



SPECTROMETER DESIGN FOR OPTIMISING MEASUREMENT DATA QUALITY IN THE REAL WORLD

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SINTEF

ONE OF EUROPE'S LARGEST **INDEPENDENT**
RESEARCH ORGANISATIONS

4,0 bill

NOK turnover

2200

employees

7000

projects

3200

customers

INTERNATIONAL

652 mill NOK

NATIONALITIES

80

PUBLICATIONS (INCL. DISSEMINATION)

6200

CUSTOMER SATISFACTION

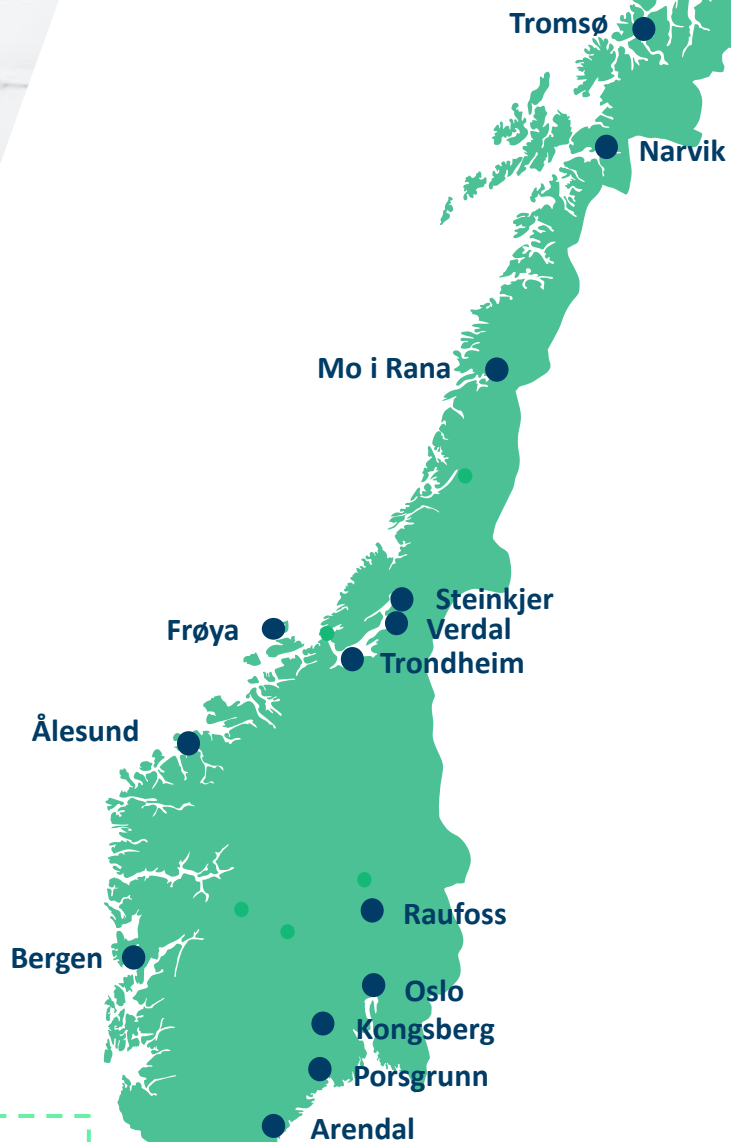
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SINTEF

