

PU FOAM

Backfill *For All Seasons*

IPLOCA – Berlin – 11:15 – 15th March 2018

- Introduction & Concept History
 - Basics of PU Foam
 - Full-scale Commercial Trial
 - Solution Elements
 - Important Numbers
 - Health & Safety – Silica
 - Timelines
 - Future Steps & Developments
-
- Questions & hopefully answers!

Introduction – Concept History



- VelociFoam is a development company, HQ'd in Malta, to take advantage of Patent Box system.
- Based around a patent concerning the use of PU foam as replacement for backfill in buried pipelines – originally hydropower penstocks
- Original problem – cost reduction: import of graded aggregate into hard terrain:



- PU foam knowledge & experience from slab-jacking
- Initial skepticism: cost, environment, geotechnical, etc.
- Primary feasibility study was positive: cheaper, faster, safer



Trapezoid Trench Version

- Suited to loose soil types
- Suitable for wet weather laying
- Lowest consumption of foam
- Highest degree of precision, due to use of moulds and guides
- Best for higher drainage requirements

Property	Security Factors
Buoyancy	2.2
Compressive strength	17
Axial stability 30°	5.5
Axial stability 45°	3.2

Calculations according to the Norwegian Water & Energy Department (NVE) guidelines & model

Square Trench Version

- Suited to harder / stiffer soil types
- Quickest, must be completed in 24hrs to comply with Norwegian trench regulations
- Higher foam consumption
- Less suited to wet weather laying
- Very suitable for steep terrain angles

Property	Security Factors
Buoyancy (no friction)	1.57
Buoyancy (with friction)	55.9
Compressive strength	14.5
Axial stability 30°	77.3
Axial stability 45°	44.6

Calculations according to the Norwegian Water & Energy Department (NVE) guidelines & model

Basic of PU Foam

- Closed-cell rigid PU foam: two components, polyol & isocyanate
- Mixed, with an exothermic reaction that produces CO₂ that forms gas cells
- May be poured or sprayed, normally 1:1 by volume
- Cures within minutes, hardens within hours
- Inert, reacts to strong UV & very high temperatures, almost impossible to degrade
- Mix is almost SG1, expands up to 40 times initial volume
- Our foam is typically:
 - 45kg / m³
 - Compressive & tensile strength: 150 – 300 kPa, controllable through reaction
 - Adhesive strength GRP & ductile iron: 60 – 800 kPa, dependent on substrate temp
 - Slightly anisotropic, but spreads load quickly and evenly
 - 2% long term creep, 98% cells closed – effectively watertight at any depth



Full-scale Commercial Trial

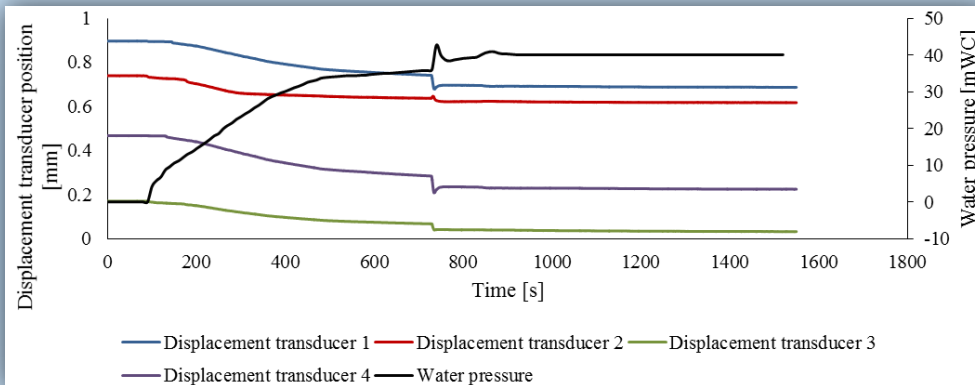
- 2016 – Lille Måsevang, Finnmark, North Norway
- Statkraft – Norwegian State, academic back-up from NTNU Trondheim
- DN800/900 hydropower pump station, 40m head, 1.3km



