smAvo: A Transcontinental Odyssey by Land and Sea

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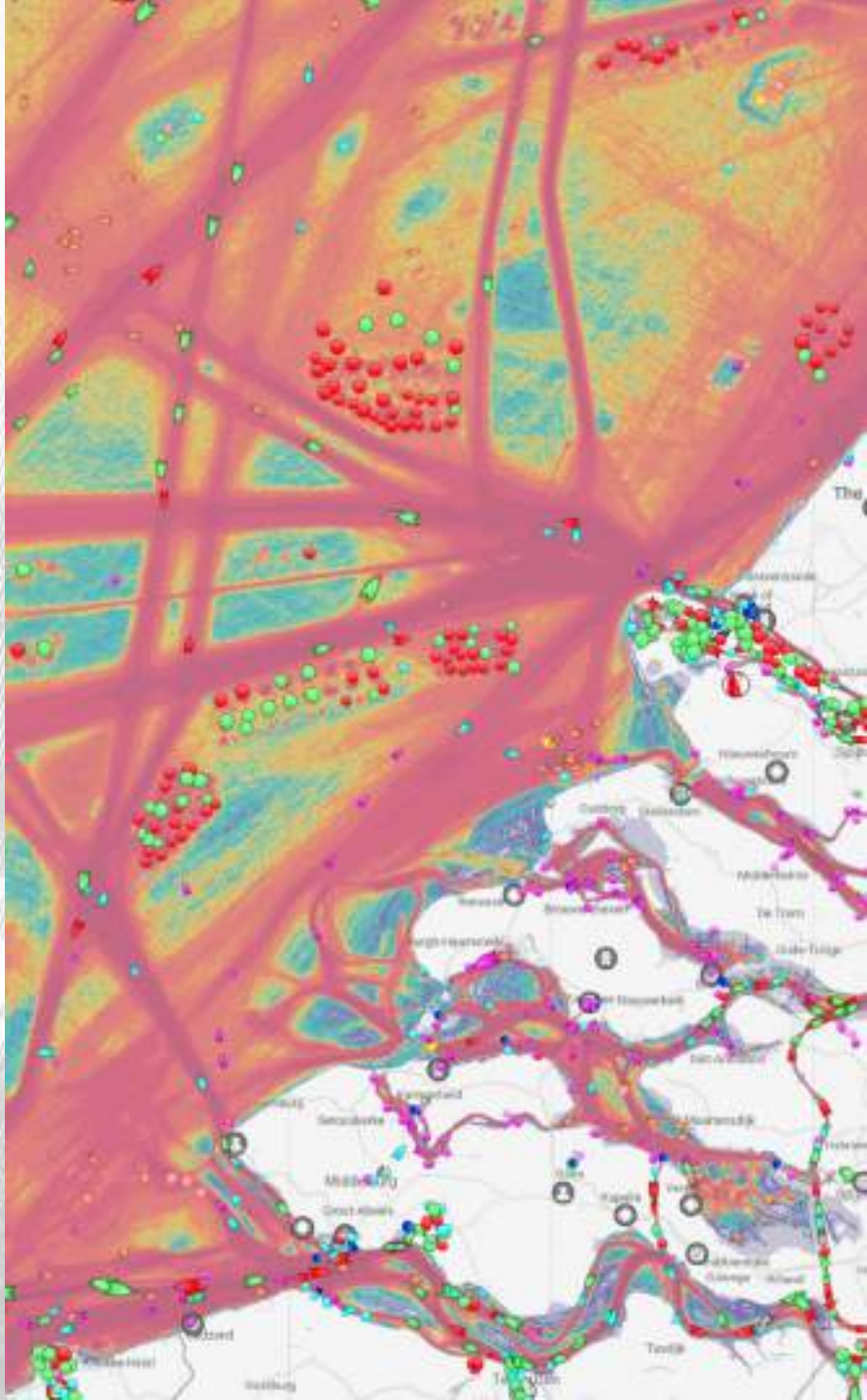
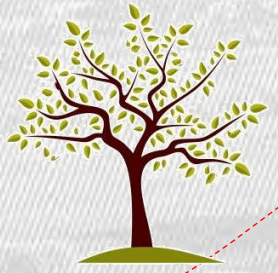


Overview

- Introduction & Research Objectives
- smAvo/smaTo Instrumentation
- The odyssey
  - Packhouse environments (**short duration, high impact**)
  - Road transportation (2-day journey, **moderate impact, low impact environment**)
  - Ship transportation (2.5-week journey, **low impact environment**)
  - So-what?
  - Future development & research
- Conclusions
- Questions & Discussion

The Great Odyssey

- End-to-end transportation chain
- Transportation engineering in action



Process and package (packhouses)

Local transportation network

Transcontinental freight

Last mile target transportation network

Quality of local transportation network

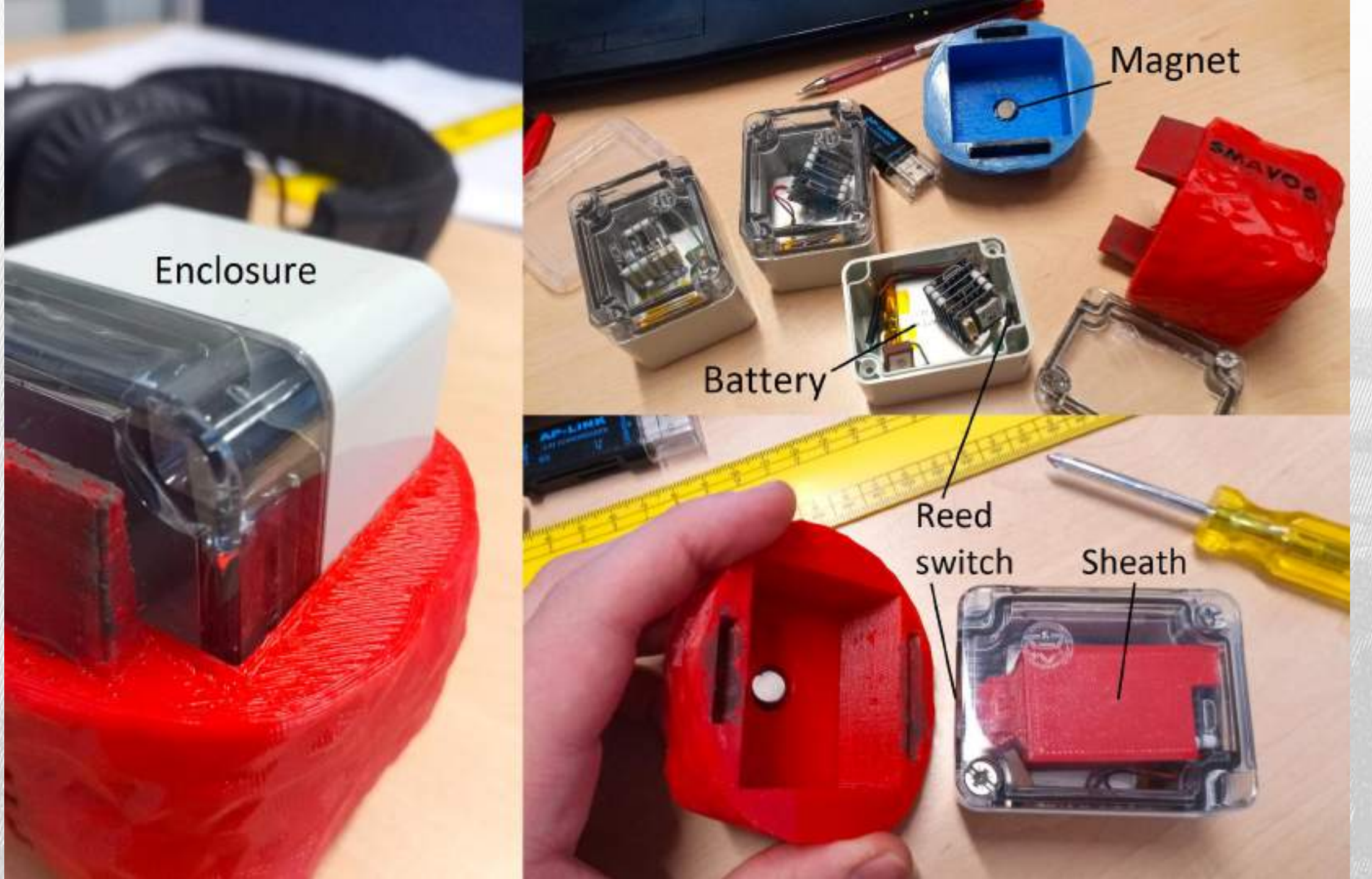
Quality of 3rd party transportation network and cold chain