CLOSE PROXIMITY TO CLIENTS

— YOU'LL FIND US ALL ACROSS NORWAY



Technology for a better society

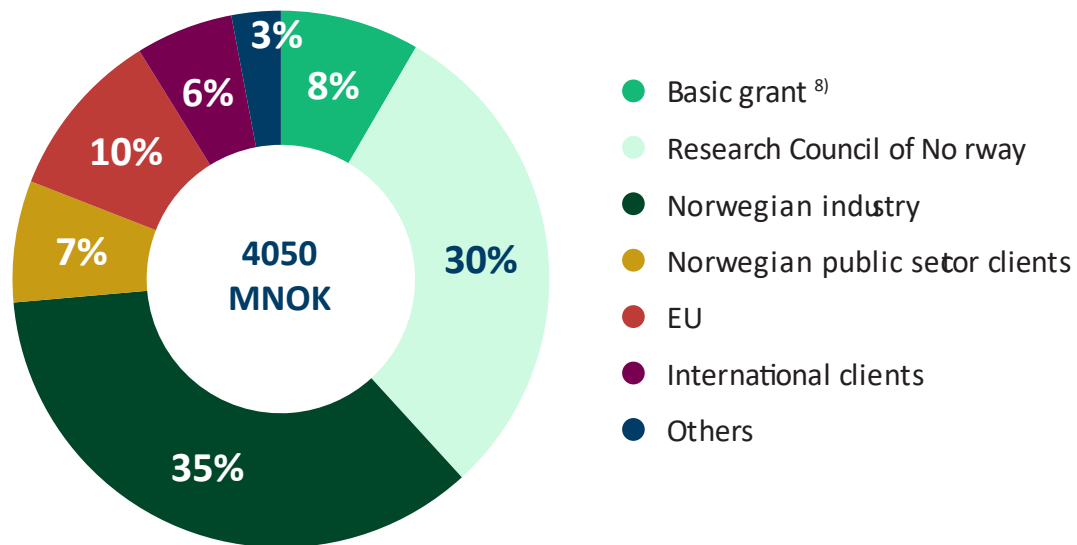


SINTEF

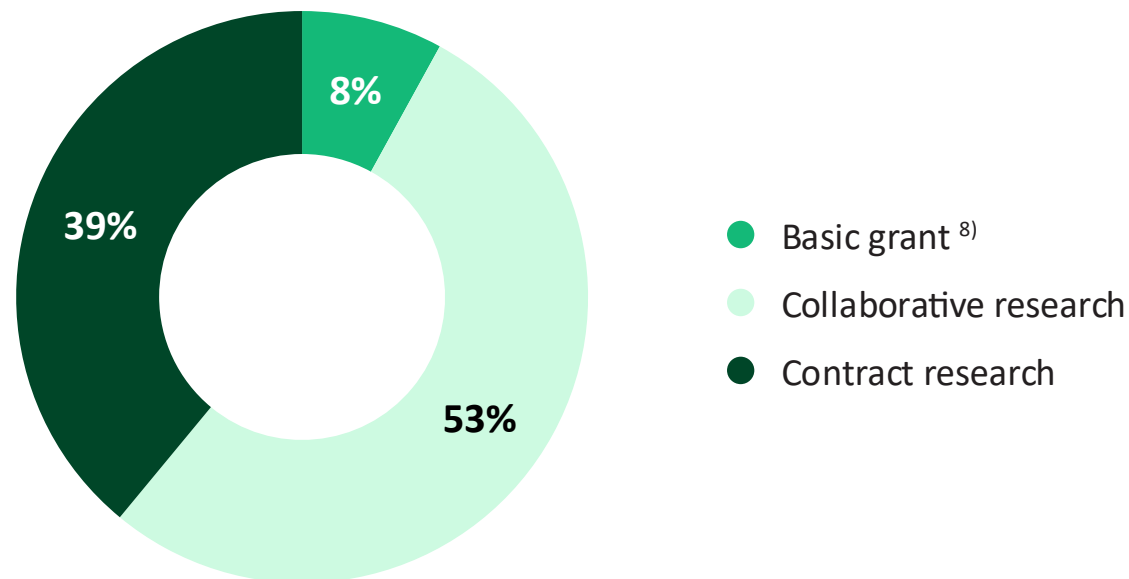
92% of income comes from open competitions

- a balanced portfolio of collaborative research and contract research

Funding sources as a percentage of gross operating income



Portfolio type



Complex food products require photon care!



Potato

Measurement: Dry Matter

Challenge: Measure through the peel. DM content varies radially



Split Cod

Measurement: Dry Matter

Challenge: Measurement must be done through a layer of salt



Whole salmon

Measurement: Fat content

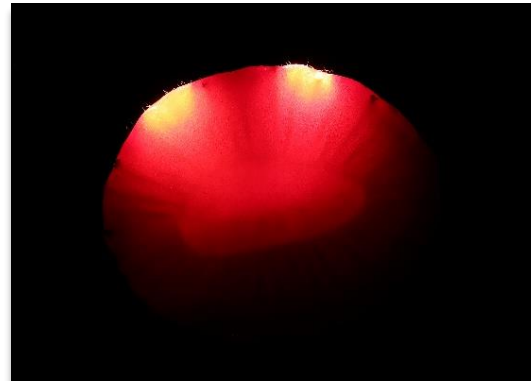
Challenge: Measure through skin, without contact, and inline



King Crabs

Measurement: Meat content.

Challenge: Distinguish between water states & measure through shell



Strawberries

Measurement: Ripeness

Challenge: Heterogenous distribution of sugar. Variations on sunny side. Surface varies due to the weather



Apples

Measurement: Ripeness/sweetness

Challenge: Heterogenous distribution of sugar and starches. Measure through skin

How to design for complex food?