Straight section – 100mm foam



15° bend section – 300mm foam



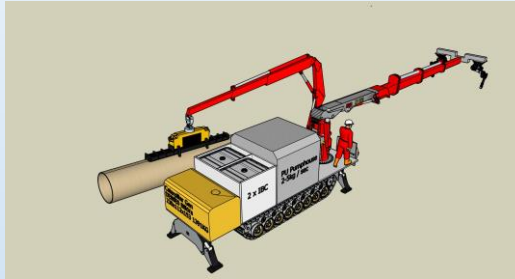
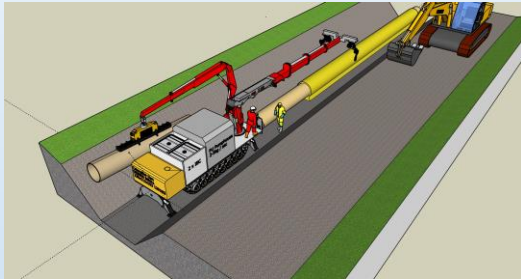
“The commissioning of Lille Måsevang penstock proves that the method with PU-foam as backfill works on a full-scale project, both for construction and operation.”

Prof. Leif Lia – NTNU Trondheim

Solution Elements – 1

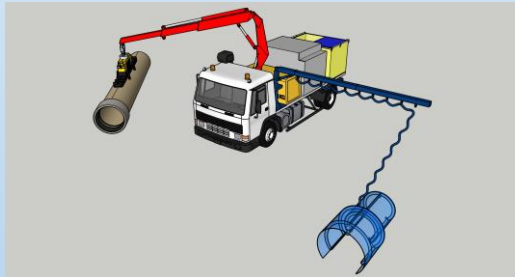
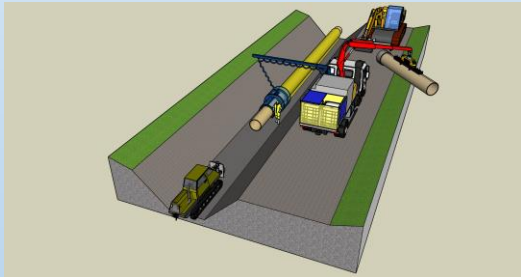
Two main strategies:

- **In-line** – installing and spraying at the pipehead, from a single vehicle



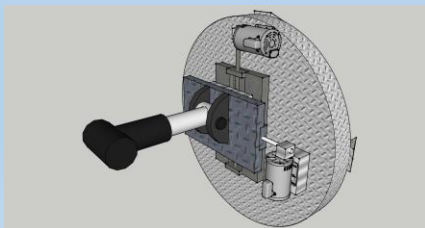
Pros: easier cycle management, lighter access road reqs, bends and straight, all pipe diam
Cons: only larger pipe diams, linear techniques (robotics), larger pump capacity, bespoke vehicle

- **Off-axis** – spraying pre-installed, or installing in-line and spraying from the side



Pros: fewer cycles, flexible for terrain, existing crawler tech, containerized, easier substrate control
Cons: not universal pipe diams, heavier access road, dismount for bends, tighter production coordination