Research Objectives

- Quantify potential damage of **avocadoes and tomatoes** in transportation environments
- Development of custom, low-cost, programmable **sensor platforms** / instrumentation
- “Big Data” processing requirements
- **Data-driven recommendations** / guidelines for improving processing & packing (packhouses, transportation by road and sea)
- Various stakeholders/projects: SAAGA, PHI, ZZ2, Halls, FleetMon and planet.com

smAvo Instrumentation

- Originally developed 3 smAvo prototype units
- Suited to initial field trials (March 2019)
- Moisture penetration during the first packhouse trial → optimize design

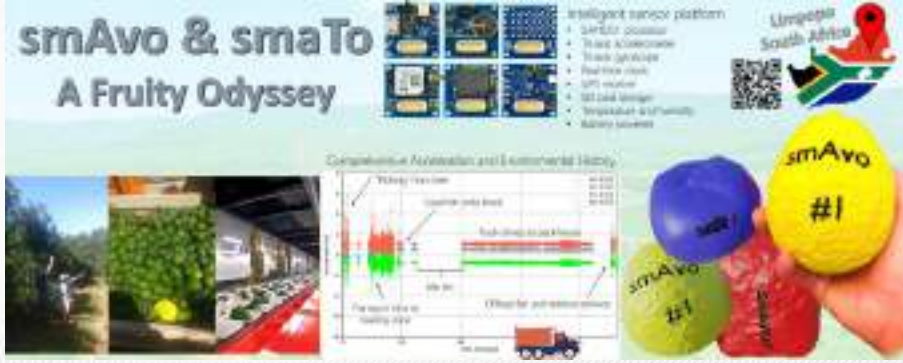

Enclosure
Magnet
Battery
Reed
switch
Sheath

smAvo Instrumentation

- Improved **waterproof** design with simplified operation
- **Smaller**, more representative volume
- **Density** lower than water → flotation
- Softer **PETG** filament used for exoskeleton
- **smaTo**: identical electronics, different shell

- Primary sensors considered for study
  - 3-axis MEMS accelerometer (100 Hz)
  - 3-axis MEMS gyroscope (100 Hz)
  - **Easy quantification of produce response on transportation infrastructure**

smAvo Instrumentation

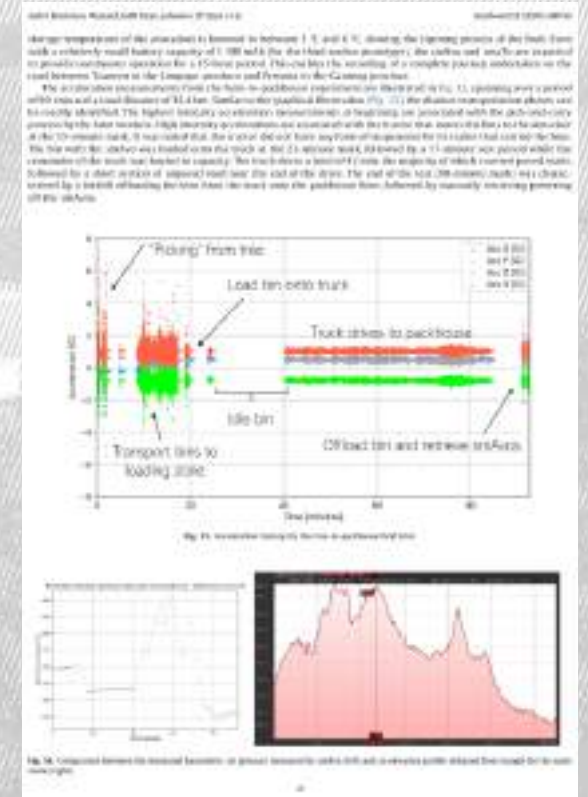


- Detailed development process published in **HardwareX**
- Open access journal: article link

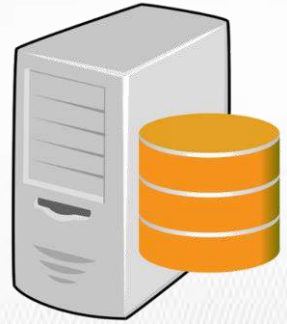

HardwareX

Hardware Article

smAvo and smaTo: A fruity odyssey of smart sensor platforms in Southern Africa



Data Processing Pipeline



- **Data stored** on non-volatile SD cards
- Automatic **post-processing** using software developed in Python
- Aggregate **representative statistics** to establish trends, insights, conclusions and recommendations