Optical sampling –

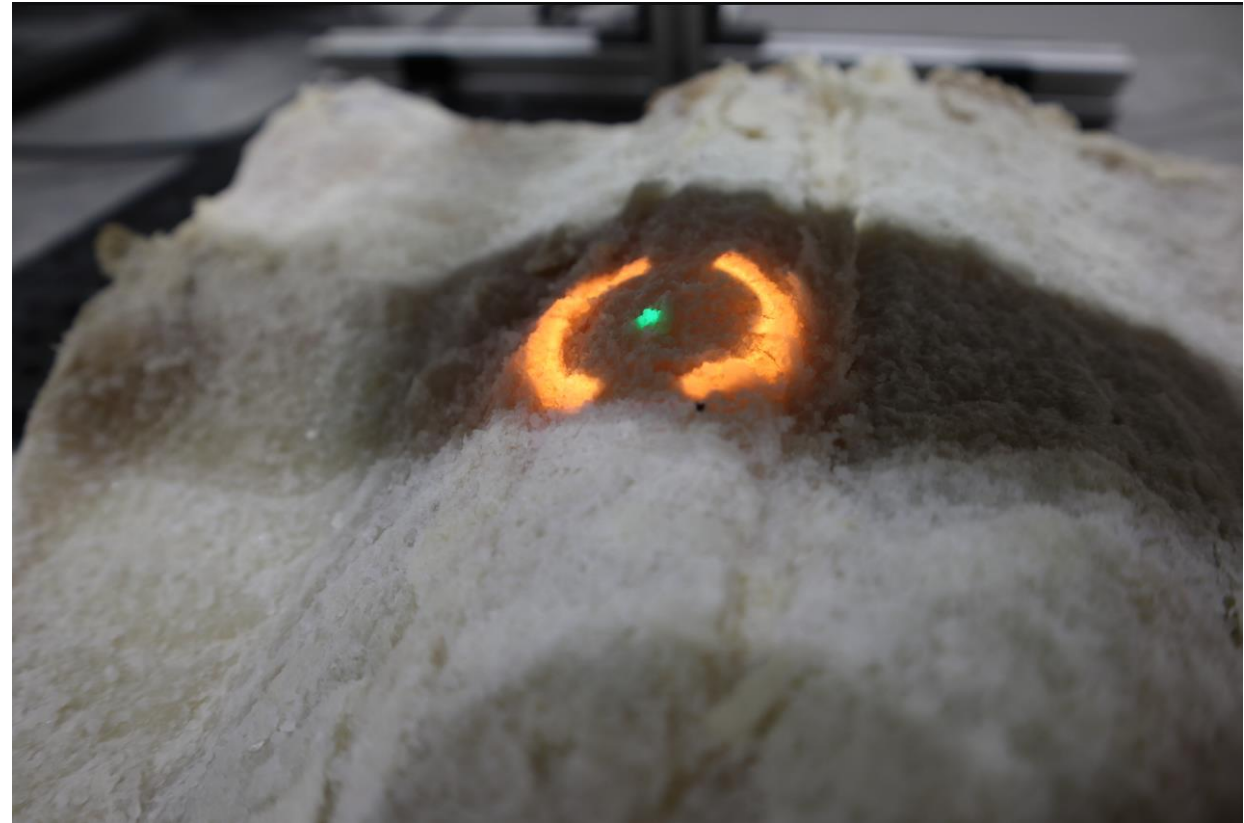
- Measure light from up to 2cm below the surface
- Better control of how light is interacting with food
- Multiple geometries options per measurement
- Non-contact measurement

Optimising for low intensity signals

- High speed measurements when your signal intensity is limited by the application
- Optimal correction for ambient light

Size

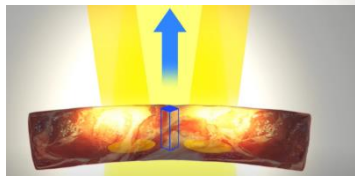
- Realistic size for required measurement quality



Innovation journey



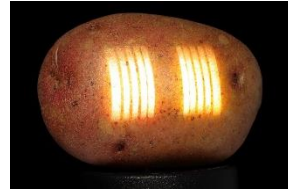
Courtesy of Tomra ASA



QMonitor



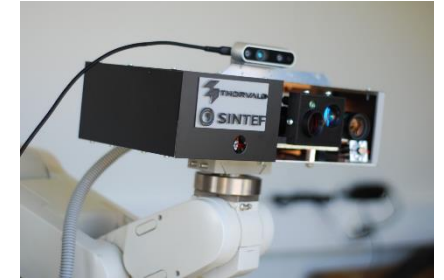
QVision



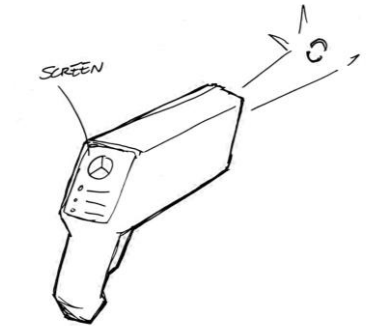
Smart Sensor



Mini SmartSensor



Fragopro



SenseInside

2002

2010

2016

2021

2023

QMonitor & QVision

Commercial products based on interactance. Used to image product on conveyor belts

Smart Sensor

Field-use prototype optimised for SNR for more complex food and allowing multiple interactance lengths.

