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Linking keeping quality models and sensor systems to an autonomous transport supervision system

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Introduction

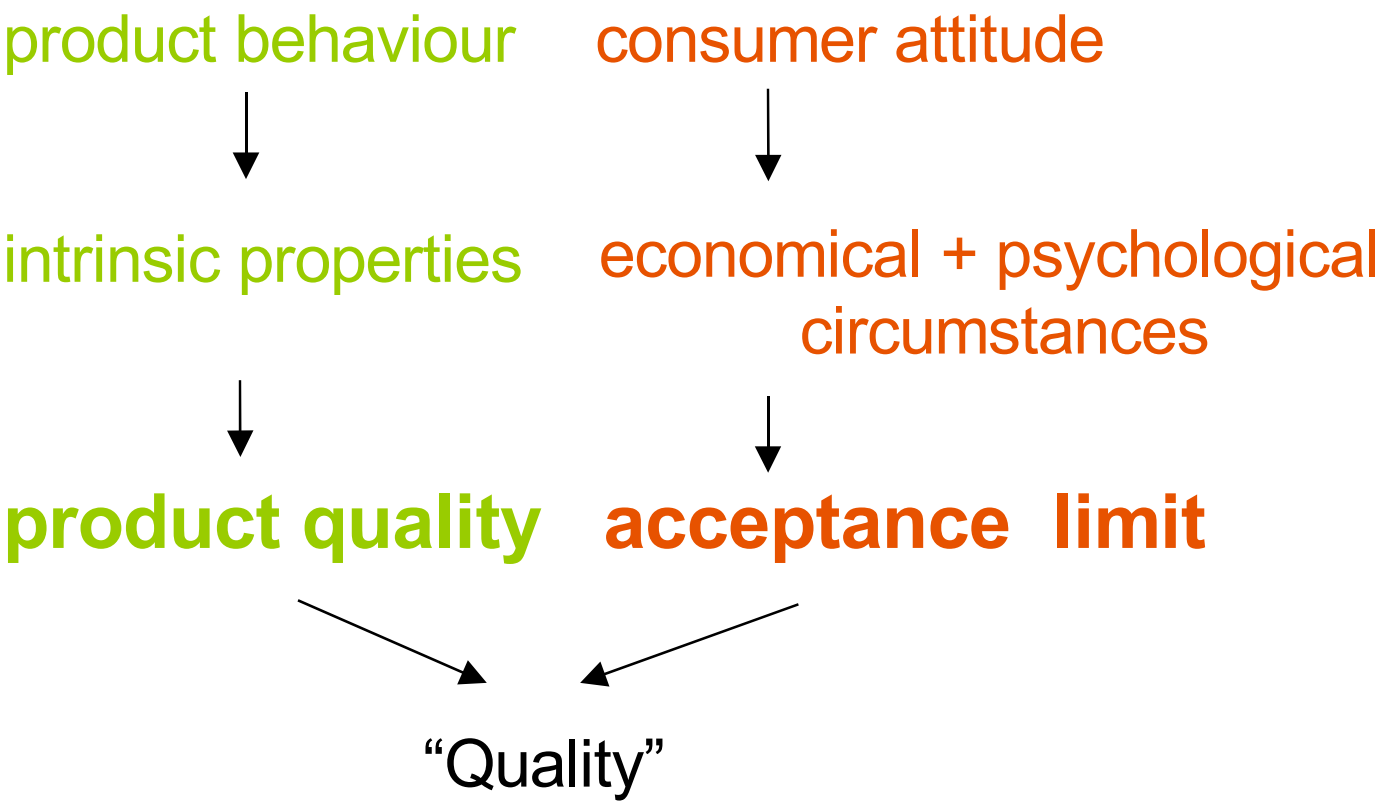
- Tracing & Tracking systems onboard trucks increasingly popular (50% of Dutch transport companies have them and 75% of the rest want them)
  - Efficiency and logistic control
  - Extra customer service

- About 35% of all trucks transports in Europe carry perishables (vegetables/fruits)

Introduction

- Telemetric monitoring of product behaviour can help
  - limit product losses (by changing storage conditions during transport)
  - limit replacements costs when the products is unacceptable
  - enhance product quality in the chain (warehouse planning)