- **Common** – pipe-jacking and vacuum pipe lifter



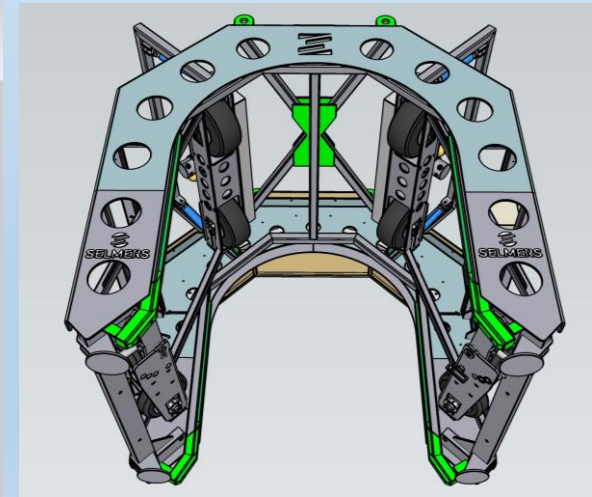
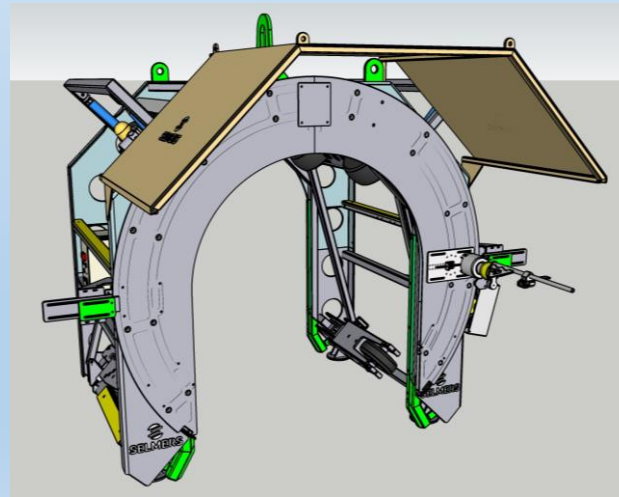
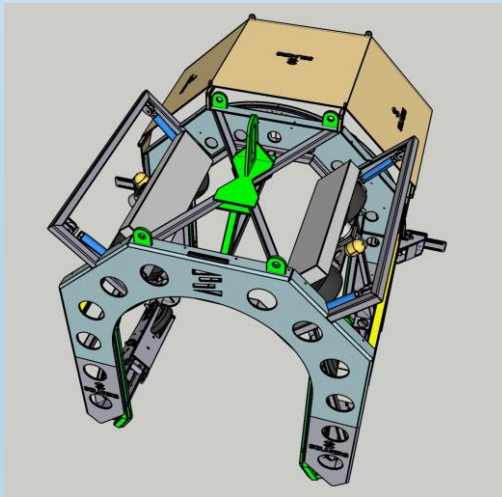
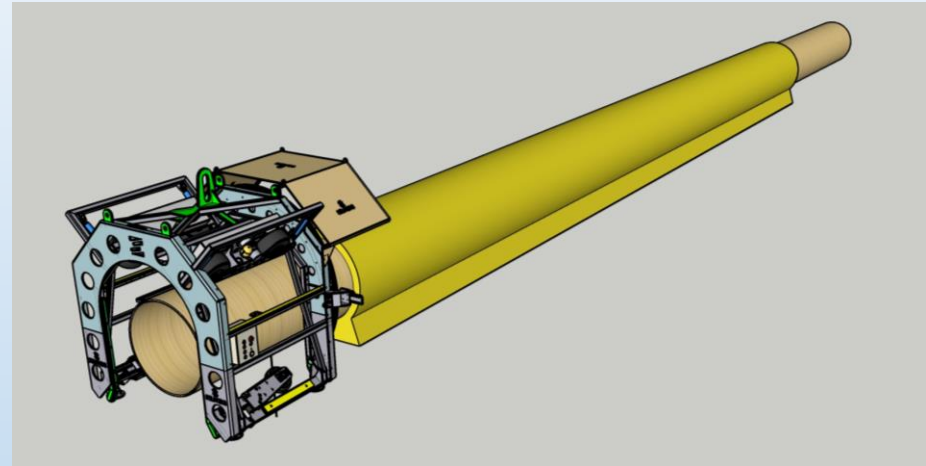
Jacking plate, reduces time, decreases gasket damage, assists in accurate deflection and GPS measurements



Vlentec VPL, electric version, assists installation speed, reduces pipe surface damage and risk to personnel from pipe handling