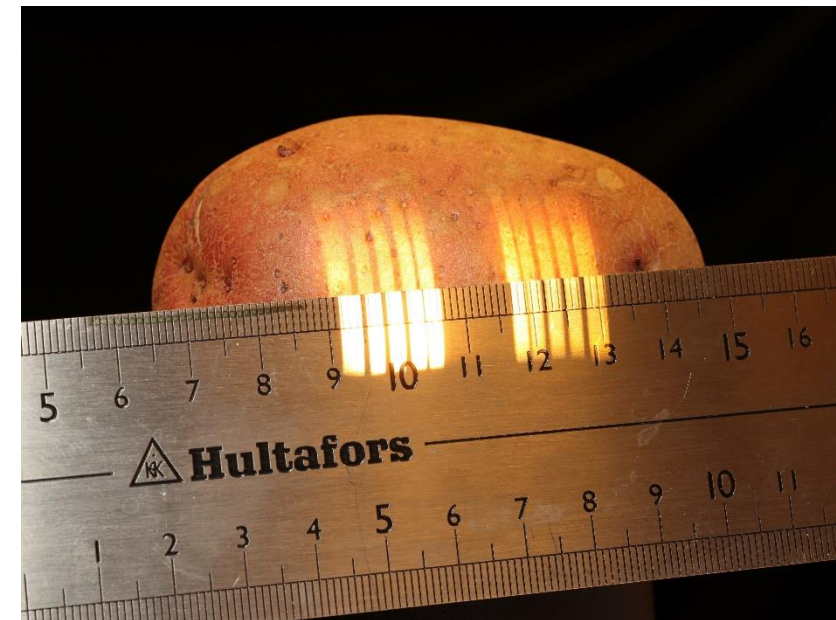
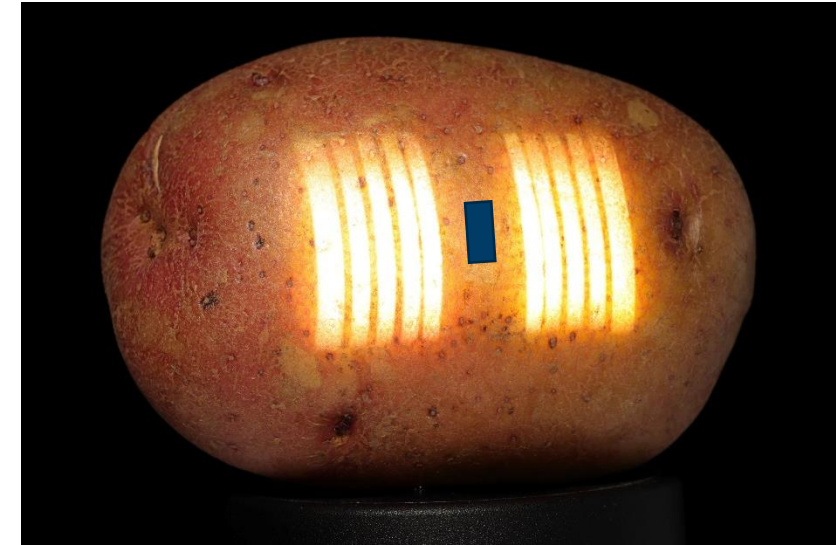
Mini SmartSensor