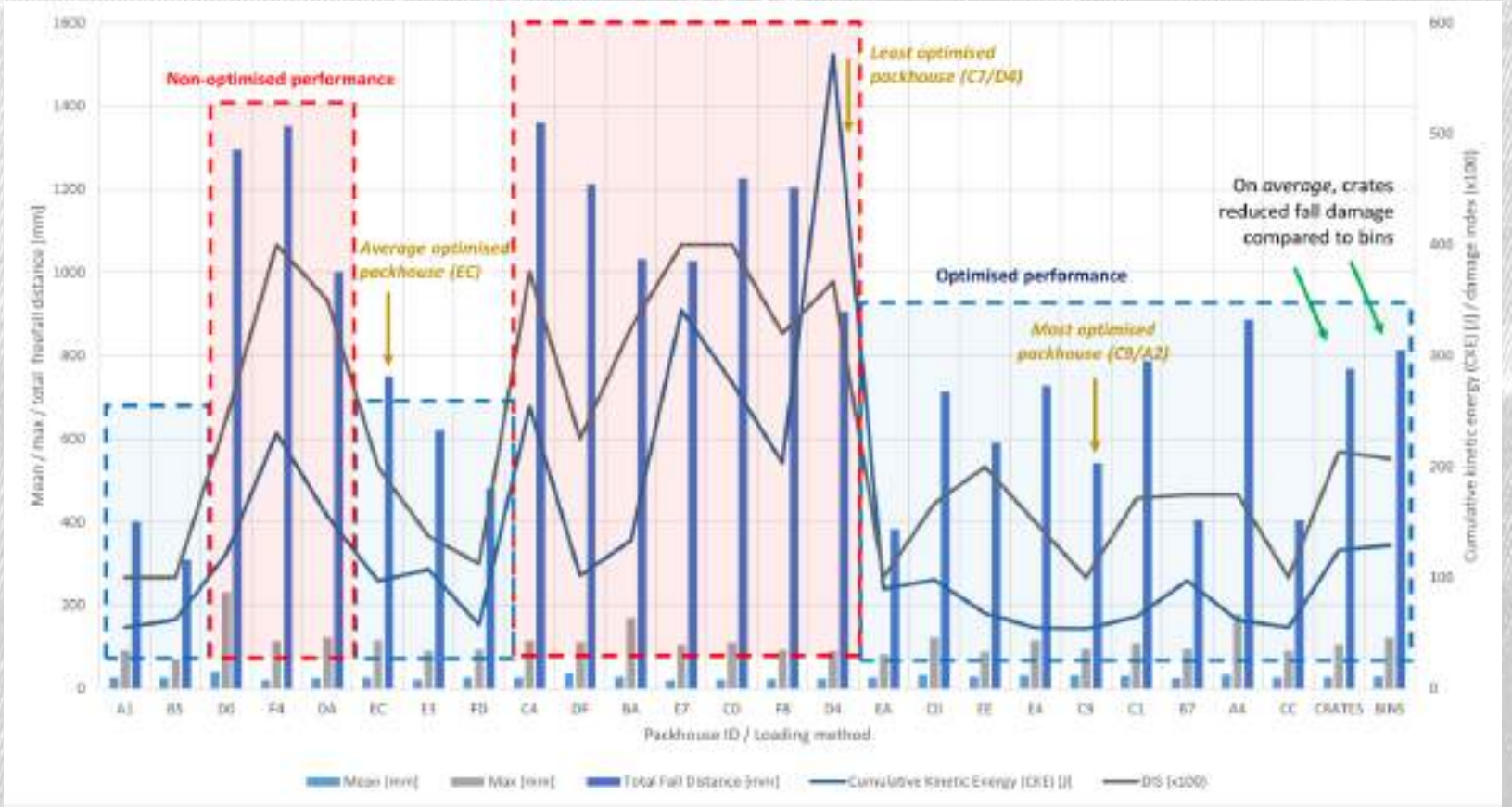
python™

Packhouse Processing (SAAGA)

- **Short duration high-intensity**
- 20 packhouses instrumented (possible 37 packhouses) over a 7-month period
- Wide geographic spread (Limpopo, KwaZulu-Natal, Mpumalanga)
- Different loading methods (bins & crates)
- Various levels of mechanization & packline capacities encountered
- Field testing conducted whilst observing all Covid-19 regulations & safety protocols

Packhouse Classification Model

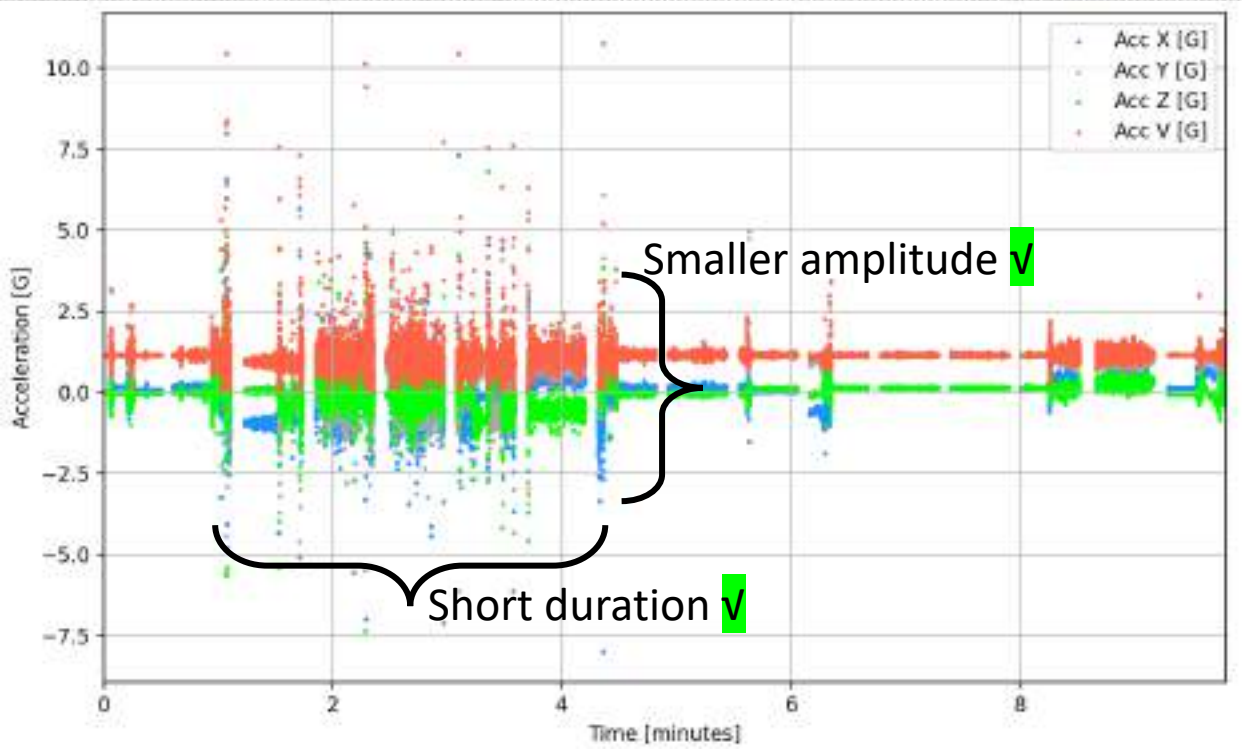
- All statistics combined; choose three candidates (**optimized**, **average** & **unoptimized** packhouse)