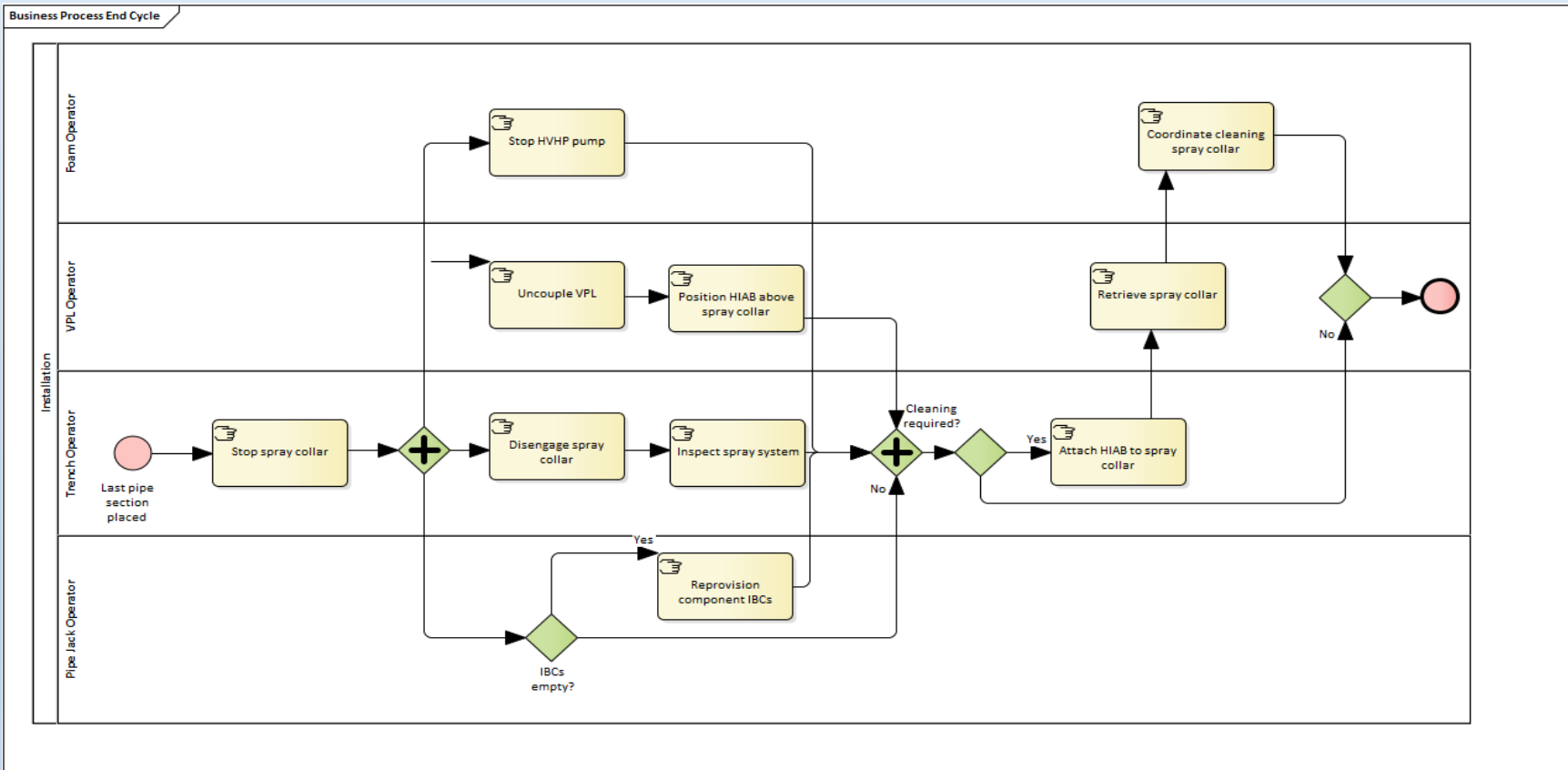
Spray Crawler / Collar

- Based on existing pipe coating frame
- 150mm pipe diameter range
- > 200mm from pipe surface
- Allows very rapid spraying
- Swivel for pipe support section
- Moves over pipe joints
- Fast time to market
- Selmers quality