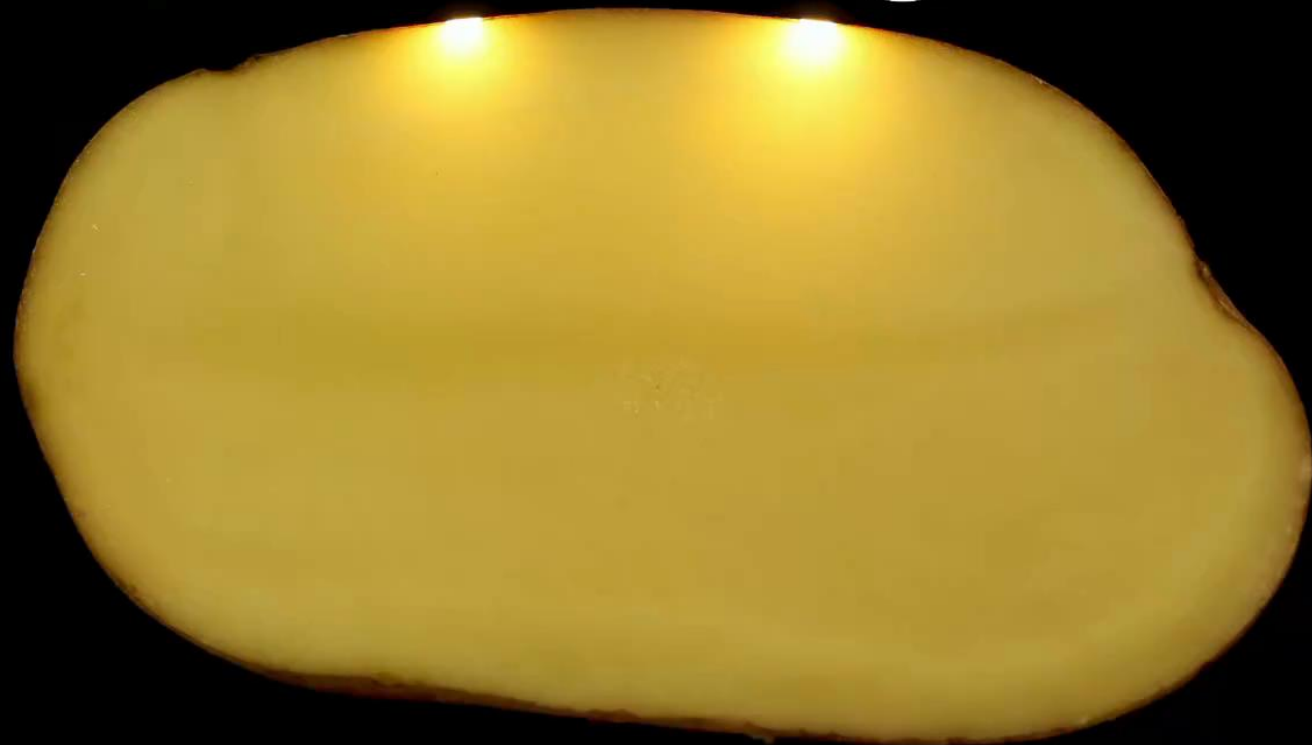
Field-use prototype optimised for size using OEM + COTS components. Designed for maintaining good enough SNR for the size

SenseInside & Fragopro

Smart Sensor

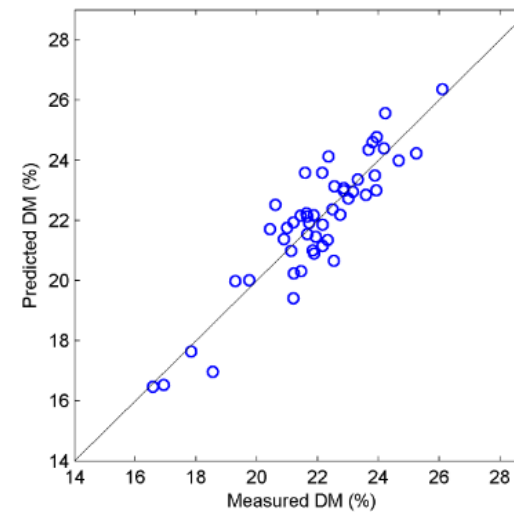
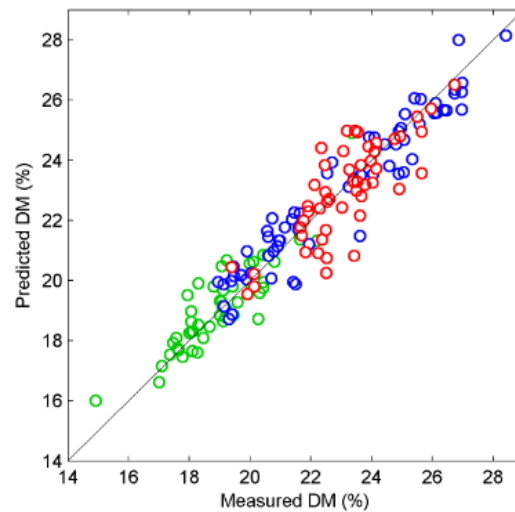
- Multiple geometries (5) per measurement
- Enhanced InGaAs to cover full water peak
- Fast correction of unwanted light
- Non-contact measurement
- High SNR



