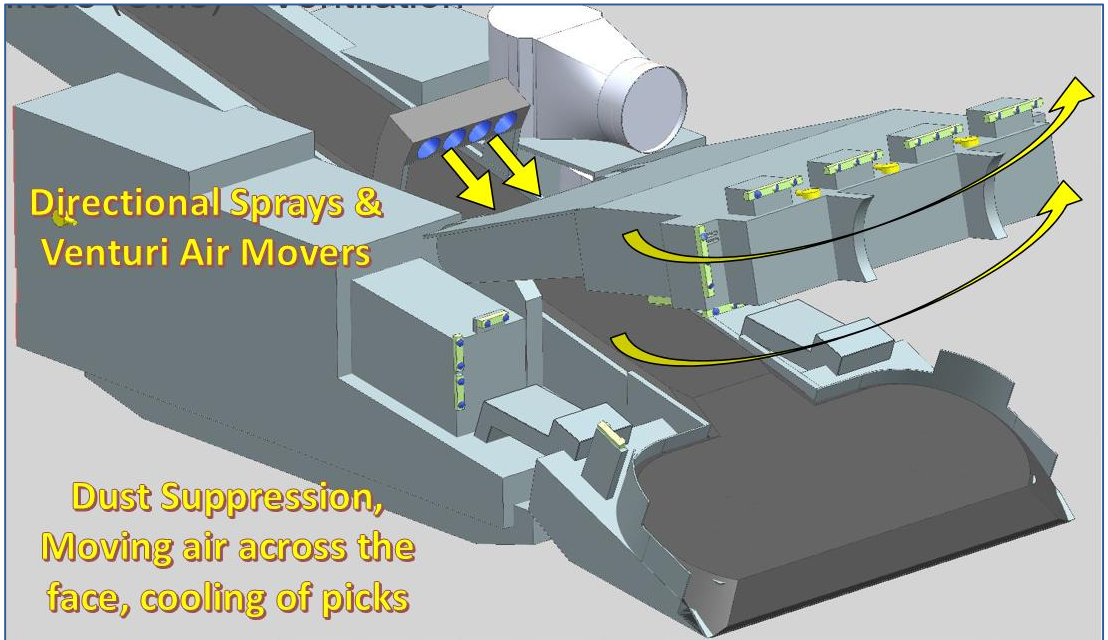
1. Auxilliary/Fresh Air
2. Scrubbers



Continuous Coal Mining

Continuous Miners (CMs) – Ventilation

1. Auxilliary/Fresh Air
2. Scrubbers
3. Spray Nozzles
4. Venturi Air Movers

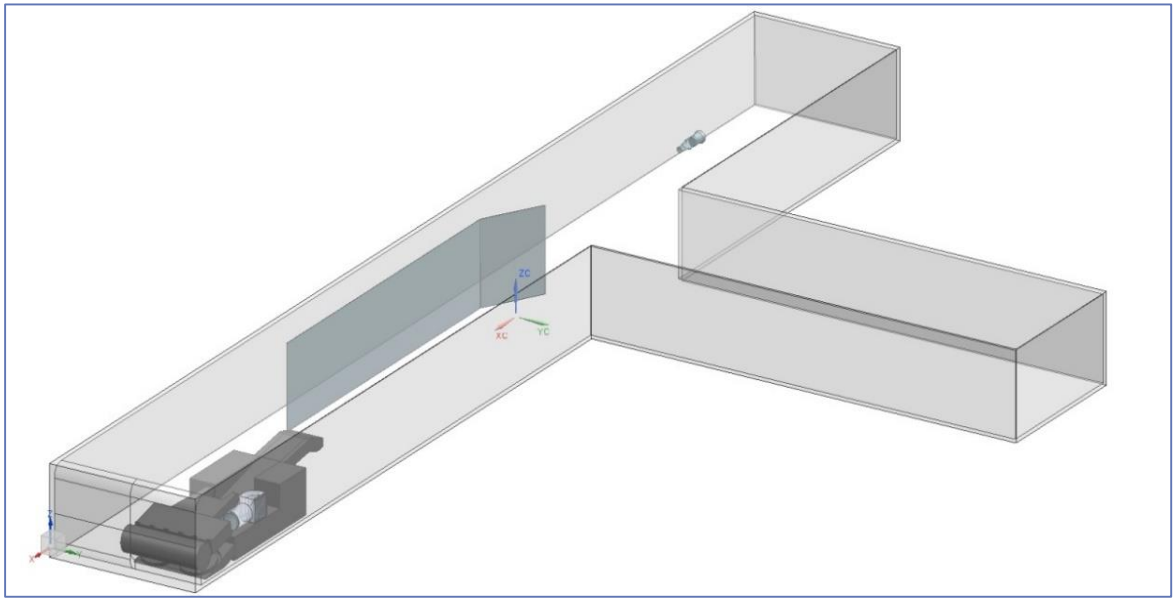


Why the need for CFD then?

- Recent increase in occurrence of methane ignitions:
- Why? What has changed?
  - Production rates increased (**more** dust/methane/air/water...)
  - Practical implementations (jet fan/ducting/brattices – locations/positions)
  - **Increased Emphasis** on **Safety** (operators, personnel)
- COL518 principles outdated?
- Complex system interactions
  - More insight necessary to understand current situation
- Coaltech Project Initiated: Preventing Methane Ignitions
- **Enter FloEFD...**

Proof of Concept

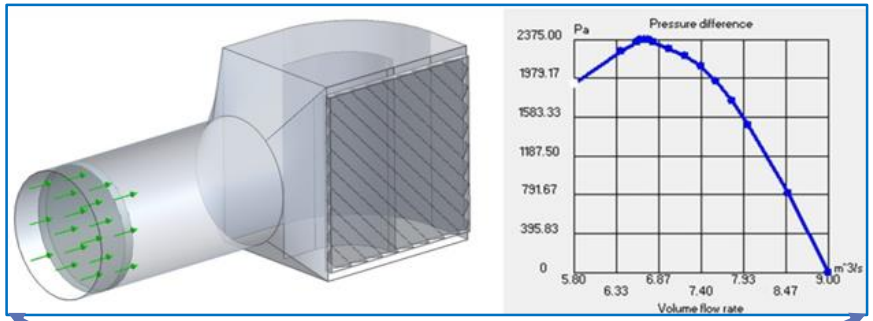
- **February 2013:** ESTEQ Approached by Coaltech (for CFD solution)
- ESTEQ to demonstrate capability/applicability of FloEFD
- Proof of Concept Scenario:
  - First Heading (30m) on Section Intake with Jet Fan and Brattice