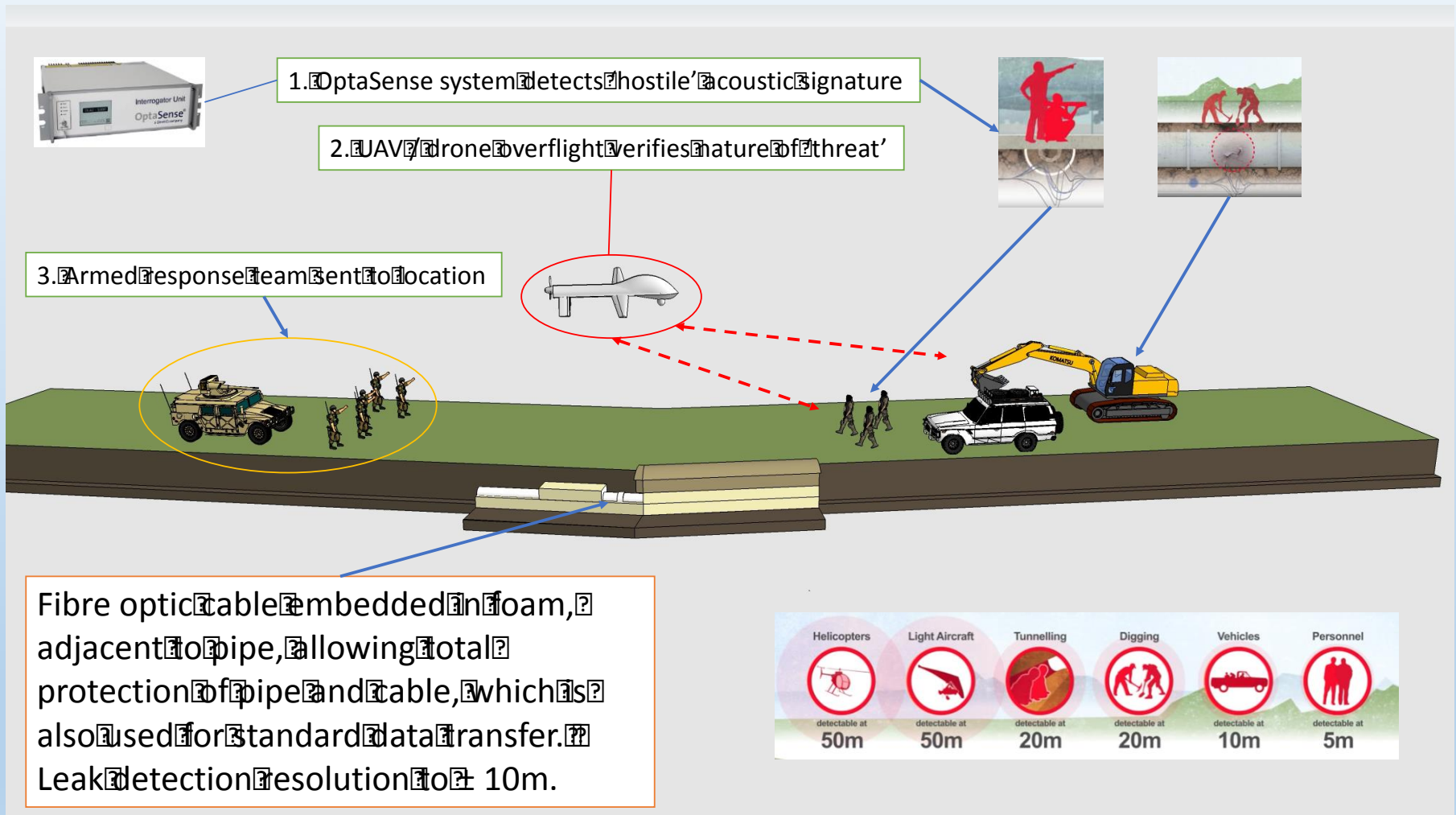


Solution Elements – 3

- Initial choice made for DN700-900 Off-Axis, due to R&D costs / timeline.
- In-line will be developed after Off-Axis, Q4-2018
- Personnel: Foam specialist, site boss, 2 / 3 general construction workers
 - Minimal specialist training required
 - 'Ballet' coordination most important



Solution Elements – 4



*detection and UAV / ISR priced separately to core VelociFoam offering on a project-specific basis

Important Numbers – 1



Bend Geotechnical

Calculations based on 3 types of theory:

- Tensile strength of foam on bend legs: 'x'-only, at 1:2 and 3:4
- Tensile strength of foam & compression against soil: 'x' & 'z'
- Full distribution of forces through system at any given length from bend apex
 - 'x', at 1:2 and 3:4
 - Compression Lr & Lbr to 'z'
 - Shear strength of base foam layer (between pipe and trench bottom)