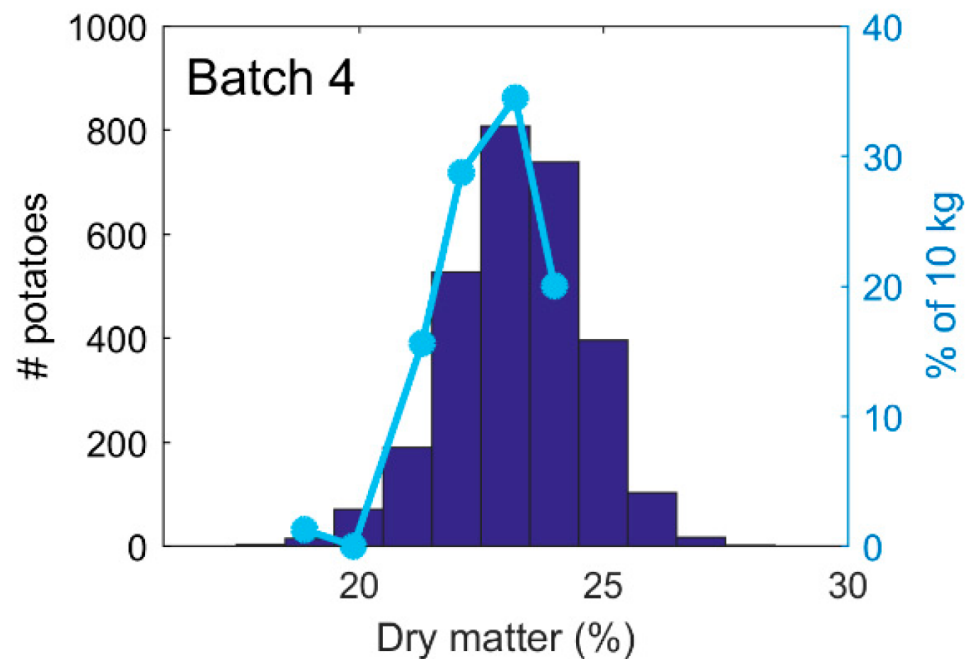
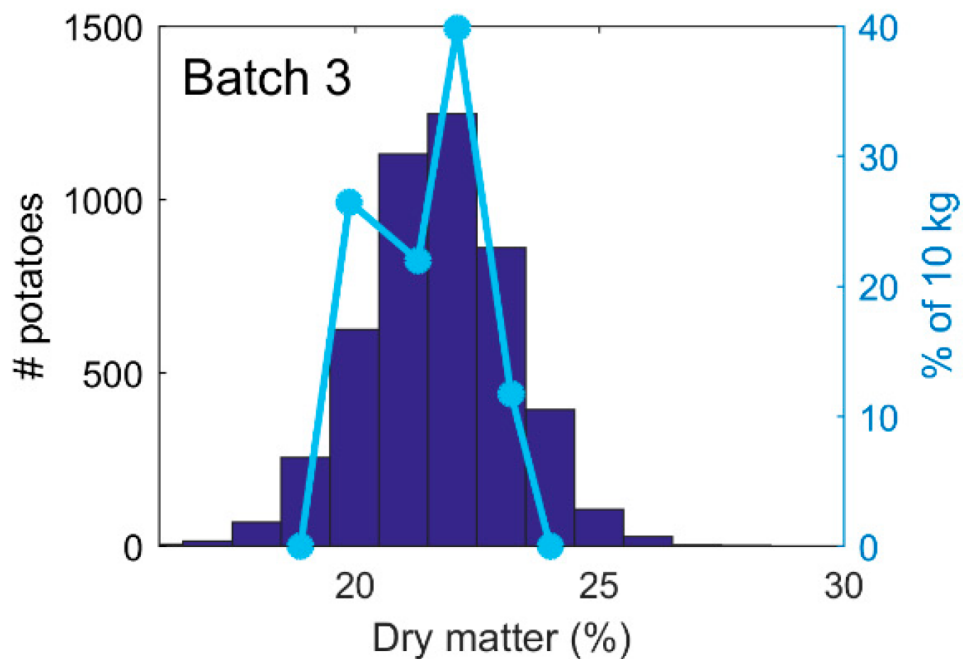
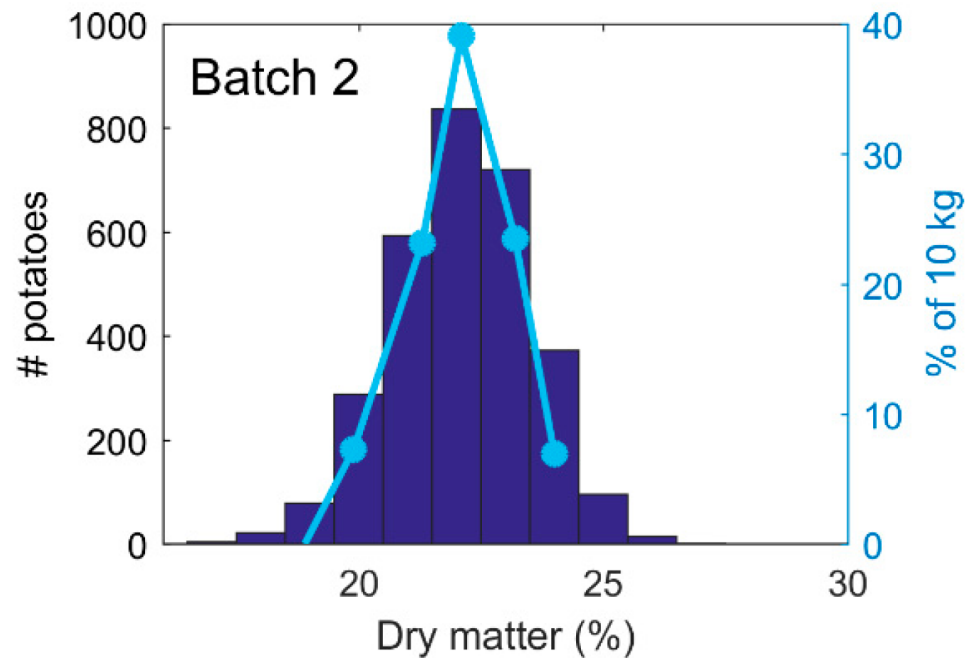
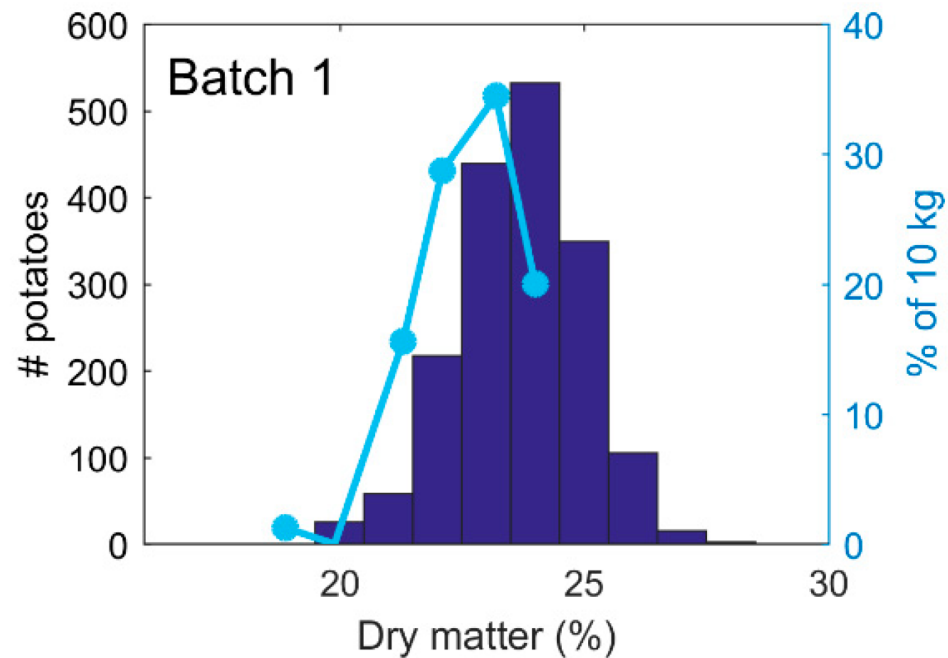