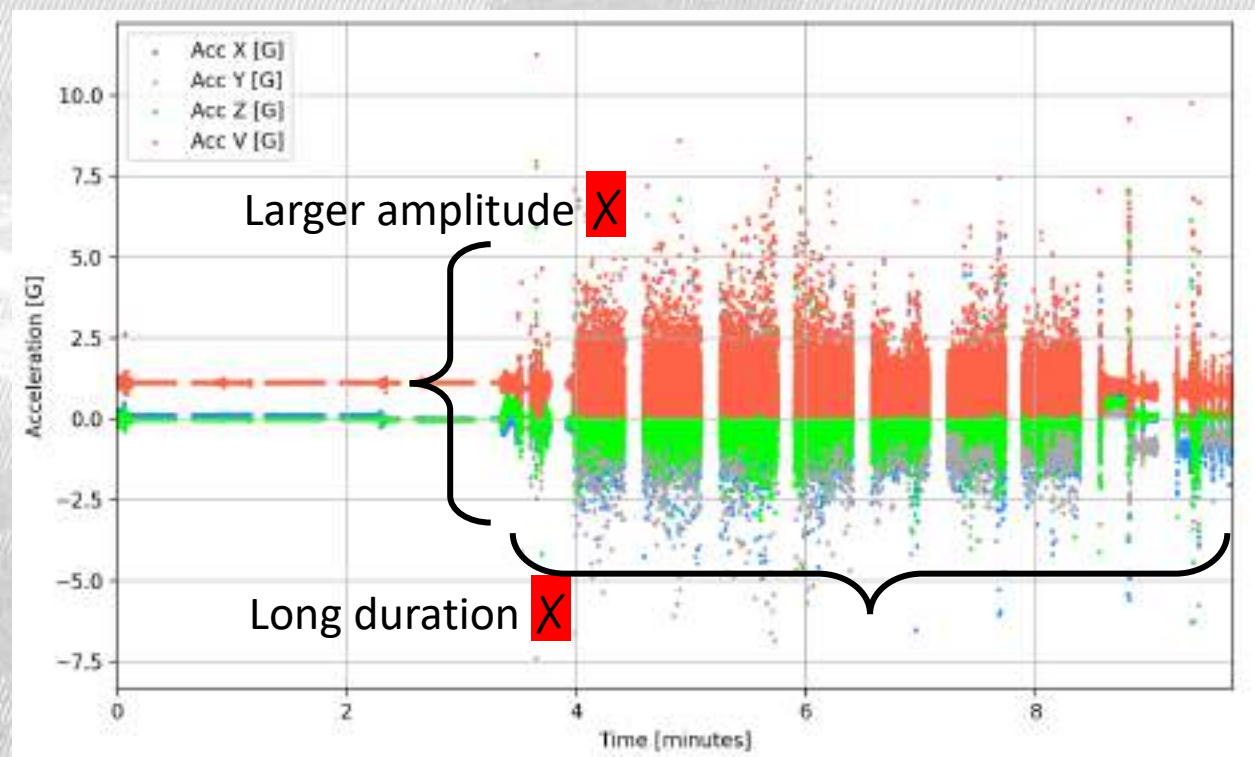
Packhouse Acceleration History

- Large differences in **duration** and amplitude experienced by smAvos
- Large amplitude accelerations → **roller elements**

Optimized packhouse



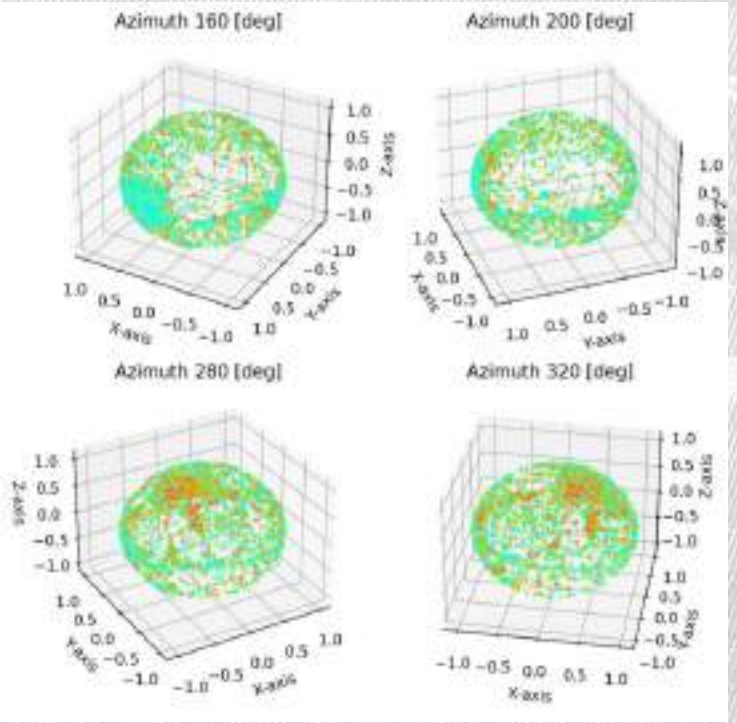
Unoptimized packhouse



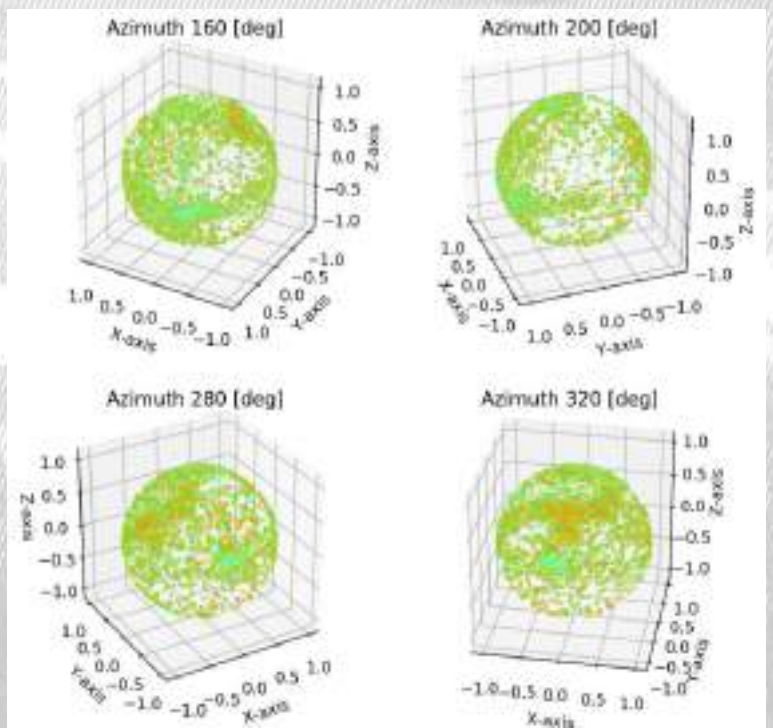
Acceleration Vector Distribution

- Largest intensity about section with smallest second moment of area, i.e. large flat face tends to align with **rollers**