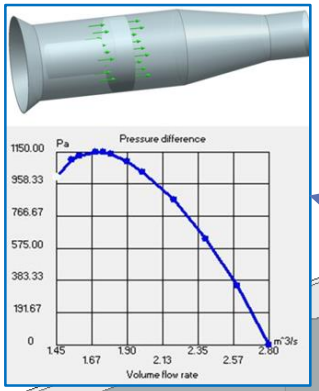


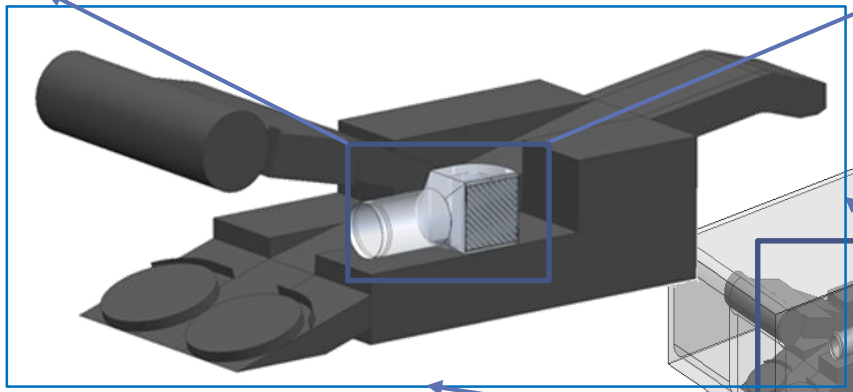
2013
2014
2015
2016
2017
2018

Proof of Concept

- Basic CAD geometry of CM
- Internal Fan functionality for Scrubber + Jet Fan

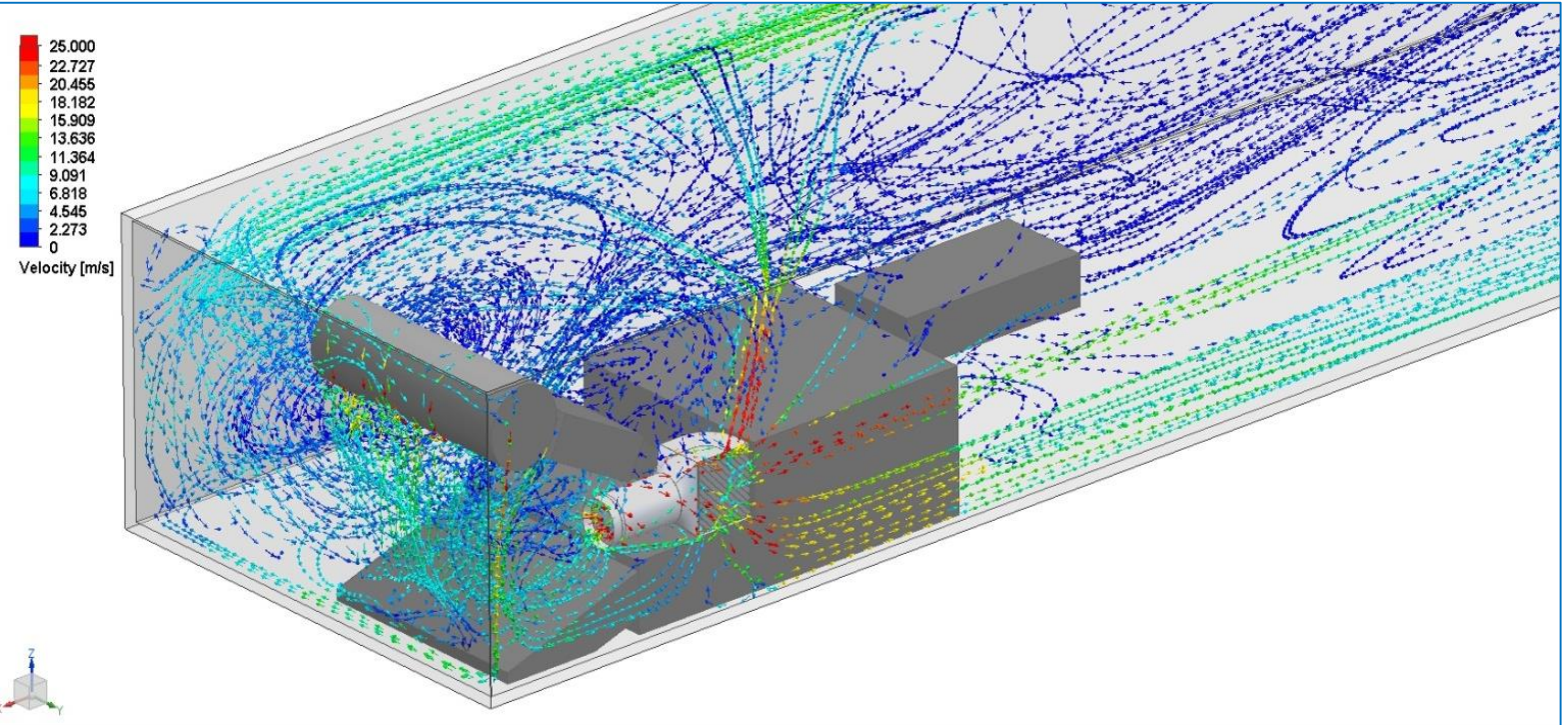






Proof of Concept

- Proof of Concept Results



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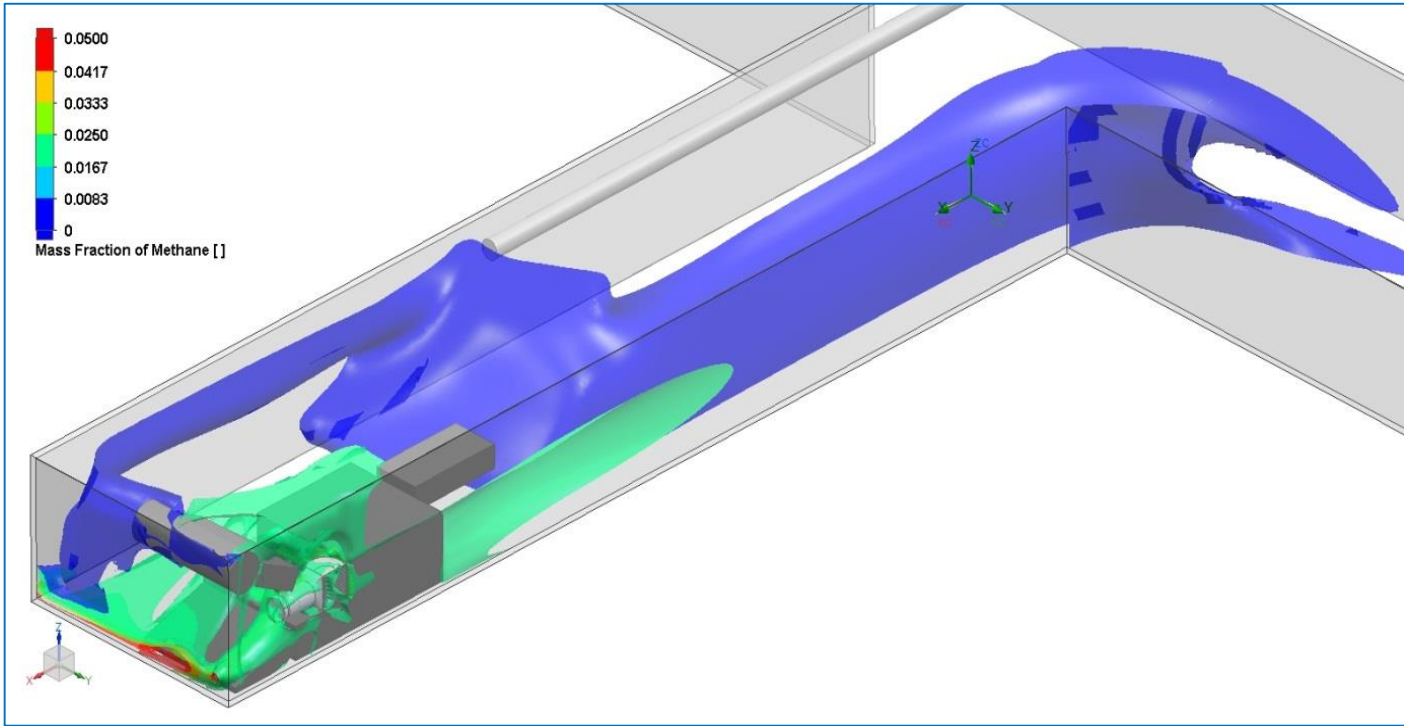

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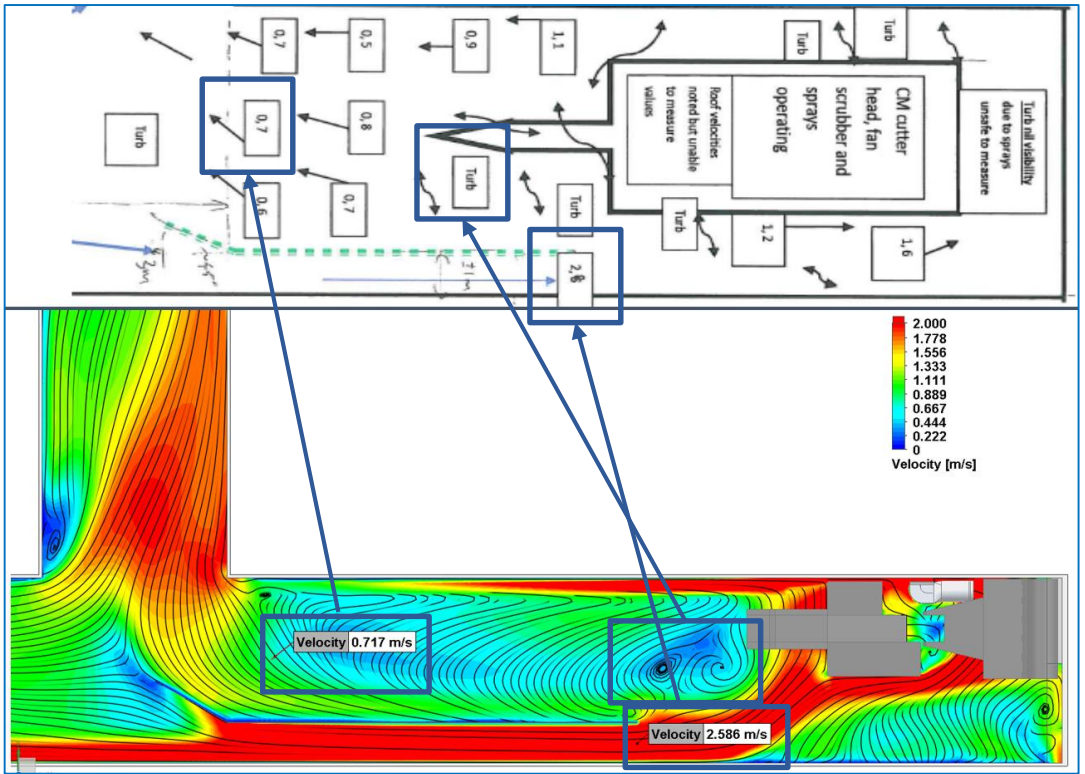
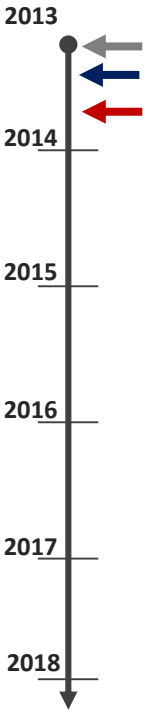


Proof of Concept: Outcome



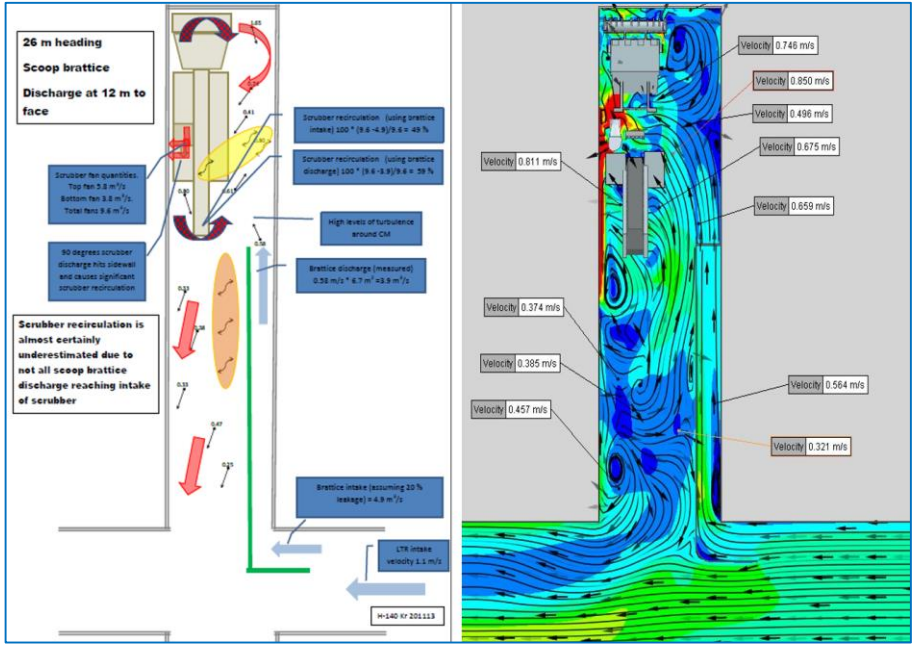
- Proof of Concept Validated
- Good agreement with experimental velocity measurements
  - ESTEQ successfully demonstrated capability/applicability of FloEFD.
  - Infinitely more insight than point velocity measurements
  - Possible to predict methane concentrations

- **2013 April** – Coaltech officially launched project: Preventing Methane Ignitions

- **2013 August – Coaltech purchased FloEFD**

Stage 1:Initial Investigations

- Simulated 3 scenarios – velocity measurement data available:
  - Airflow pattern visualisation & verification
  - Quantify **Recirculation**



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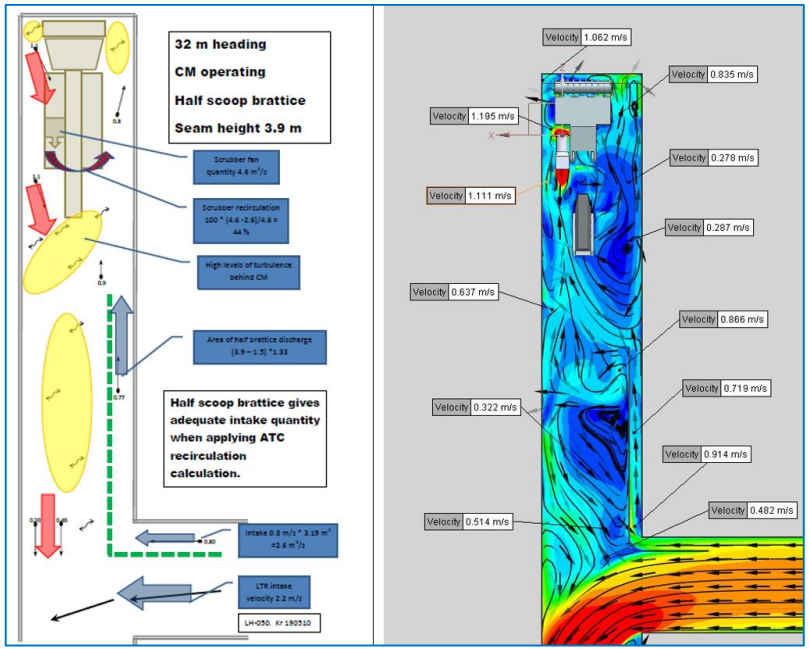

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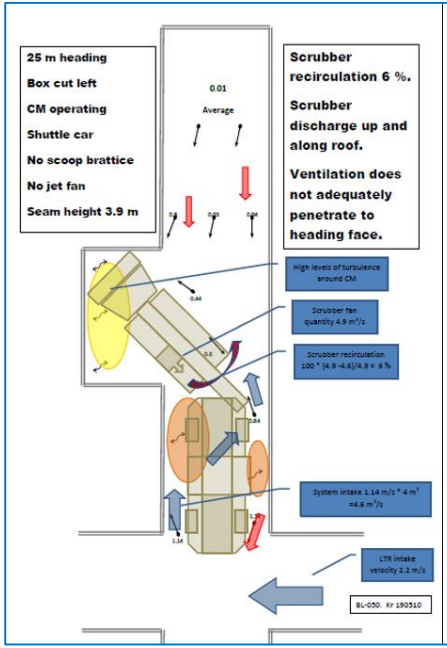
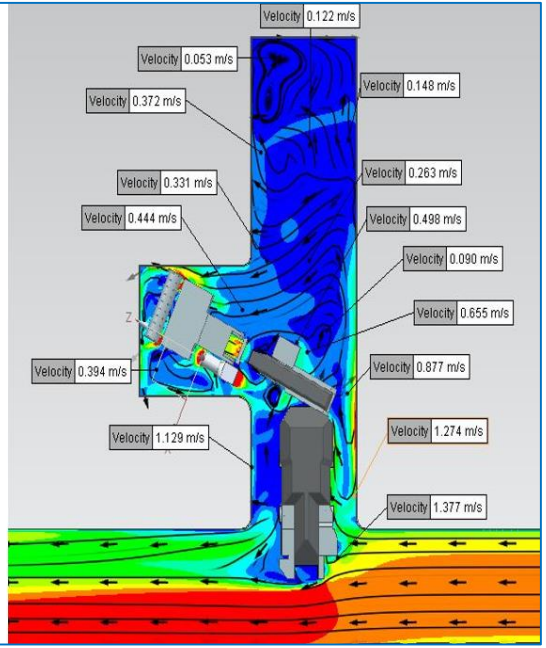