Calibration for dry matter

Calibration set (n=163)				Test set (n=50)	
Scanning in Motion				Test In-Line	
Dist	#LV ^a	R ²	RMSECV ^b (%)	R ²	RMSEP ^b (%)
1	5	0.83	1.11	0.52	1.30
2	7	0.87	0.91	0.72	1.00
3	7	0.89	0.89	0.74	0.94
4	7	0.91	0.78	0.77	0.88
5	7	0.87	0.98	0.63	1.14

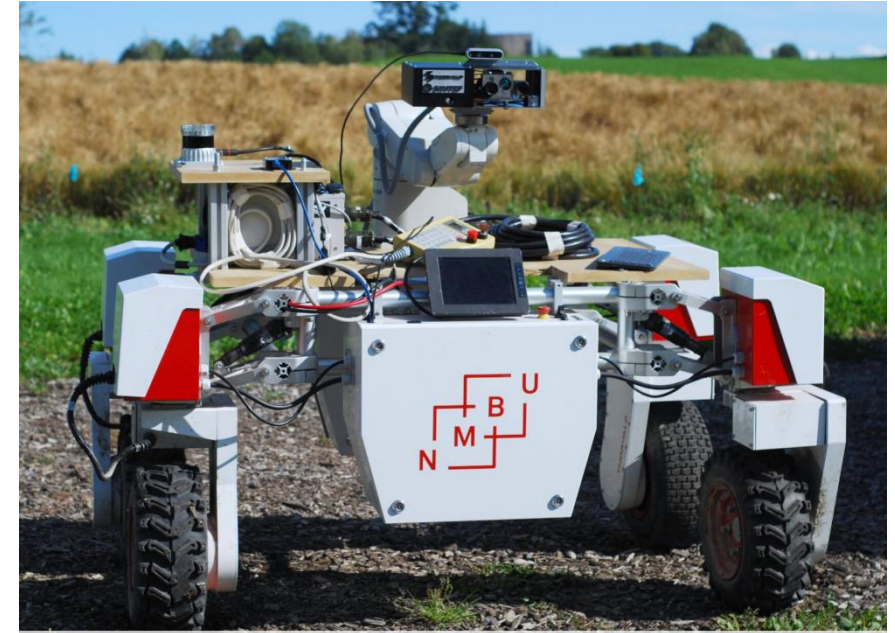






Size *after* performance!