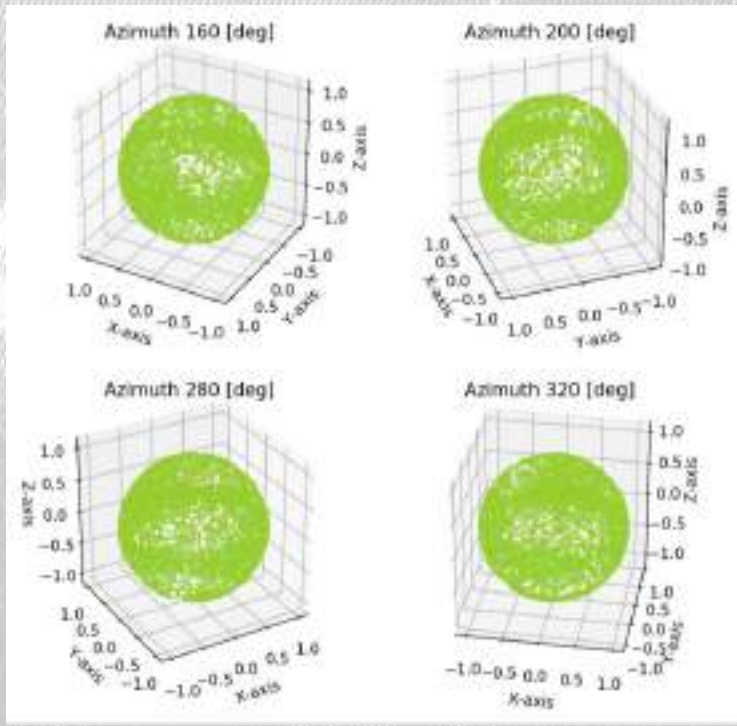
Optimized packhouse



Average packhouse

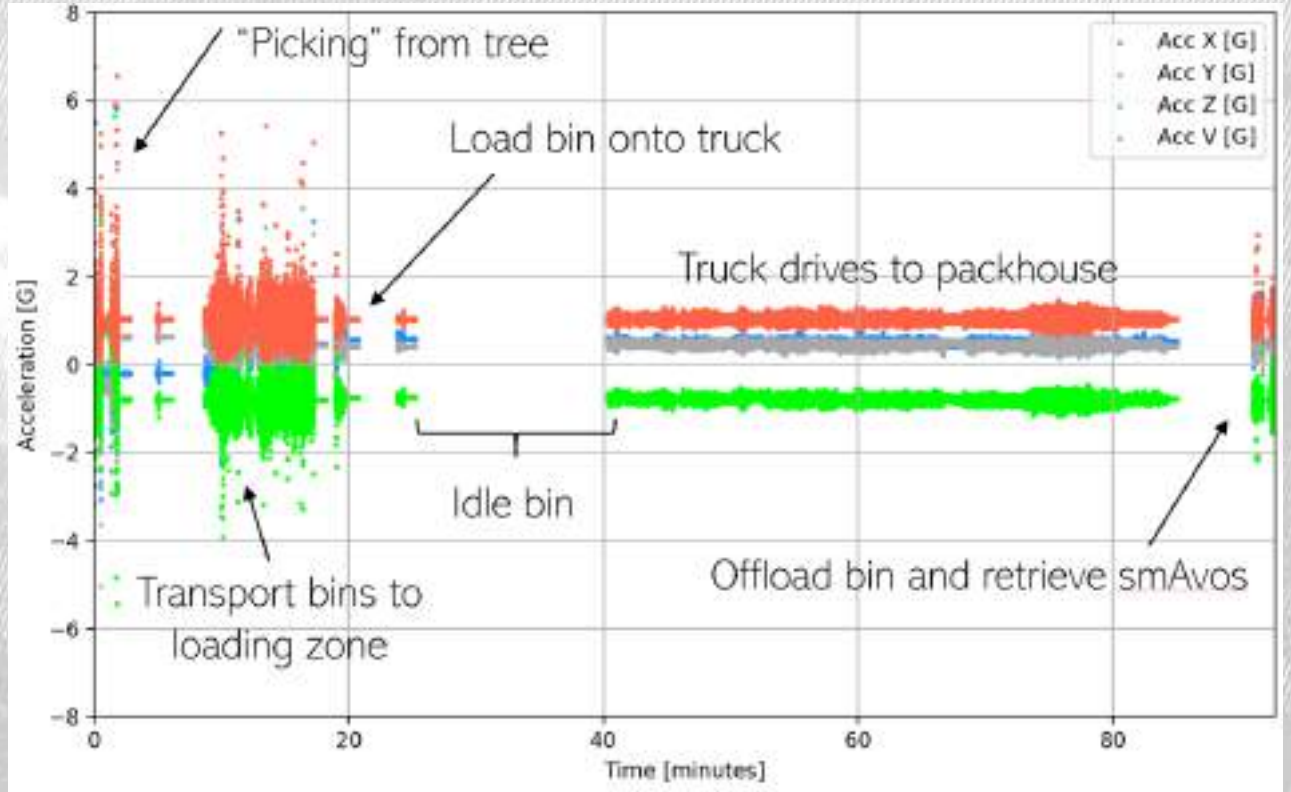


Unoptimized packhouse



Transportation by Road (ZZ2/PHI)

- Farm-to-packhouse route (**short sections, high variability**)
- Differences between tractor and truck transportation (**paved and unpaved**)

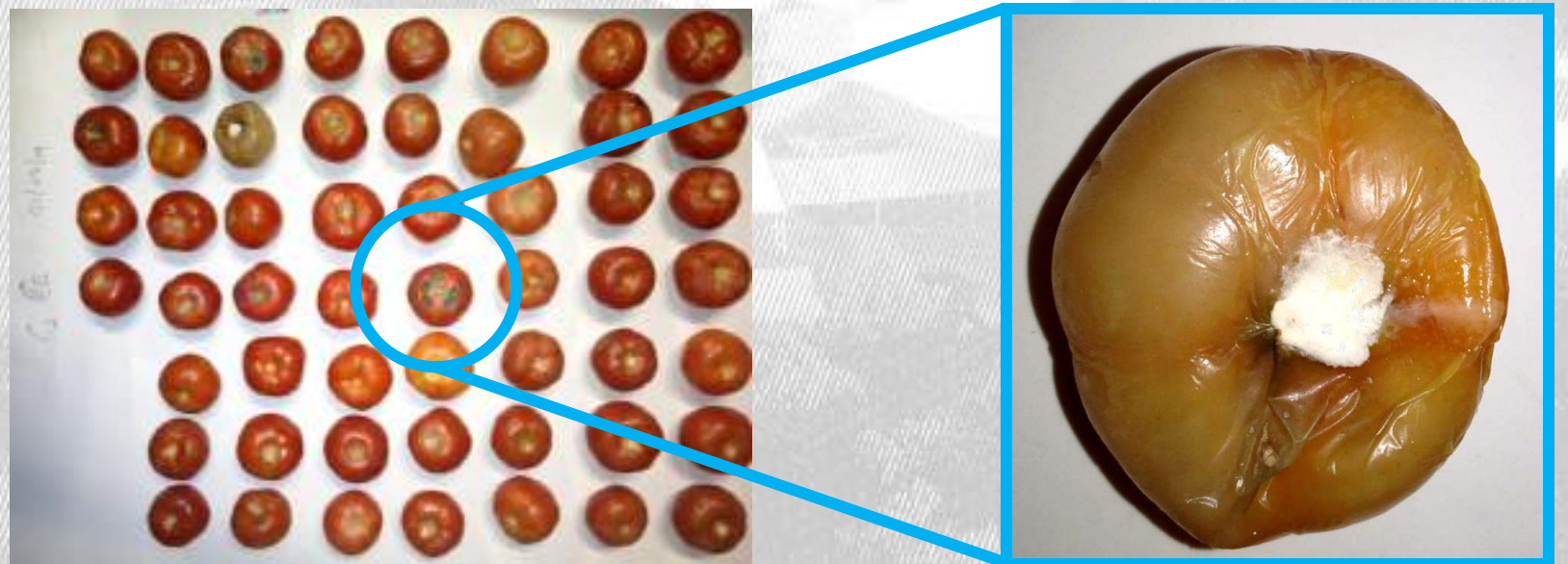


Transportation by Road (ZZ2/PHI)

- **Excessive vibrations** lead to lenticel damage → shorter shelf life → poor quality and low value

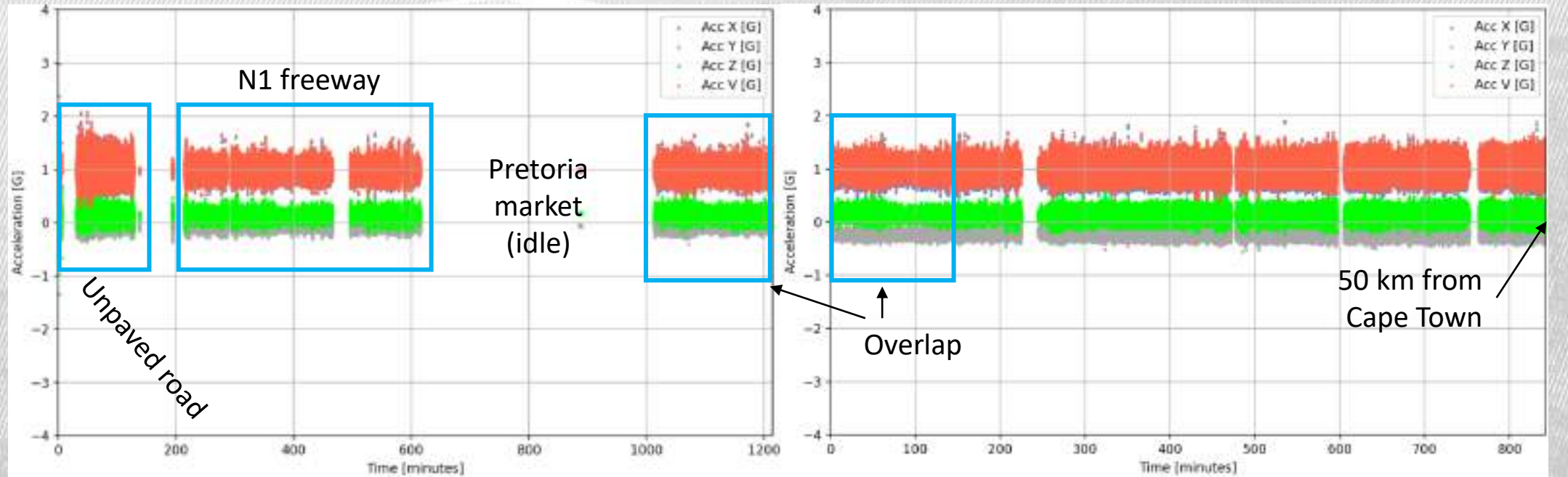
Transportation by Road (ZZ2/PHI)