Stage 1:Initial Investigations

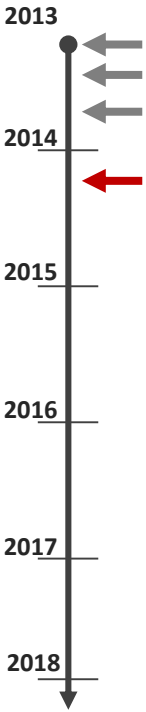
- Quantifying Scrubber Recirculation
  - **Particle Study** – Actual fresh air quantity reaching scrubber intake
  - Recirculation calculation improved: Theoretical → Actual (CFD)

Theoretical: $(Q_{Scrubber} - Q_{Fresh\ Air} / Q_{Scrubber})x100$

Actual (CFD): $(Q_{Scrubber} - Q_{Actual\ Fresh\ Air,CFD} / Q_{Scrubber})x100$

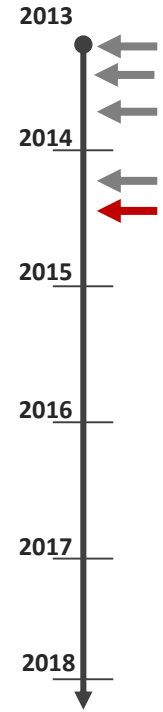
Recirculation	Theoretical	Actual (CFD)
Scenario 1	59%	62%
Scenario 2	43%	65%
Scenario 3	6 %	54%

Stage 1:Outcome

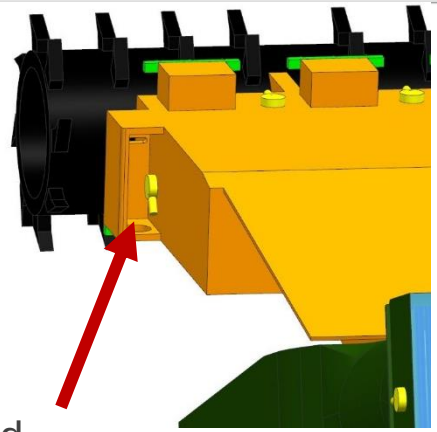


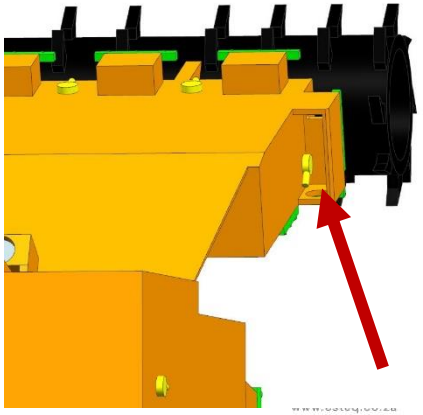
- **March 2014**
- FloEFD provided valuable information into **complex interaction** of ventilation configurations for various cutting stages
- FloEFD instrumental in exposing potential discrepancies in **recirculation** (Theoretical vs. Actual)
- Recirculation identified as one of main reasons for **methane build-up**
- Focus attention on **detection and prediction of methane**...

Stage 2:Focus on Methane Prediction



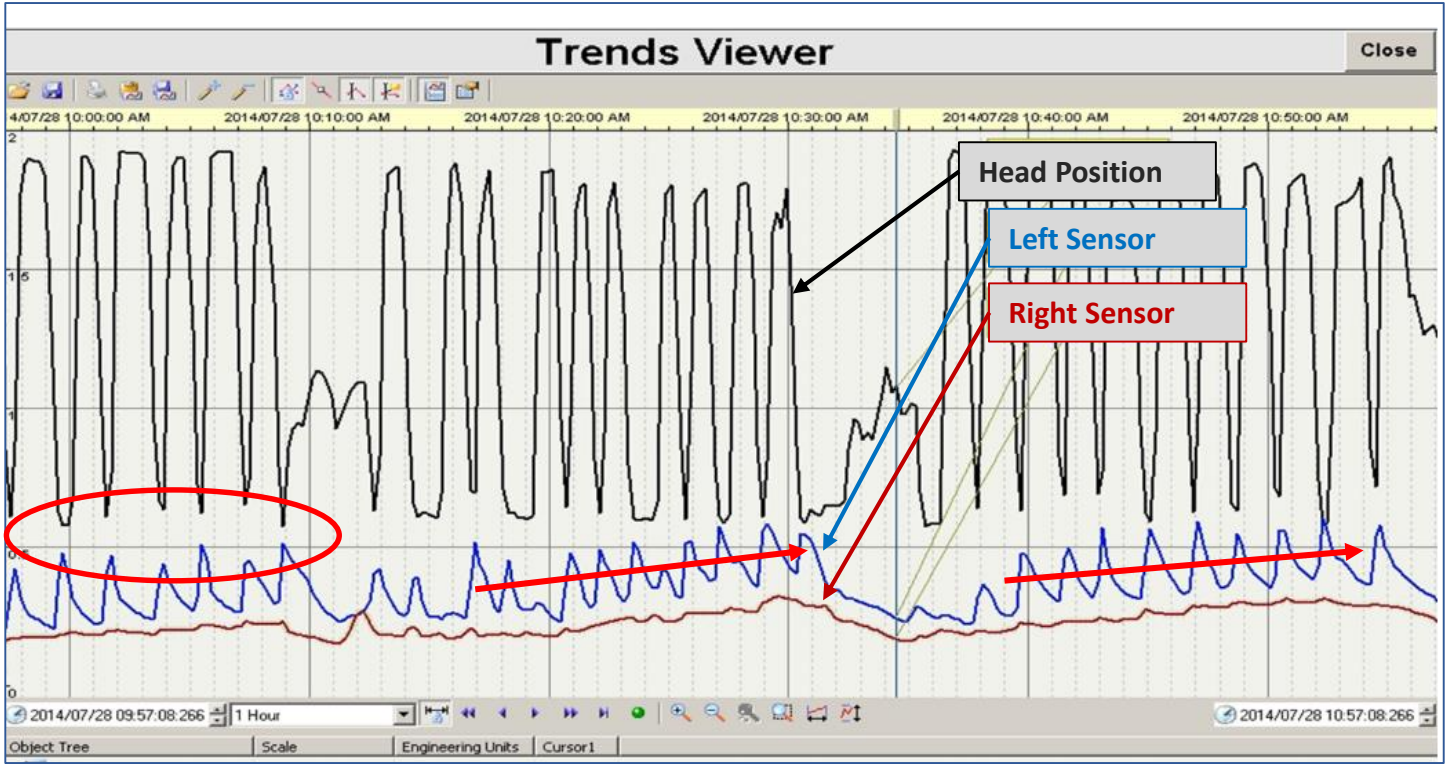
- Prediction of methane with CFD
  - Verify CFD with Physical measurements
- Methane sensors on CMs:
  - Only used to trip machine – CH_4 > 1%
  - No data recorded
  - Traditionally only x1 sensor – Left Side of cutting head
- **July 2014**: Underground measurements during operation
  - CM instrumented with additional sensor on Right Side
  - Data acquisition system installed
  - Recorded methane levels + Head position