MultiConsult – Mathcad - Adamselv

1.2 Geometri
1.2.1 Rør, dimensjoner:

Langte pr. totallengde rørseksjon: $L_r = 6m$ Lengde på bender: $L_{br} = 3m$

Vanntrykk (inkl. trykkløst): $H_0 = 250m$ Karaktærisisk trykk: $P = H_0 \cdot \gamma_0$ $P = 2.5 \cdot 10^3 kPa$

Rør indre rørdiameter: $D_{in} = 700mm$ Rør ytre rørdiameter: $D_{out} = 738mm$

Foam tykkelse: $D_{fo} = 438mm$ Thickness of backfill soil: $A_{fo} = 0.5m$

Austad topp tykkelse til senter rø: $O_0 = 1.8m$ Effective in situ soil depth for deformation calculation: $A_{so} = 5m$

if ($D_{fo} > D_{out}$ "Inndata er OK", "Kontroller inndata (1.2.1)", "Inndata er OK")

if ($O_0 < 0.8m + 0.5D_{fo}$ "Kontroller inndata (1.2.1)", "Inndata er OK")

Vanfengingensal: $A_v = \frac{D_{out}^2}{4} = 0.38 m^2$

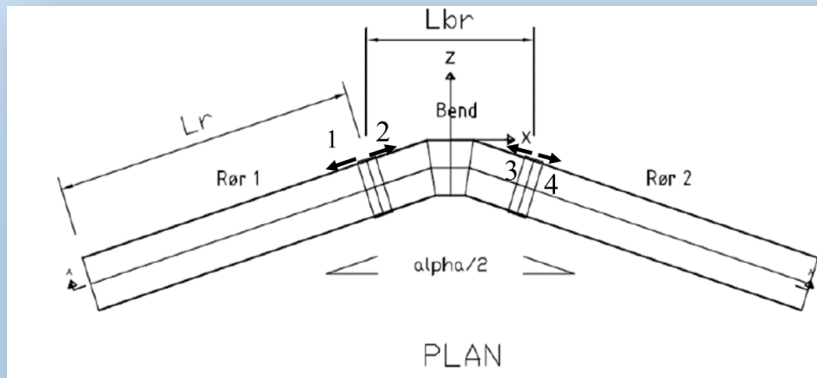
Benders vinkel (horisontalplanet): $\alpha = 54deg$ Gullvengingens vinkel: $\alpha_{max} = 54deg$

Vertikale vinkel, Rør 1 (med 0.5 deg): $\beta_1 = 20.14deg$ Vertikale vinkel, Rør 2: $\beta_2 = 20deg$

Overflate vinkel: $\gamma = \frac{|\beta_1| + |\beta_2|}{2}$ $\gamma = 20.07 deg$

Example

- DN 900 (35")
- 30 BAR (100m head) & 2.5 m/s flow
- 30° Horizontal Bend
- Resultant Force 'z': 1,003 kN
- 300mm foam thrust block depth



x-axis	Force Mobilised (kN)			Total	State	Security Factor
	Bend	Leg	Bed			
Deformation	Compressive	Tensile	Shear			
0.1 mm	4 kN	3 kN	1 kN	8 kN	Unstable	0.008006175
0.5 mm	20 kN	13 kN	7 kN	40 kN	Unstable	0.040030873
1.0 mm	40 kN	25 kN	15 kN	80 kN	Unstable	0.080061745
2.0 mm	81 kN	51 kN	29 kN	161 kN	Unstable	0.16012349
3.0 mm	121 kN	76 kN	44 kN	241 kN	Unstable	0.240185235
4.0 mm	161 kN	101 kN	59 kN	321 kN	Unstable	0.32024698
5.0 mm	202 kN	126 kN	73 kN	402 kN	Unstable	0.400308725
6.0 mm	242 kN	152 kN	88 kN	482 kN	Unstable	0.48037047
7.0 mm	282 kN	177 kN	103 kN	562 kN	Unstable	0.560432215
8.0 mm	323 kN	202 kN	117 kN	642 kN	Unstable	0.64049396
9.0 mm	363 kN	227 kN	132 kN	723 kN	Unstable	0.720555705
10.0 mm	403 kN	253 kN	147 kN	803 kN	Unstable	0.800617451
11.0 mm	444 kN	278 kN	162 kN	883 kN	Unstable	0.880679196
12.0 mm	484 kN	303 kN	176 kN	964 kN	Unstable	0.960740941
13.0 mm	524 kN	329 kN	191 kN	1044 kN	Stable	1.040802686
14.0 mm	565 kN	354 kN	206 kN	1124 kN	Stable	1.120864431
15.0 mm	605 kN	379 kN	220 kN	1205 kN	Stable	1.200926176
Resultant Force:		1003 kN				