- Substituted the smAvo for smaTo devices (identical electronics)
- ZZ2 packhouse (Tzaneen) → Pretoria market → Cape Town market (**1800 km**)



Transportation by Road (ZZ2/PHI)

- Acceleration history representative of both the **box confinement** and **road conditions** (paved / unpaved)
- Lack of geolocation data (GPS signal) compensated for using **barometric air pressure** measurements (smaTo is not completely waterproof)



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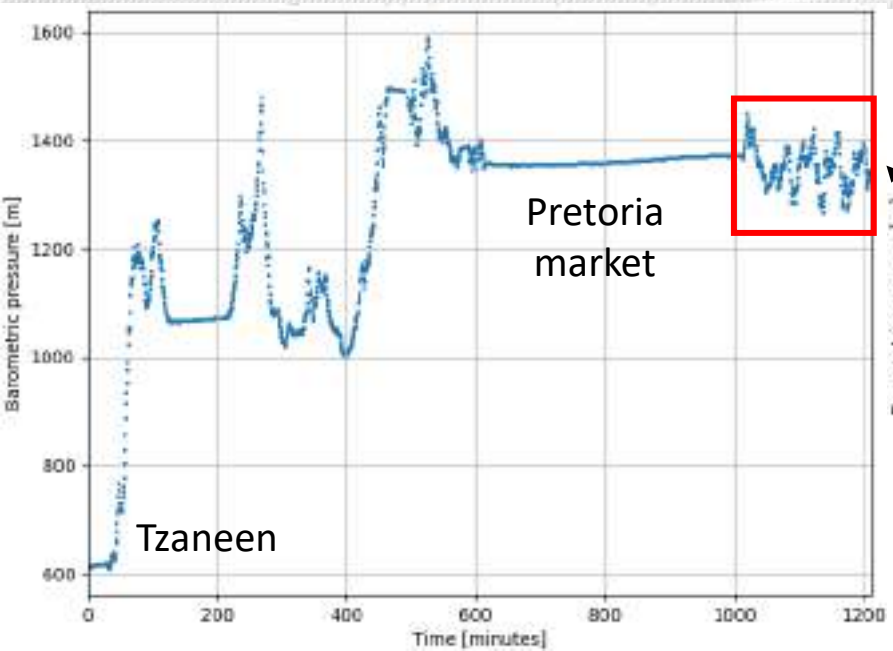
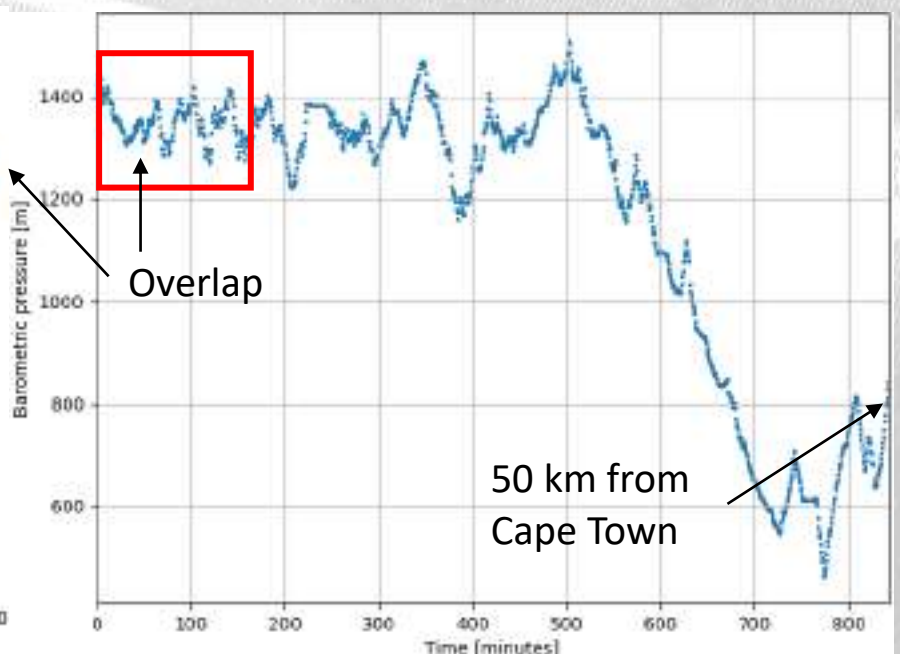
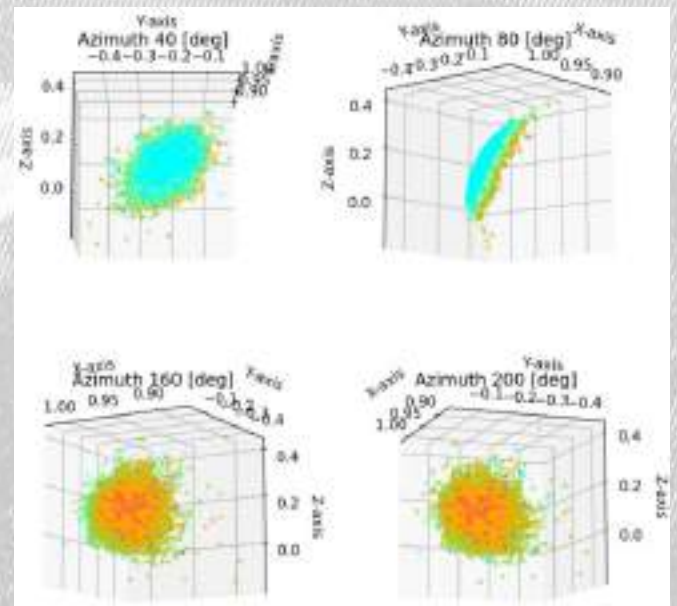