Stage 2:Methane Monitoring

- Data sheet example: Recorded during CM operation

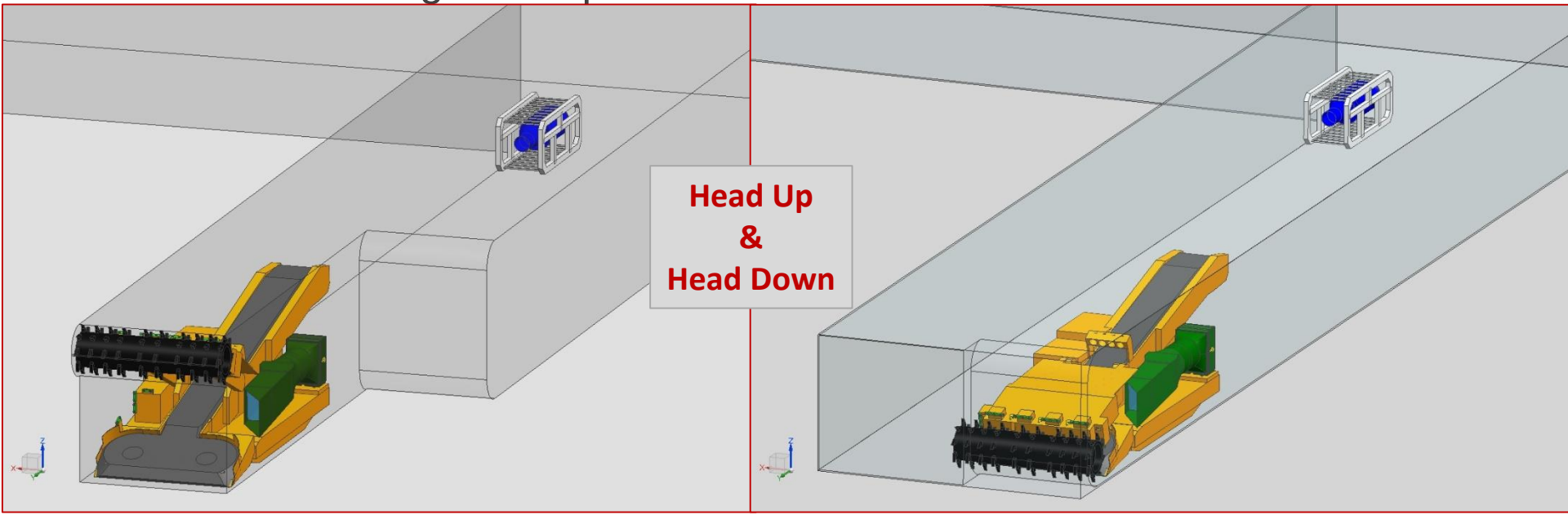


Stage 2:CFD Simulation

- FloEFD model representing heading development sequence

Scenario A: Right Sump

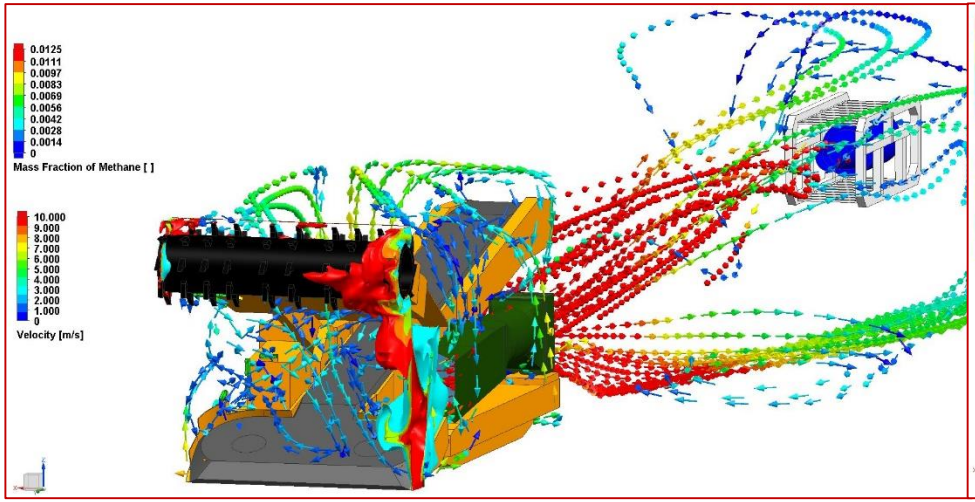
Scenario B: Left Shear



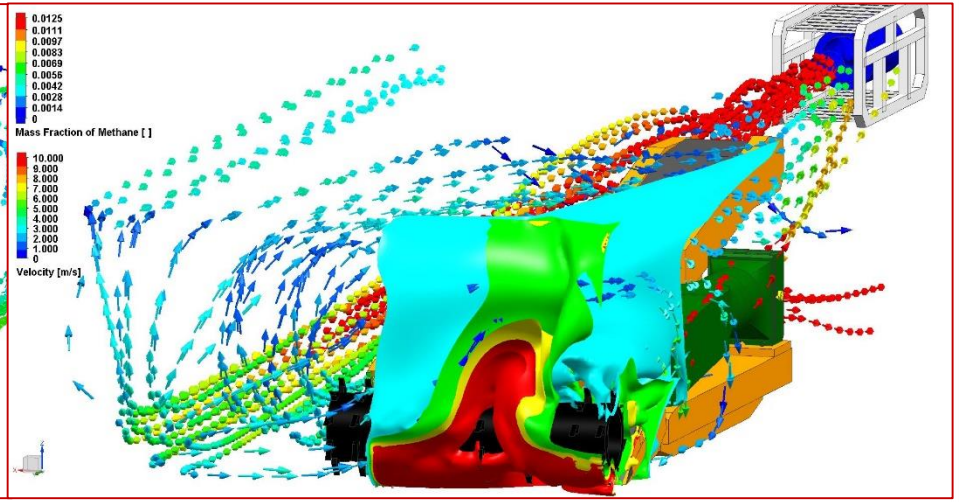
Stage 2:CFD Simulation

- Steady-state Methane Concentrations

Scenario A: Right Sump



Scenario B: Left Shear



Stage 2:CFD Simulation

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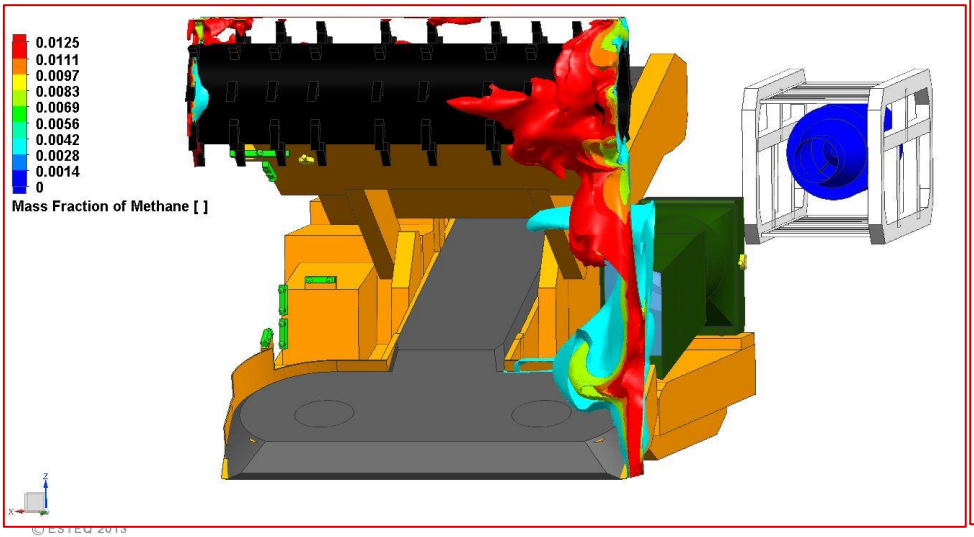

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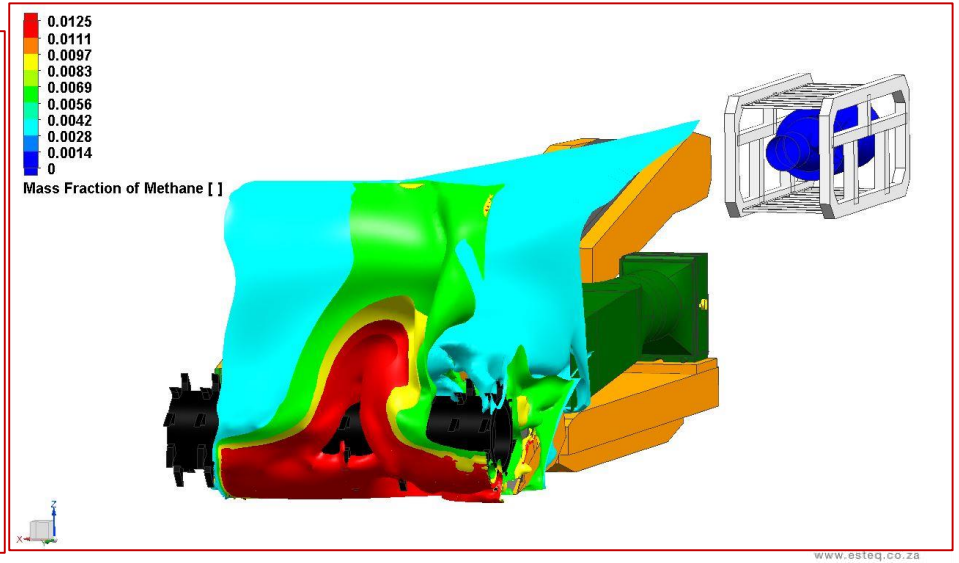

Stage 2:CFD vs. Recorded Data

- FloEFD predictions in good correlation with Data sheets
- **October 2014**: Methane Prediction Model
  - (>120 simulations by this time)

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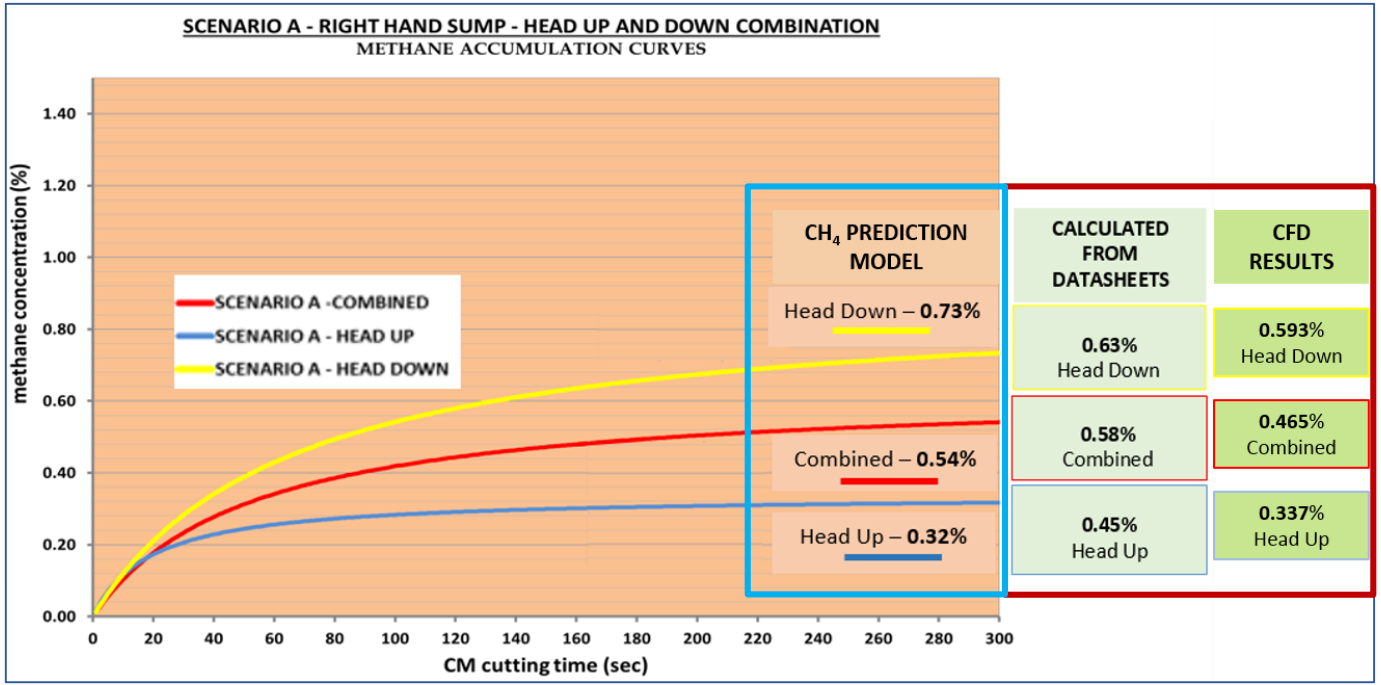
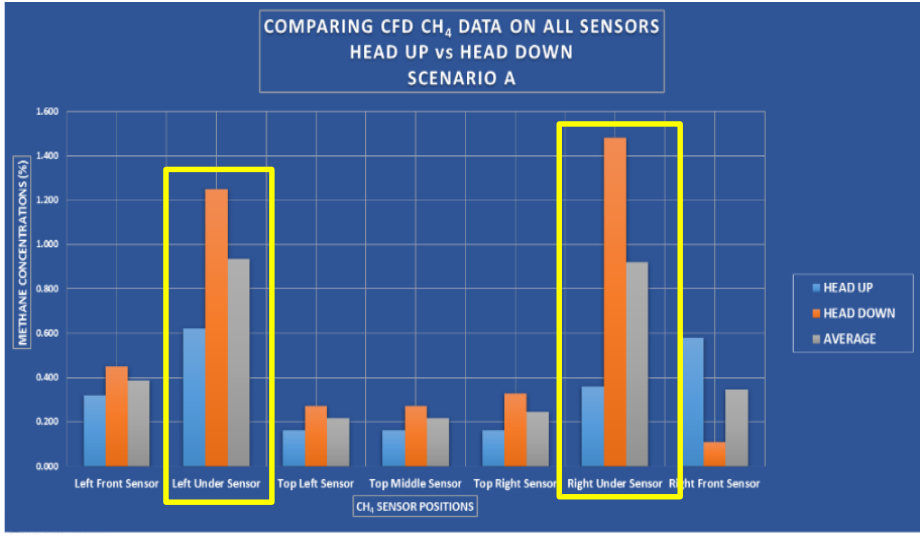
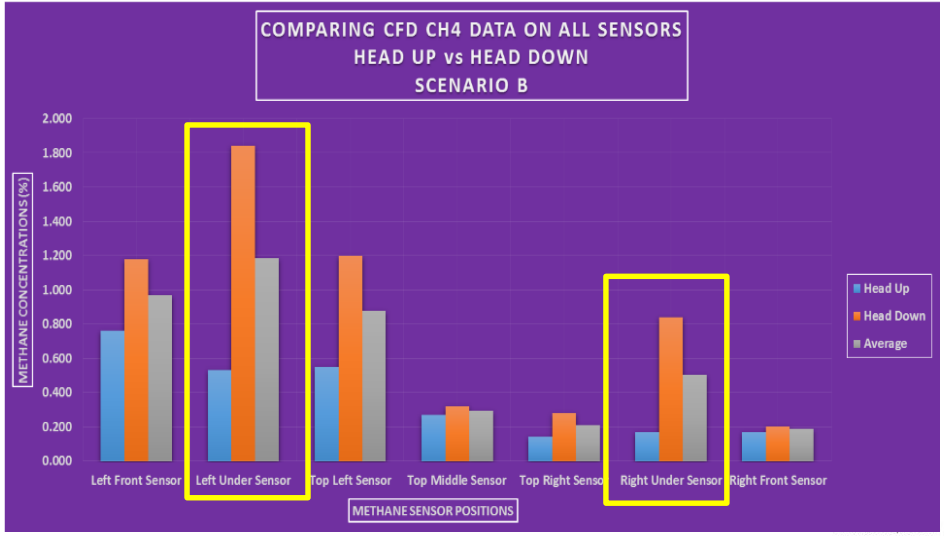
2018



Stage 2:Methane Prediction Revelation

- FloEFD model equipped with **additional sensors**
- Reveal build-up of CH_4 **underneath** cutting head
- Intuitive? Probably – **Never before visualised/quantified**
- **Importance** of CH_4 sensors underneath the head





Stage 2:Methane Monitoring – Phase 2

- **November 2014**: Conduct 2nd underground tests
- Machine instrumented with 2x additional sensors underneath cutting head