Maximum movement in an unrestrained joint, at 1:2 or 3:4 is 3.26mm

Production Estimates

Calculations based on:

- DN750 (30") pipe
- < 15° gradient
- No bends more than 3° per section
- Foam depth: single 100mm pass, upper 270° orbit, (machine capacity 200mm)
- 200mm lower 90° orbit
- OMS EcoPlus High-Volume High-Pressure Pump System @ 33 litres per minute (real capacity 85 l/min)
- Spray head tracking speed 100 mm/sec (real tracking speed 450 mm/sec)
- Cycle time per 6m pipe section 10 minutes (real time 5 minutes)
- 12 hour production day
- 50% weather risk

Foam Volume Per Length Metre	0.327839508	m3
Foam Weight Per Length Metre	14.75277784	KG
Component Volume Per Length Metre	13.41161622	L
Component Volume Per 6m Pipe Section	80.4696973	L
Theoretical Tracking Speed	450	mm/s
Spray Time per Pipe Section	03:03	min:sec
Cycle Time per Pipe Section	10	min
Tracking Speed	91.26326659	mm/s
Nominal Length per Day (12 hour shift)	432	m

Internal calculations

The proposal is based on the following pipe specifications:

- GRP pipe
- Pipe diameter range: 24" – 30 "
- Pipe length range: 6 – 12 metres
- Max pipe weight 60 kg/m
- Jacking force 1,2 mT
- PU foam coating thickness max. 200 mm
- Production speed application (netto) 200 – 500 m/day (12 hours)
- Clearance under the pipe 200 – 400 mm
- Applicator width approx. 2100 mm

Selmers proposal

216 length metres per day





The Commercial Case

The advantages of the VelociFoam method are based on three elements:

- Speed of installation – dependent on theatre, but ± 80% reduction in installation time
- Reduction in risk: massively increased system predictability – security and geotechnical
- Reduced infrastructure requirements

Typical Norwegian Project Details

Length of Pipeline: 1,500 m Pipe Diameter: 500 mm Conditions: 50% 'dry', 50% 'wet'

	Stone Backfill	Foam Backfill
Length of Project (weeks)	 125 work days	 14 work days
Number of Truck Loads (x2)	 295 truck loads – 40 tons 11,800 tons of aggregate	 2 truck loads – 26 tons 46 tons of foam
Cost (per metre)	NOK 4,200	NOK 2,000

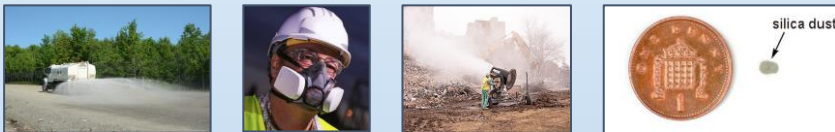
- Far fewer concrete bend anchors
- Lower bend engineering costs
- Increased laying precision
- Lower access road requirements
- Lower risk of pipe damage and failure
- Less ecological damage, due to smaller footprint & shorter ground opening period
- Lower finance costs: shorter projects
- Better dynamic loading
- Fewer leaks in all sectors
- Ease of repair through earlier detection (FMEA)
- Use of lighter materials (GRP)
- Increased annual production capacity for General Contractors
- Fast time to market for developers

Health & Safety – Silica (SiO₂)

VelociFoam is a game-changer for the silica exposure management problem, reducing levels of exposure by more than an order of magnitude.