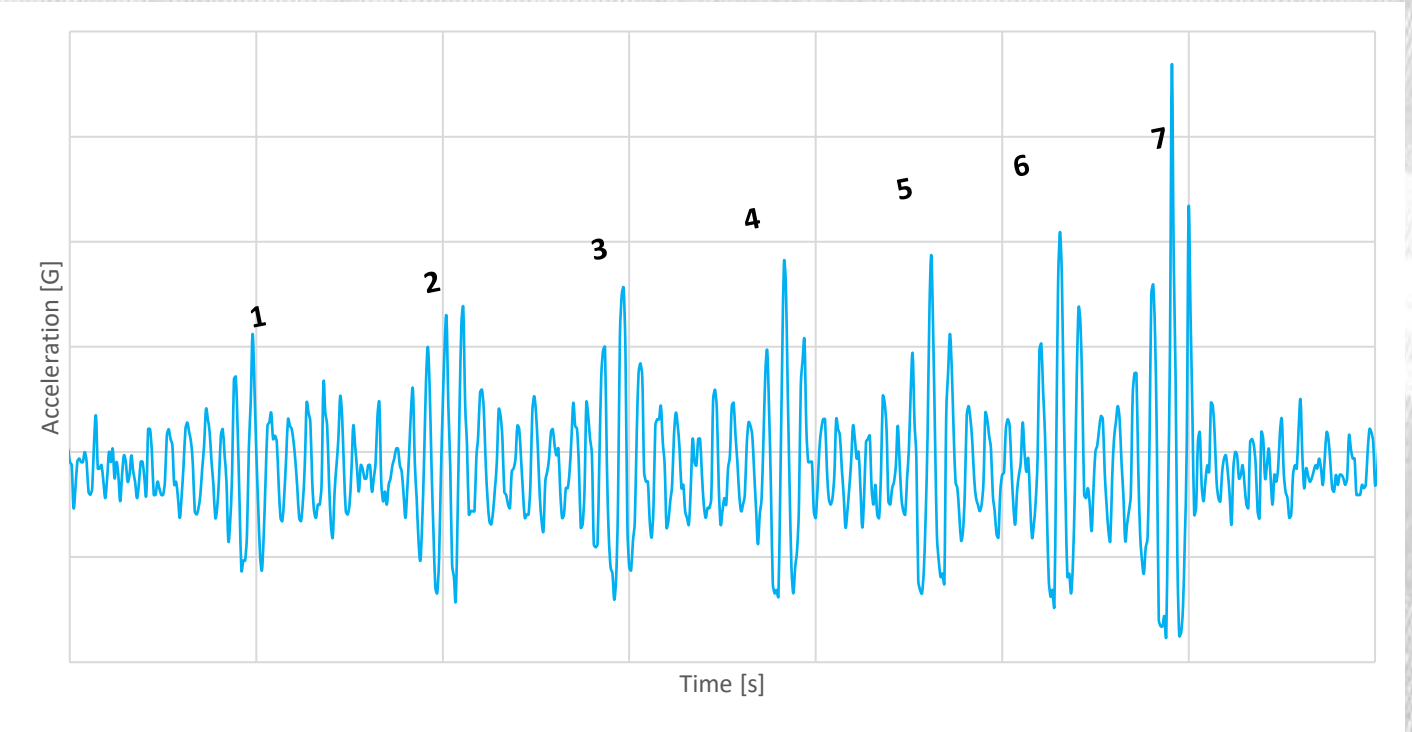


Stable fruit orientation



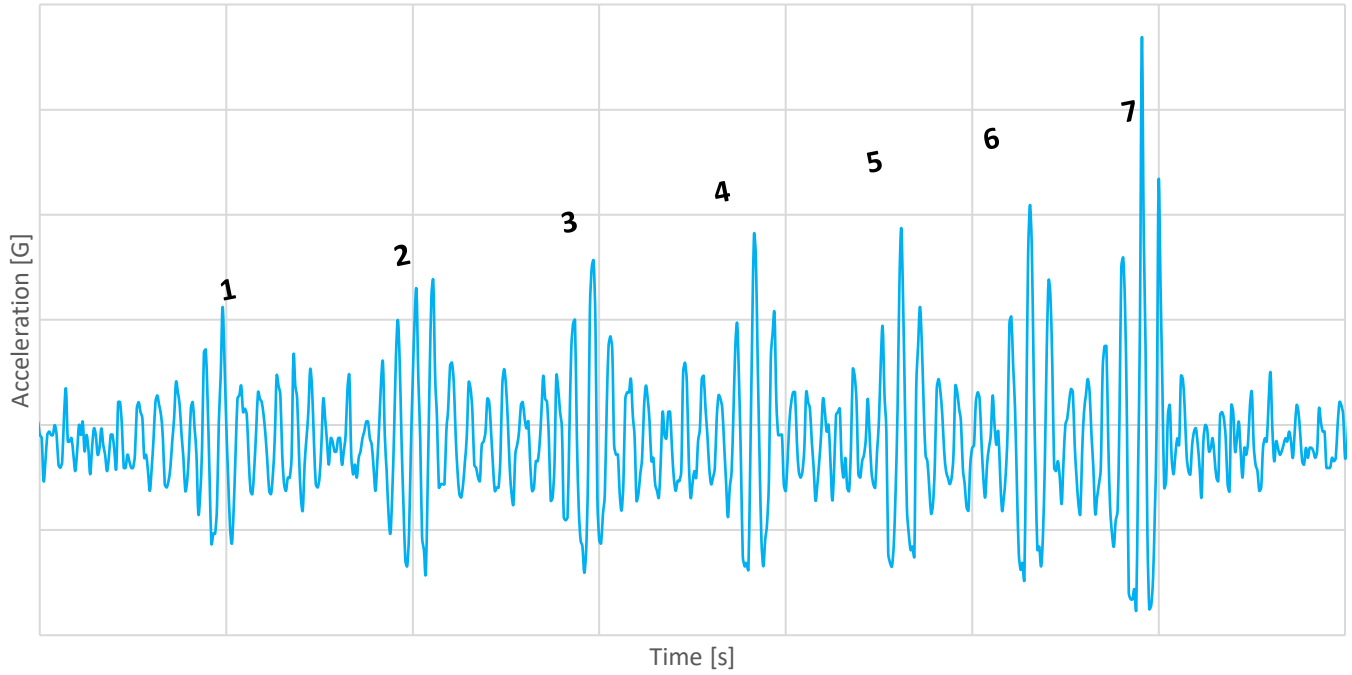
Transportation by Road (ZZ2/PHI)

- Unexpected resonance / high-intensity vibration phenomena



Transportation by Road (ZZ2/PHI)

- Unexpected resonance / high-intensity vibration phenomena
- Link back to geolocation and road information for **impact on produce**



Transportation by Sea (Halls)

- Avocadoes are exported from Cape Town harbor to Rotterdam in the Netherlands (**13 500 km**, ~2.5-week journey)