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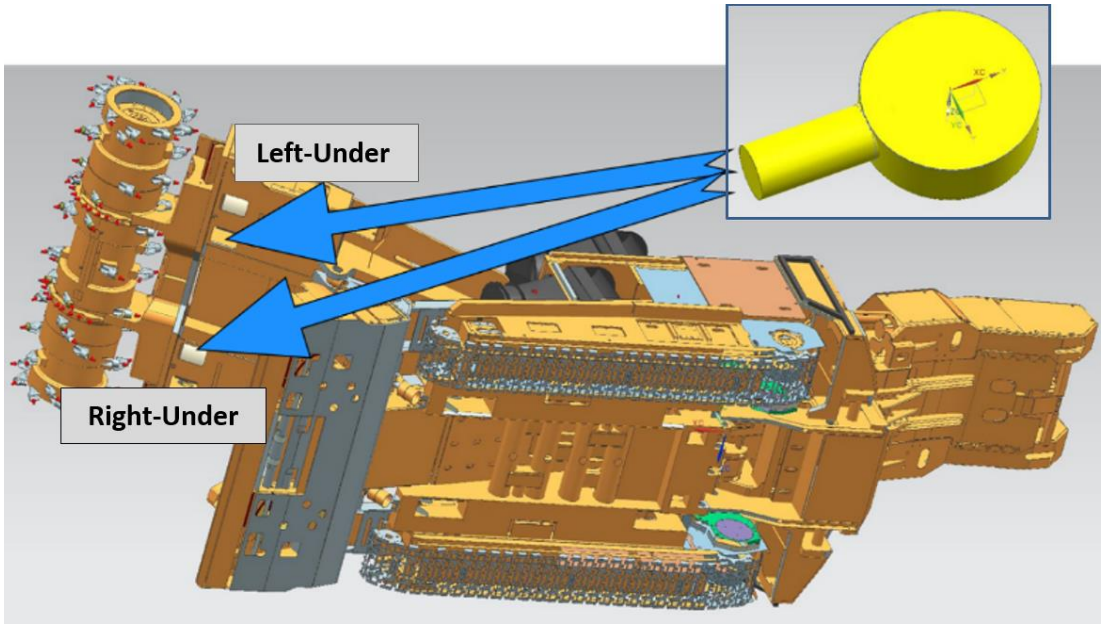
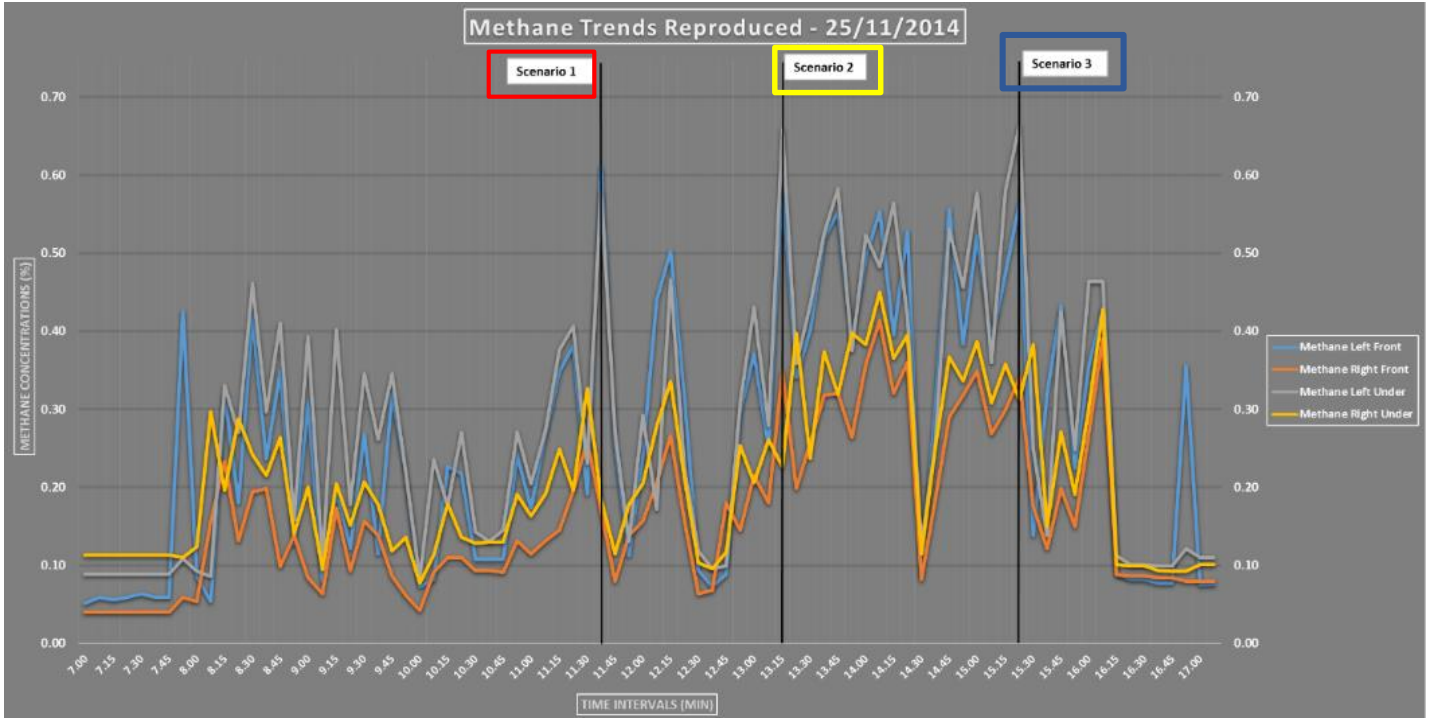
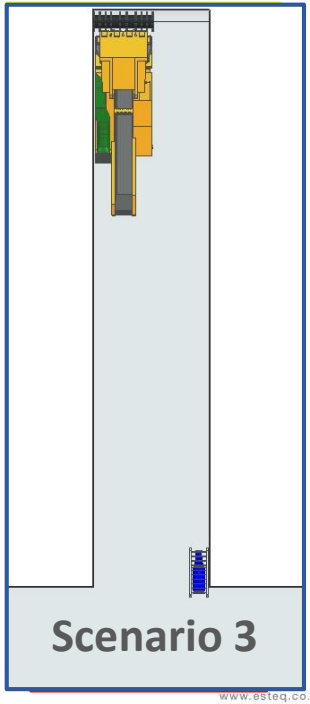


Stage 2:Methane Monitoring – Phase 2

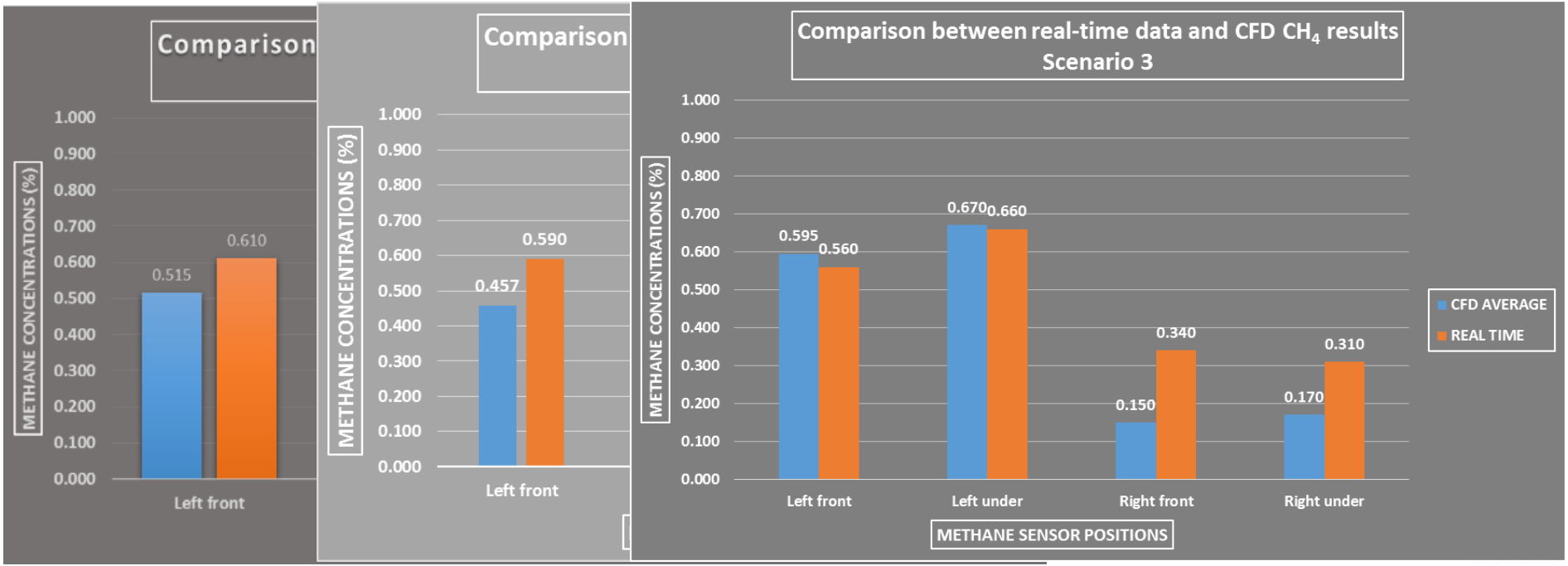
- Data collected & processed
- Identified 3 scenarios with peak methane levels to simulate



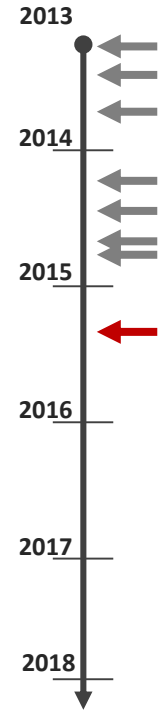


Stage 2:Methane Monitoring – Phase 2

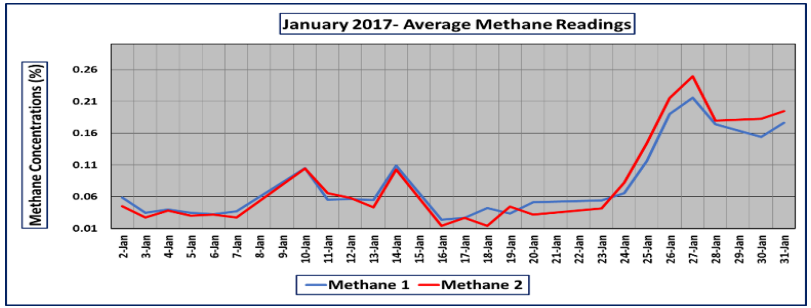
- Comparison between CFD & Real-time data
- FloEFD predicts **trends in CH_4 levels** very **accurately**



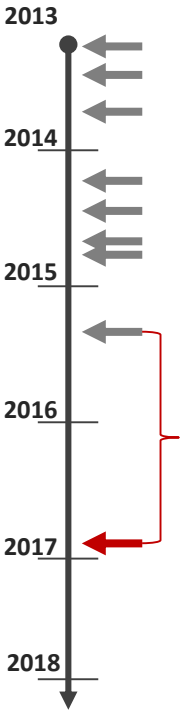
Stage 2: Outcome



- **April 2015: Major Breakthroughs thanks to FloEFD:**
  - Higher CH_4 levels – Head down
  - CH_4 build-up underneath cutting head
- Confirmed by measurements & reports of frequent machine trips with Head Down
- Importance of **sensors underneath** cutting head
  - Actual Machine instrumented accordingly.
- Importance of **continuous recording** of CH4 levels.
  - Identify when approaching high methane stores – Safer environment