In pipeline construction, major sources of SiO₂ are trenching, crushing and road construction.



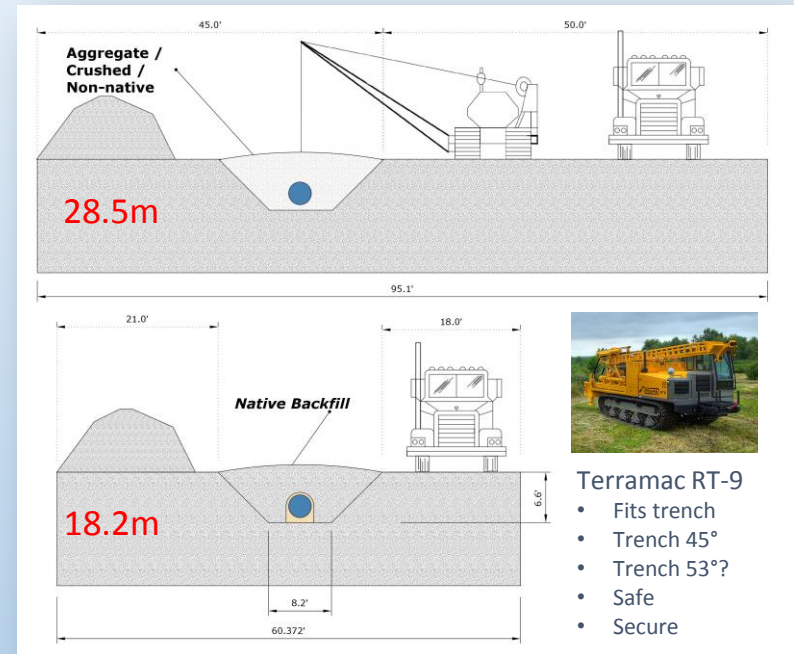
Dust suppression is expensive & operationally onerous.

Major reduction in Crystalline Silica production:

- Up to 90% reduction in road traffic:
 - Native backfill, removing the need to use imported or locally-crushed aggregate
- Much smaller (up to 50%) operational footprint:
Norwegian project used 15m v typical 30m construction row (DN900)
- Lower access road construction requirements due to lower traffic load, less use of fines, less dust when dry

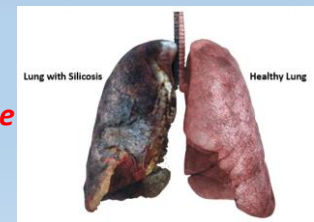
Cost reductions:

- Dust suppression
- Medical costs, both preventive and reactive



Quote from Pace

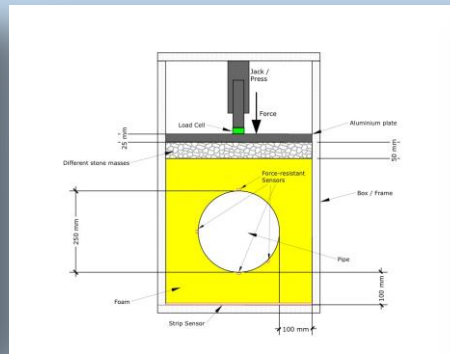
“In terms of operational and OHSA costs, such a large reduction in the use and production of crushed stone represents a game-changing proposition for the pipeline industry.”



- Q1 / 2 2018: Engineering & Construction
- August 2018: Assembly & Full-scale testing – 2km (likely in Houston, TX)
- Q4 2018: Operational – First machine
- Q1 2019: Roll-out with new Off-Axis machine
- Q2 2019: Roll-out with In-Line machine

Future Steps & Developments

- Partnership with Engineering & General Contractors
 - VelociFoam not intending to be GC
- Full implementation of fibre-optic security / leak detection / intrusion system, with defence / UAV
- Update laying rules / standards ISO / AWWA



Questions & Answers

... and thank you!



VelociFoam

Contact:

Guy Harris: guy.harris@velocifoam.com +31 638628394

Andrew Whitney: andrew.whitney@velocifoam.com +1 415 6025007

VelociFoam Ltd, Level 16, Portomaso Business Tower, St. Julian's, Malta – Company ID – C 84262