- Robotics arms, portable and handheld applications often require measuring intact objects.
- It is tempting to think you just need smaller components but, the smaller the size; the smaller optical throughput
- Reducing the size of Mini Smart Sensor and FragoPro required:
 - Application characterisation – we use Smart Sensor for this
 - Close dialog with suppliers.
 - Extensive performance testing

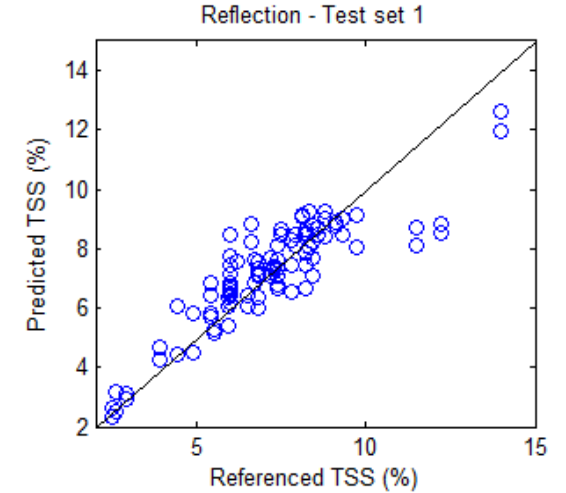
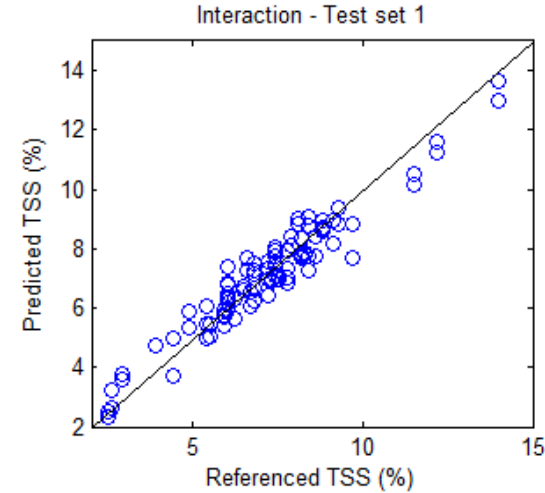


Strawberry tests

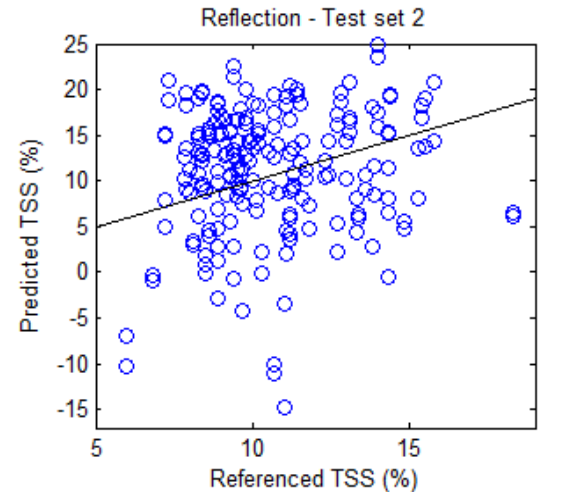
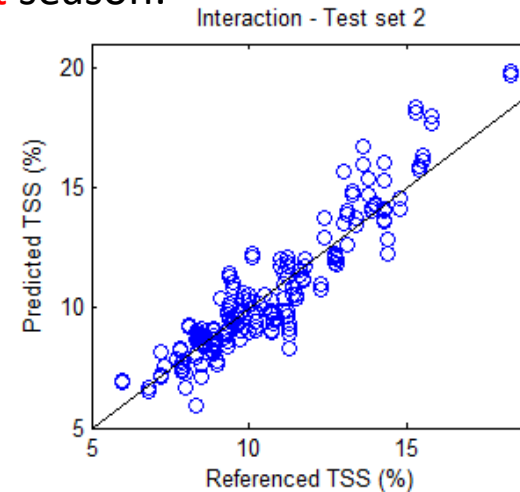
- Smart Sensor (interactance) versus commercial mini-spectrometer (reflectance)



Test set **same** season:



Test set **next** season:



Conclusion

- Use first principles: if you do not understand how the data behave in a controlled measurement, you will never understand it in an inline environment.
- Use an iterative approach: move back and forth between controlled and realistic measurements to build a fundamental understanding.

Acknowledgements

Research Partners



Industry Partners



Funding bodies





Thank you!





Teknologi for et bedre samfunn