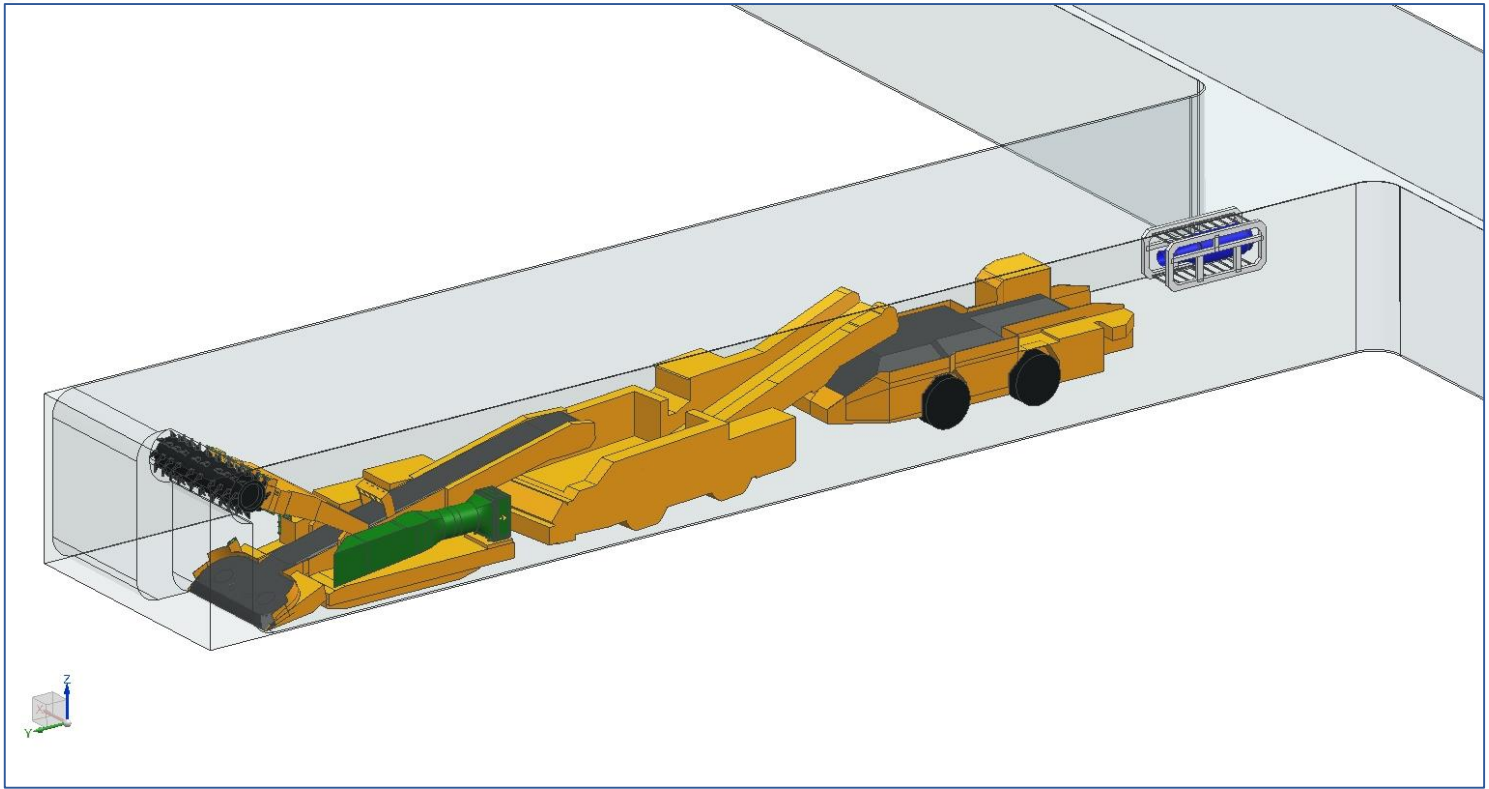
Stage 3:Advancing Methane Control



- Where to from here..?
- Early detection of methane – may **prevent ignitions**
  - Machine trips causing downtimes/production losses
- Need to address the question of **methane build-up**:
  - Reducing Recirculation (Balanced vs. Unbalanced)
  - Need more effective form of removing methane from working face
- **FloEFD used extensively!**
- **2015-2016**: >600 simulations ~30TB data later
  - Countless scenarios: Variations of CMs + Scrubbers + Auxilliary ventilation arrangements
  - High fidelity models: Increased complexity of CAD models and scenarios + **Sliding Mesh**

Examples of Model Complexity

- Scenarios



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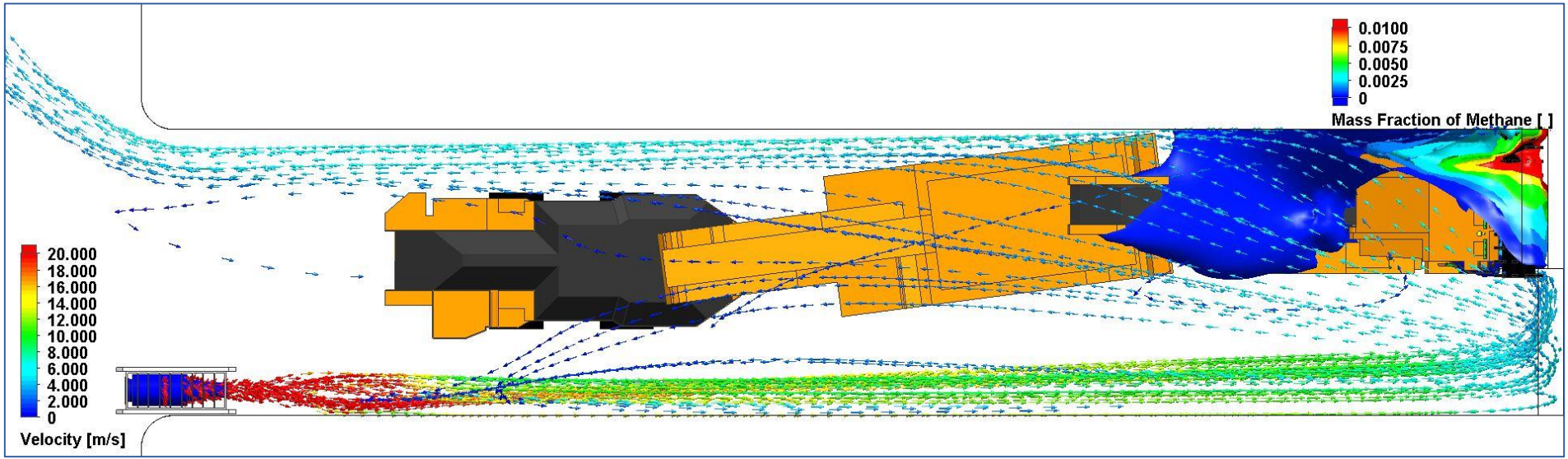

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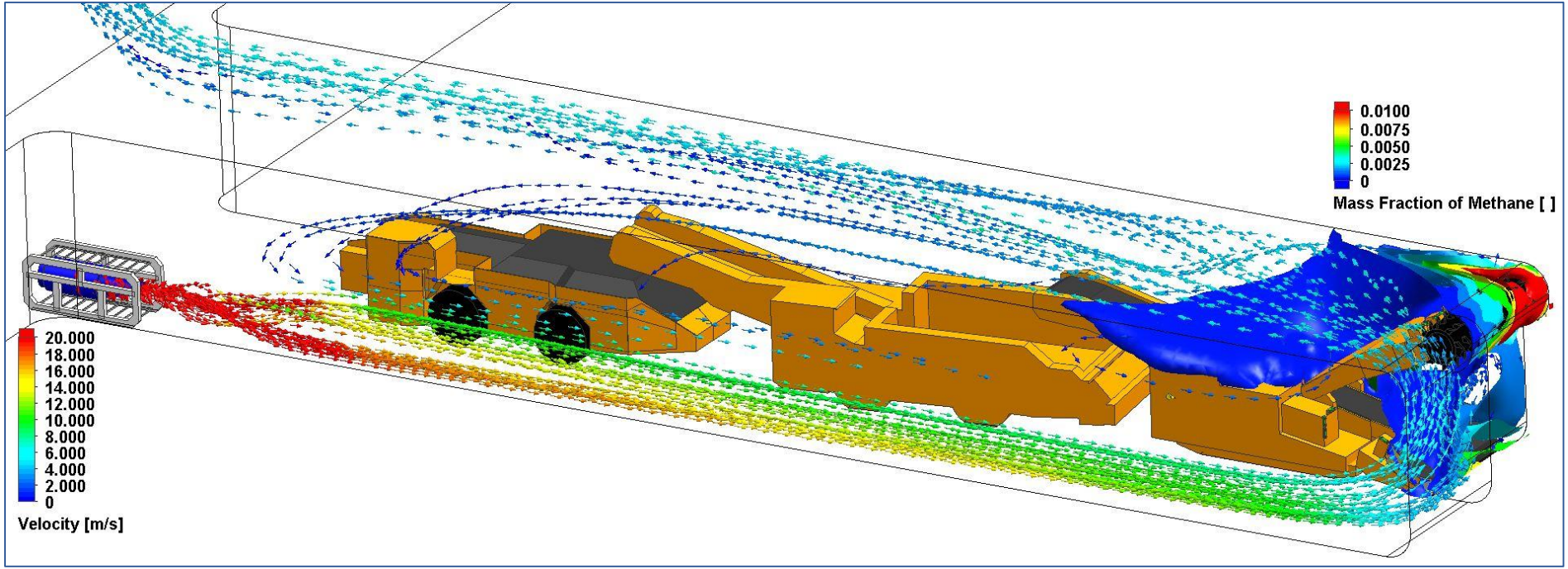

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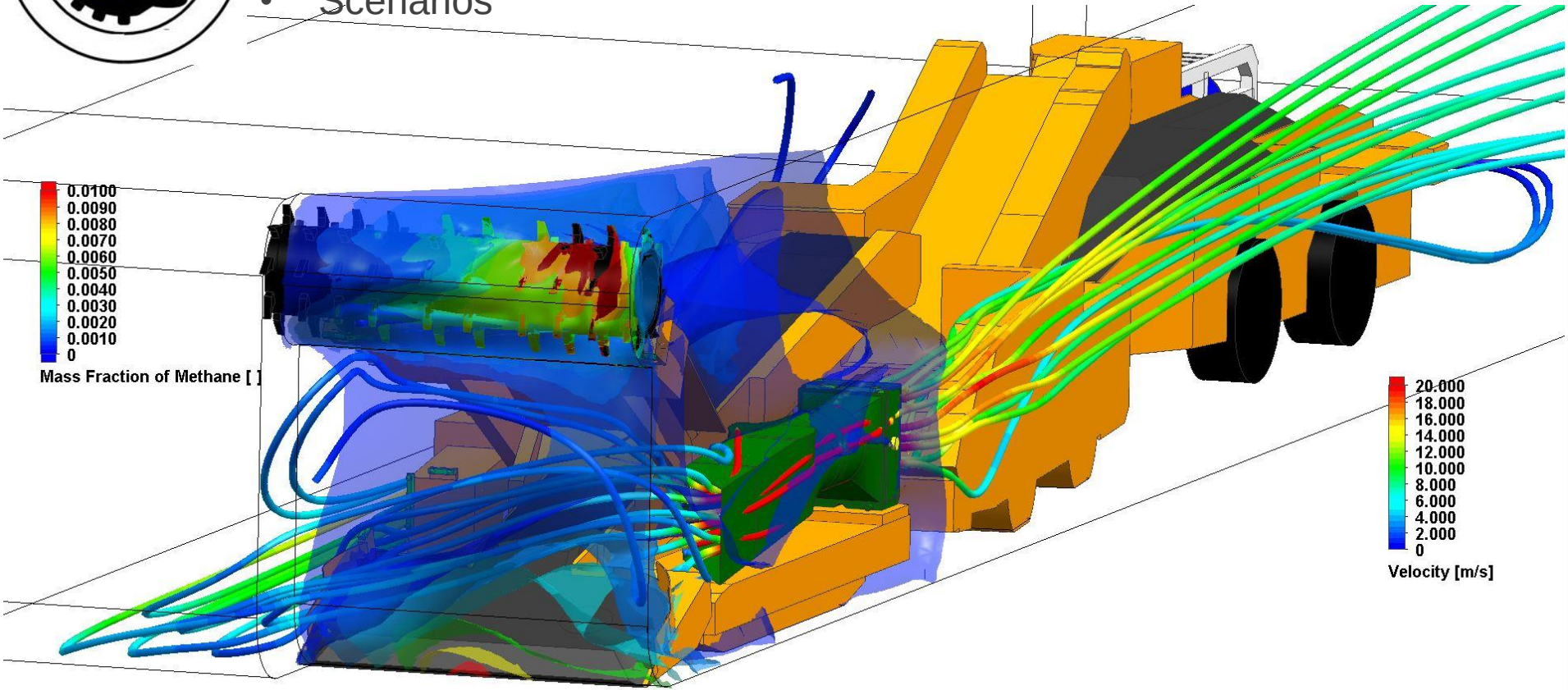