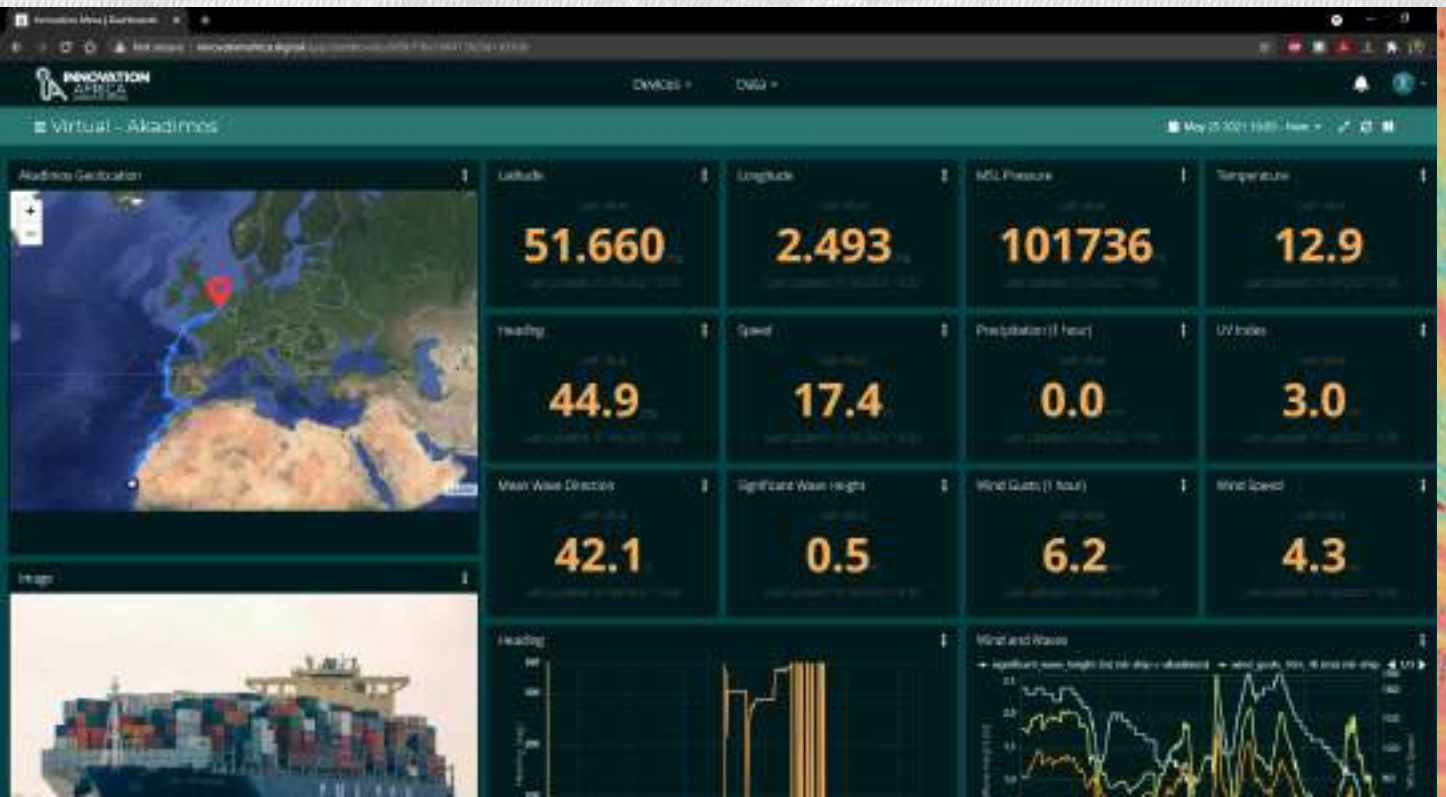
Instrumentation installation (2021/05/11)

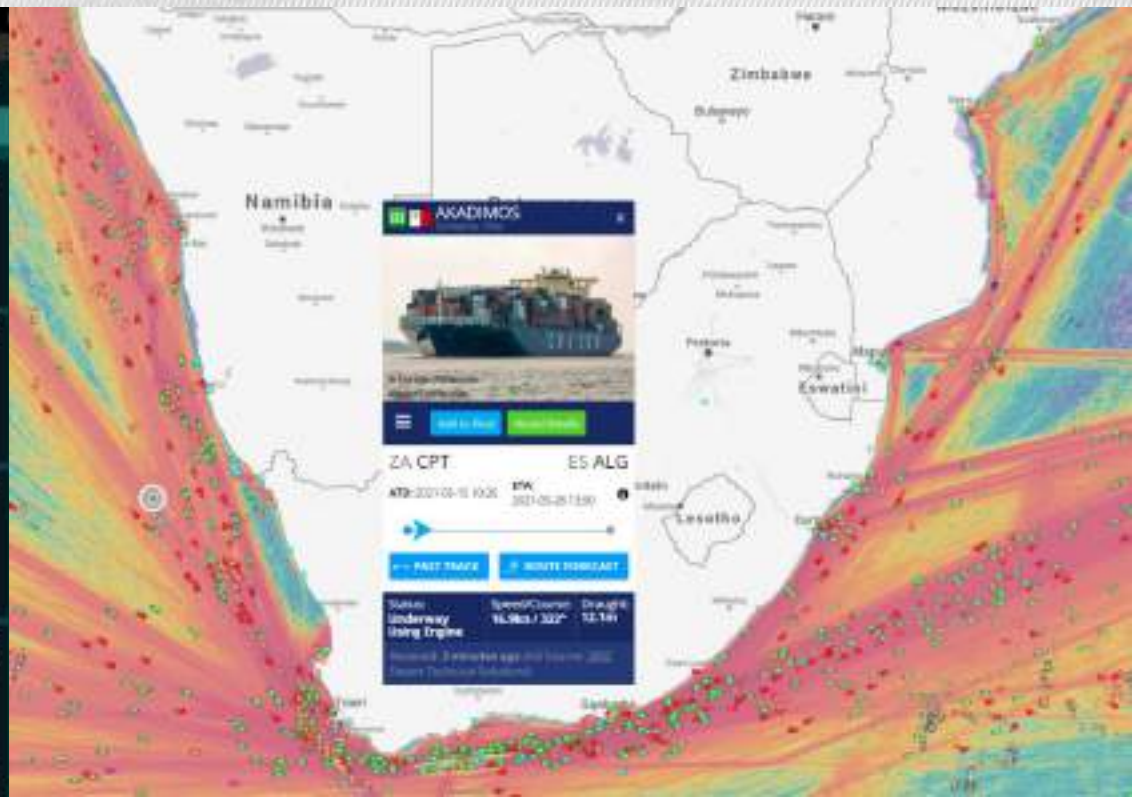
Akadimos container vessel (9500 TEU) in port of Cape Town (2021/05/13 12h00)

Akadimos arrives in Rotterdam (2021/06/01 14h19); live webcam

Transportation by Sea (Halls)

- **Real-time tracking** using in-house data platform (Innovation Africa)
- Incorporation of **satellite positioning** and maritime weather models (**FleetMon**)





Transportation by Sea (Halls)

- Majority of the 8× instruments **operated as expected**
- Successfully measured **movement of the vessel** and barometric effects associated with quality control measures
- **Battery technology** remains primary limitation (for refrigerated environments)
- Post-processing of data and results **in progress** with follow-up studies already underway

Instruments in Rotterdam
Gerard de Jong – Quality Manager

Conclusions

- Custom designed **instrumentation (smAvo and smaTo)** works as designed
- New insight into **packhouse dynamics, road transportation network, logistic operations, cold chain management** and condition monitoring at sea
- Monitor not only produce, but also **operating conditions** pertaining to **machinery** (packhouses) and **roads** (with localization)
- Industry (**15 500 km** in total) stands to benefit from new sensor technology for risk identification and mitigation
- **Identify areas for investment** to reduce variability and non-conformant links leading to damaged produce

Future Research Endeavors

- Continuous instrumentation of export / international shipping routes that remains the **least understood** → **LoRaWAN** deployment at UP
- **Discrete Element Modelling (DEM)** of physical environments
- Blockchain technology → **non-fungible digital twin** captures origin, quality, eCO_2 footprint and **risk** to products

Acknowledgements

- **SAAGA** (South African Avocado Growers Association) for providing research funding & links with industry support
- **PHI** (Post Harvest Initiative) for funding related to smaTo/tomato work conducted in parallel to smAvo/avocado projects
- **ZZ2** for their assistance in instrumenting vehicles (tomato shipments)
- **Halls** for their assistance in instrumenting containers (shipping to the Netherlands)
- **planet.com** for satellite imagery and **FleetMon** for satellite derived geolocation and associated weather data

Questions & Discussion