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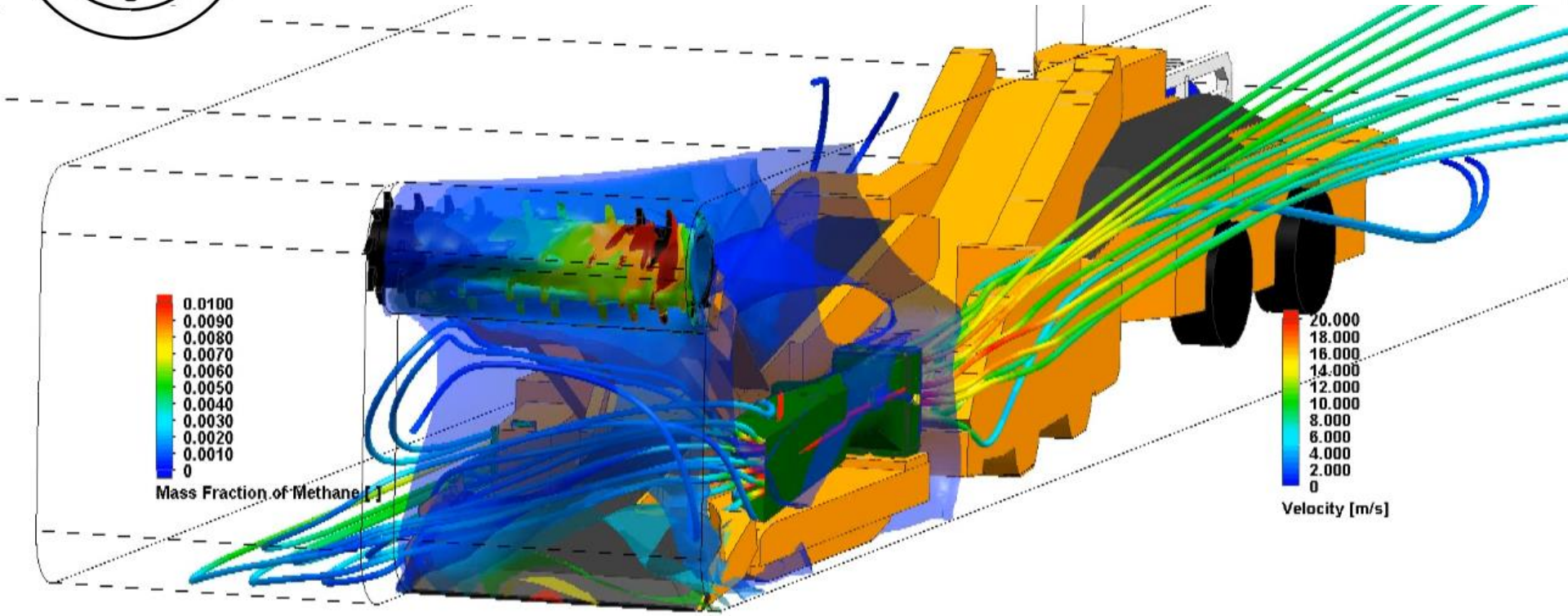
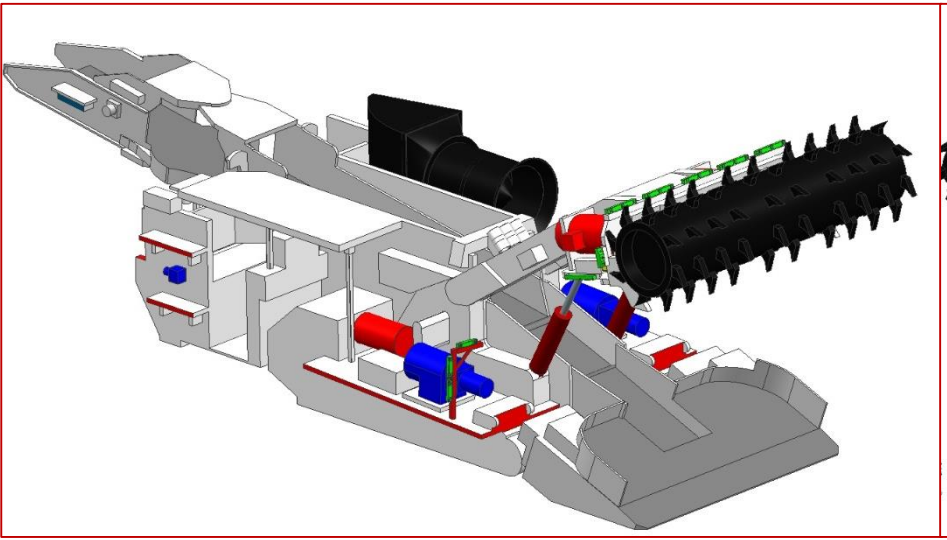
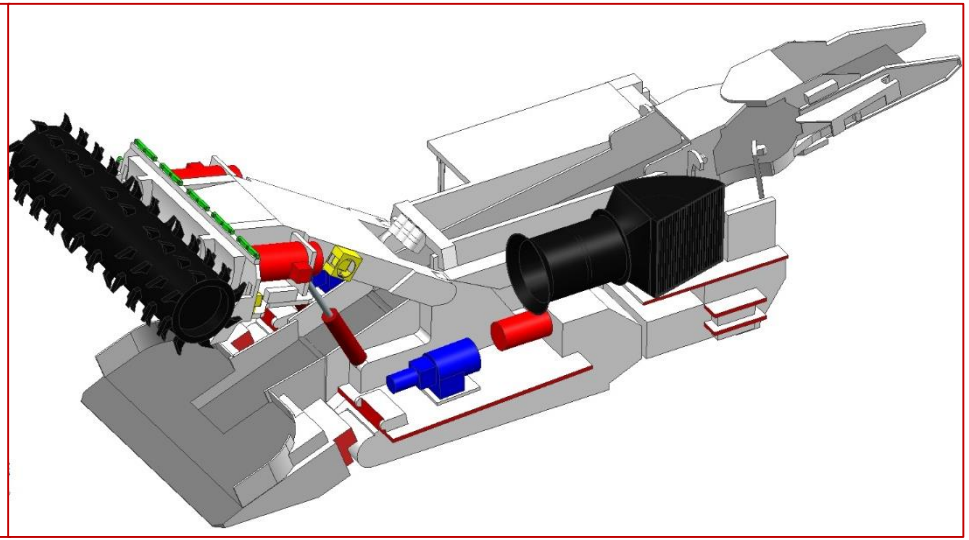


Examples of Model Complexity

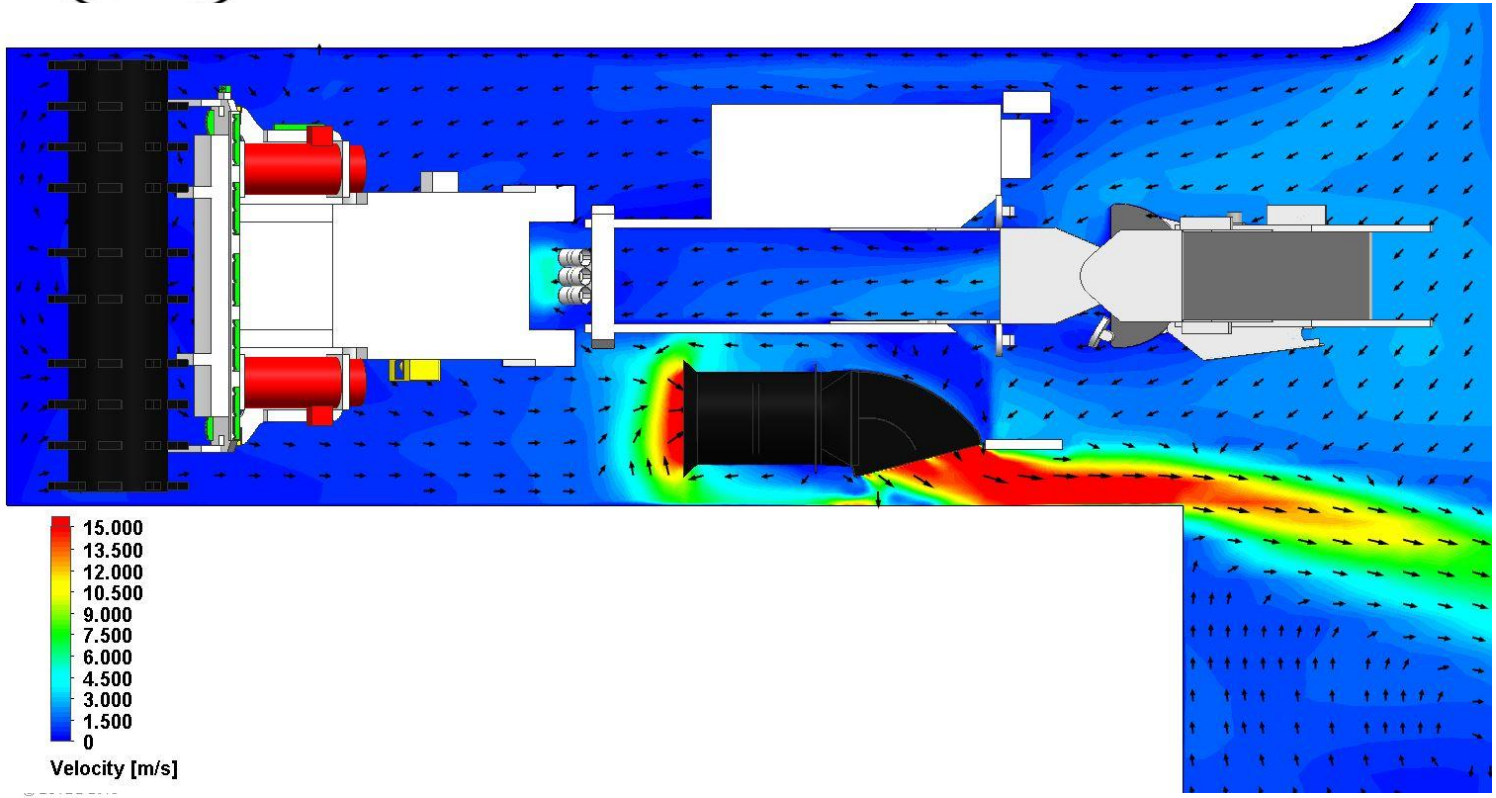
- CM CAD Geometry





Examples of Model Complexity

- CM CAD Geometry



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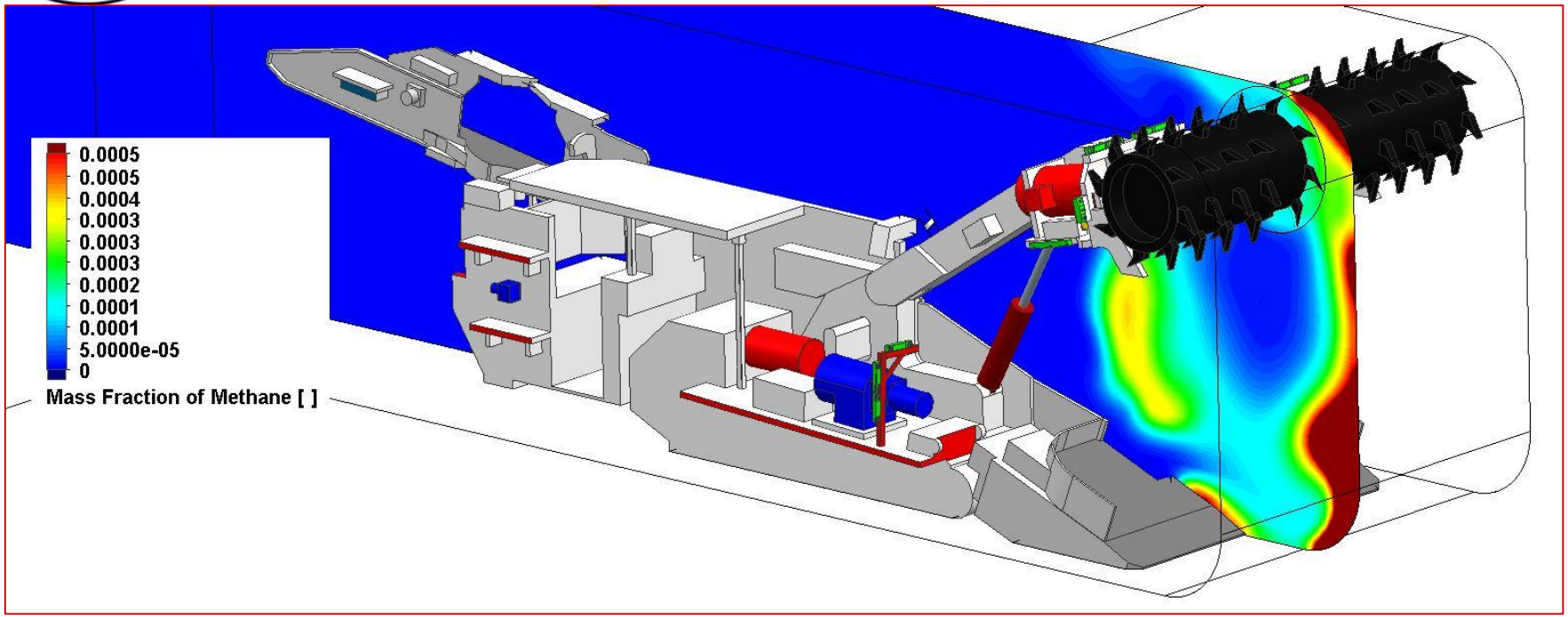
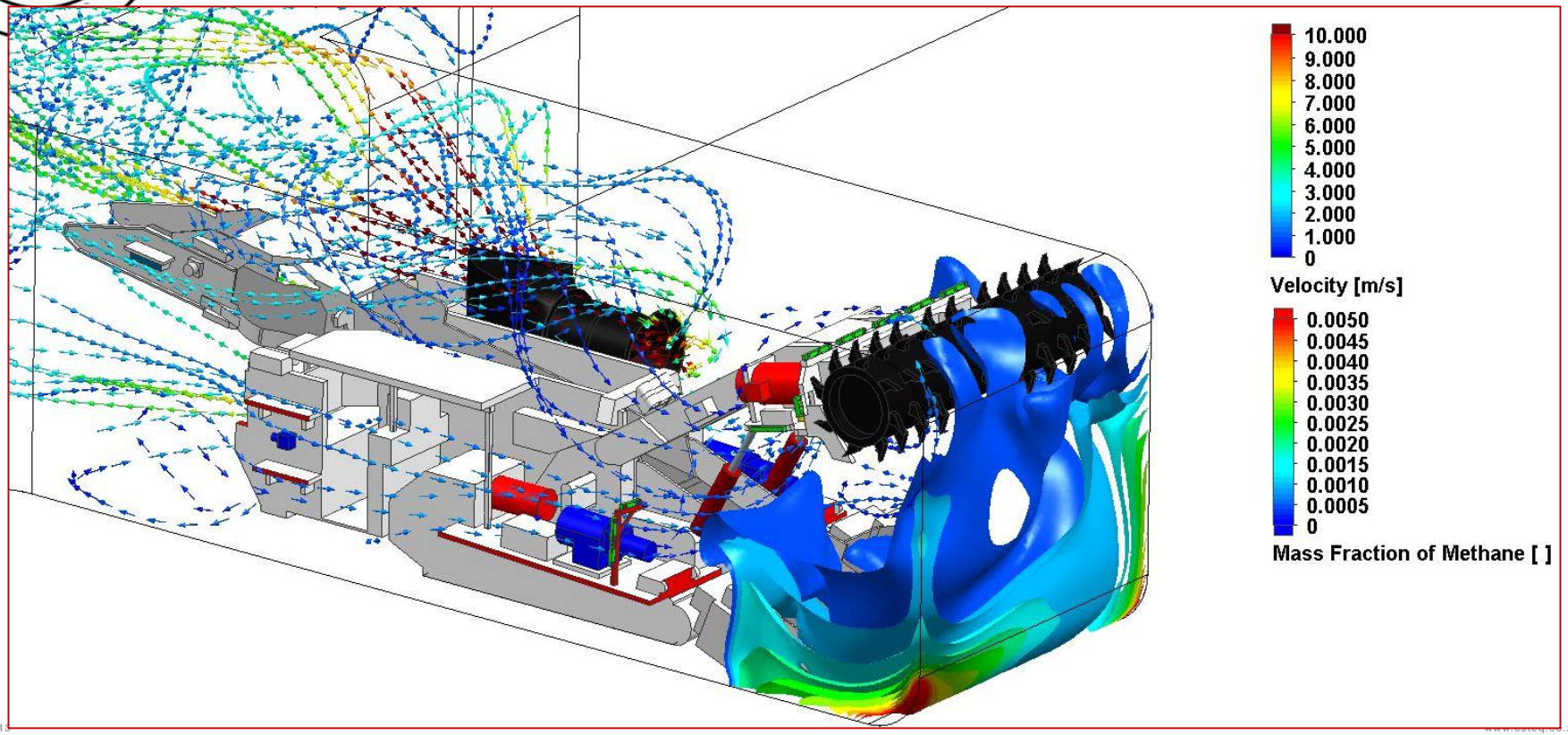


Examples of Model Complexity

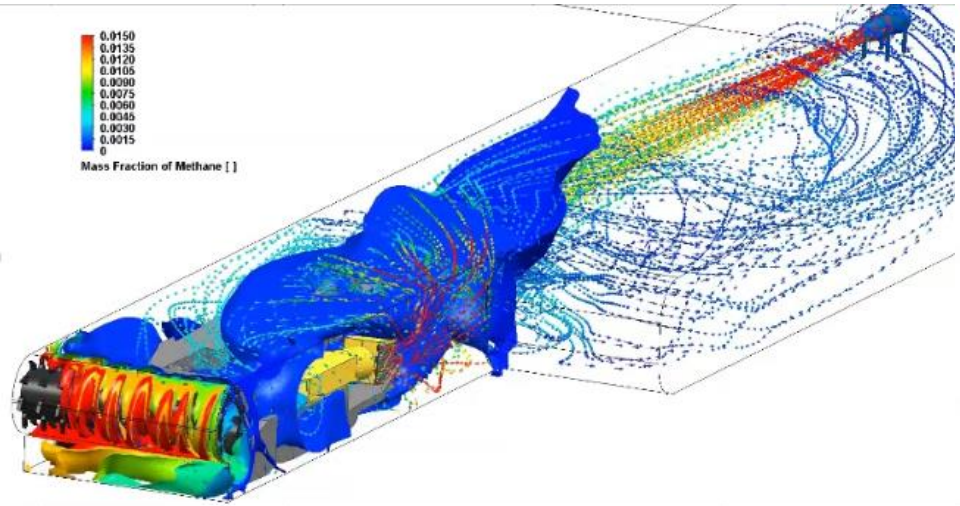
- CM CAD Geometry



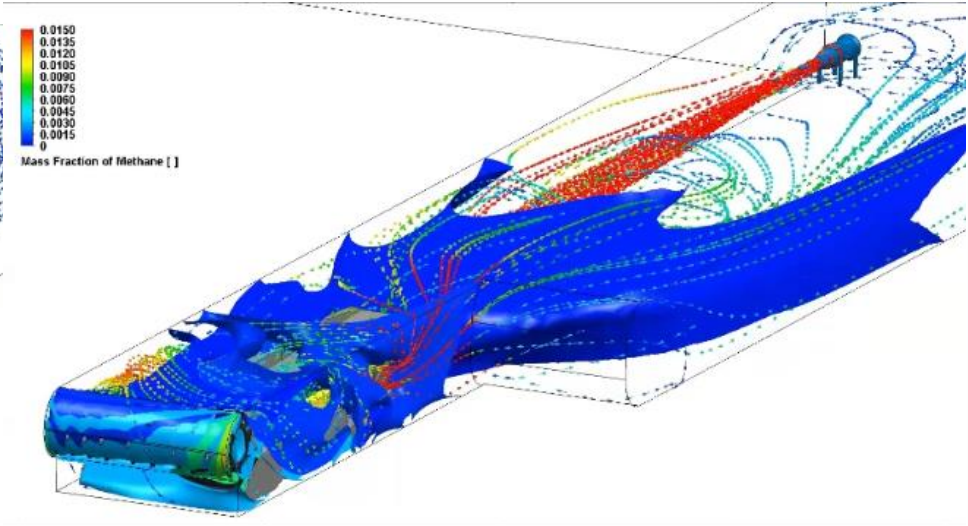
Stage 3:Advancing Methane Control

- **Balancing** Ventilation Systems
  - Considering **entire integrated system**
  - **Characteristics** of specific CM + Scrubber + Auxilliary Air setup
  - Determine **flow rates required** for that setup

Unbalanced



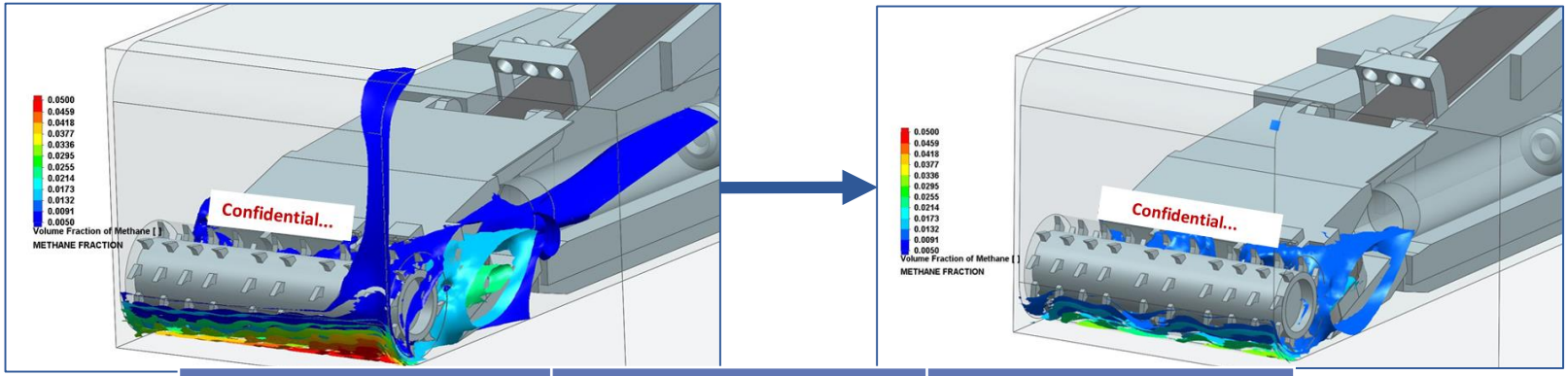
Balanced



Stage 3:Advancing Methane Control

- **2017**: Current State of Affairs
- FloEFD opened the doors to Innovation:
  - New Concept evaluated with **FloEFD Upfront** – Promising Results
  - Surface tests conducted → Underground tests in progress

2013
2014
2015
2016
2017
2018



CFD Prediction of Methane Concentrations	Methane Concentrations Conventional [%]	Methane Concentrations New Concept [%]
Cutting Edge Methane	5.70	2.82
Left Front Methane Sensor	1.91	1.37
Right Front Methane Sensor	0.36	0.14
Left Under Methane Sensor	2.04	1.22
Right Under Methane Sensor	1.52	0.90

CONCLUSION (almost)

- COL518 standard outdated?
  - Not quite...
  - Principles for effective ventilation still apply
  - Mechanisms to achieve them just outdated
  - Could see some updates / revisions based on latest research

- May see future requirement that the CM and/or Scrubber manufacturers take into account the entire ventilation strategy during CM/Scrubber design
  - FloEFD perfectly suited...

Success Story within the Success Story...

Cor Meyer: Coaltech Project Leader – Preventing Methane Ignitions

- No formal Engineering training (30+ years of experience in mining ventilation...)
- Nearing retirement – took on the challenge of doing the CFD simulations himself (with no CAD or Simulation experience)
- **Greatest testimony to FloEFD ease of use**
- Awards:
  - 2014: Best Presentation in CFD Track (ECC 2014)
  - 2017: SACMA Prize for article: "*Using CFD to evaluate factors contributing to effective methane dilution in Continuous Miners*"

To Development Team

WE Thank you!