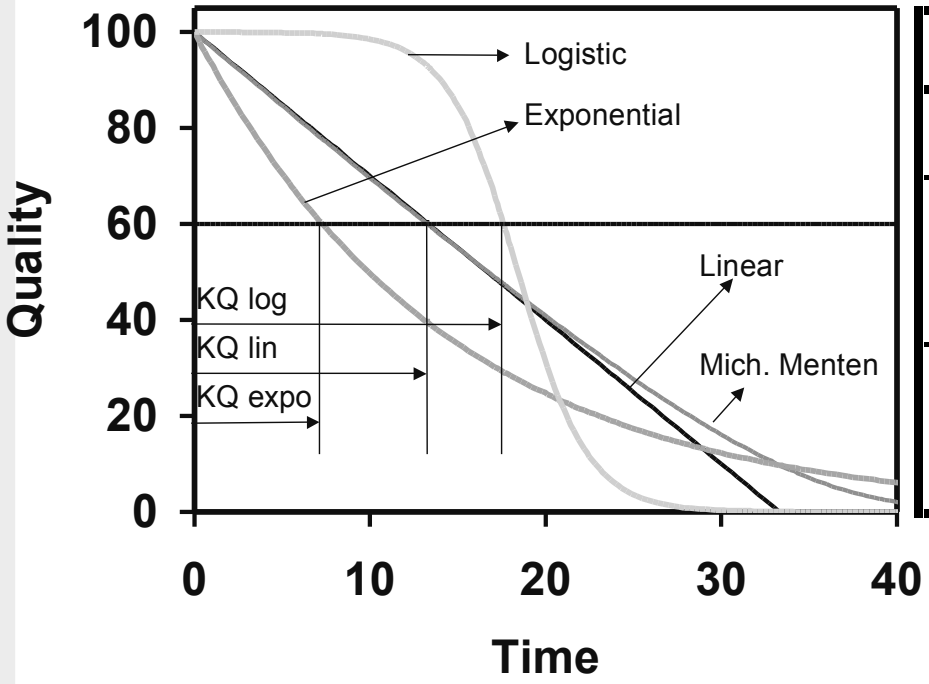
Keeping quality



Keeping quality: the time the product quality remains acceptable

Keeping quality for one quality attribute

- For a single quality attribute product behavior can be described by:



Mechanism	f(Q)
linear	$Q_0 - Q_l$
exponential	$\log_e\left(\frac{Q_0}{Q_l}\right)$
logistic	$\log_e\left(\frac{Q_{inf} - Q_l}{Q_l \cdot C_{ba}}\right)$

- Keeping quality = f(Q)/k

Temperature dependence of the KQ

- Arrhenius Law': $k = k_{ref} \cdot e^{\frac{E_a}{R} \cdot \left(\frac{1}{T_{ref}} - \frac{1}{T}\right)}$

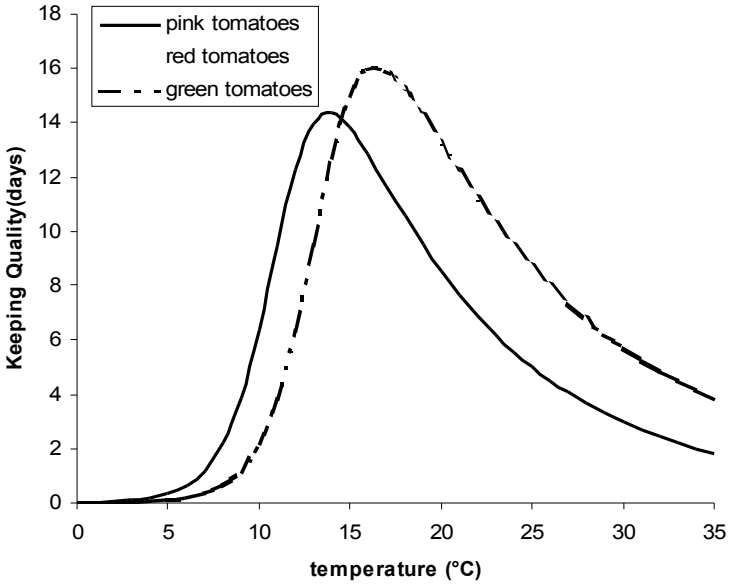
- Keeping quality can then be expressed in KQ_{ref}

$$KQ = \frac{KQ_{ref}}{k_{ref} \cdot e^{\frac{Ea}{R} \cdot \left(\frac{1}{T_{ref}} - \frac{1}{T}\right)}}$$

$k_{ref} = 1$ at $T = T_{ref}$

Keeping quality for multiple quality attributes

- Many horticultural crops have different different quality limits at different temperatures:
  - Which quality attribute is limiting at each temperature? Each attribute has its own k
  - for tomatoes:



KQ_{ref}=6.389 days

T_{ref} =10 °C

k_1= 0.24 → chilling injury

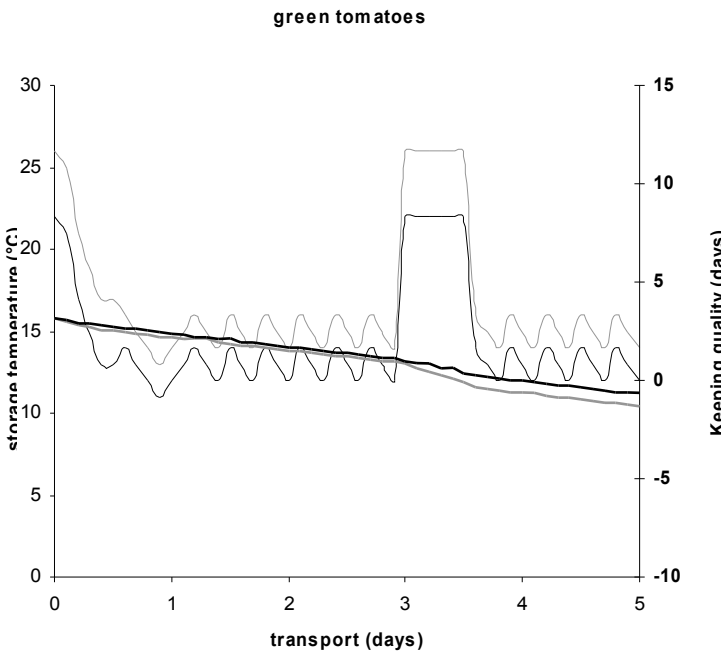
E_1= 77190

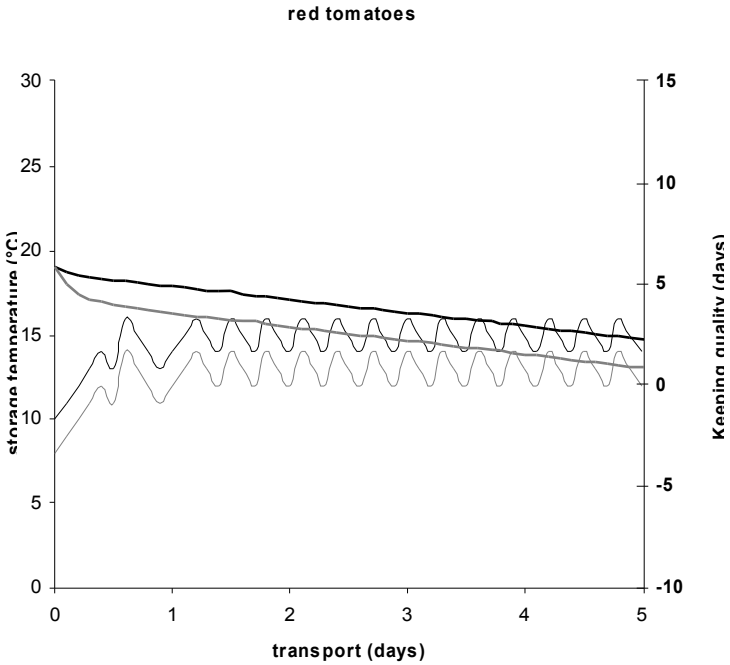
k_2= 0.76 → firmness loss

E_2= -421380

Example: temperature-time scenarios for tomatoes

- Extension to a dynamic KQ model needs to integrate over time, but needs only one fast numerical integration





How to asses the maturity / KQ estimation

- Climacteric products produce ethylene (plant ripening hormone) depending on their maturity
- Tomatoes:

  maturity
  - green tomatoes : increasing ethylene concentration over time
  - pink tomatoes : constant ethylene concentration over time
  - Red tomatoes : decreasing ethylene concentration over time

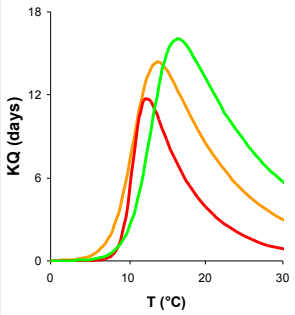
- Continuous ethylene measurement can give an indication of the maturity
- Combination of time + temperature + ethylene sensors + KQ model can provide an KQ estimation

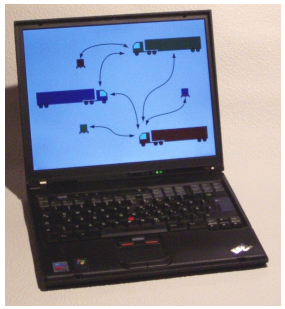
Autonomous transport supervision

- Research Centre "Autonomous cooperating processes in Logistics" (University of Bremen)

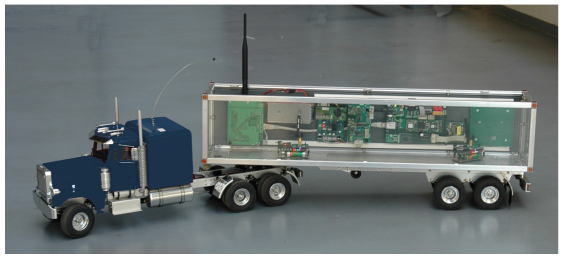
- Autonomous transport supervision system
- Extend T&T: *"We not only want to know the current location, but also in which state it is"*
- Online-Calculation of KQ-models
- Transport operator should worry about quality not about temperature values

Central or local processing?





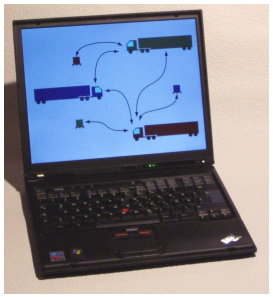
Sensor Raw Data



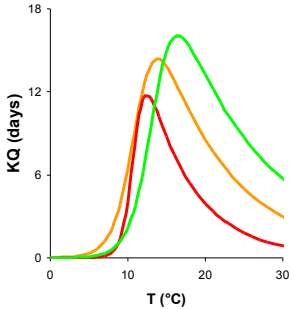
Quality Modelling

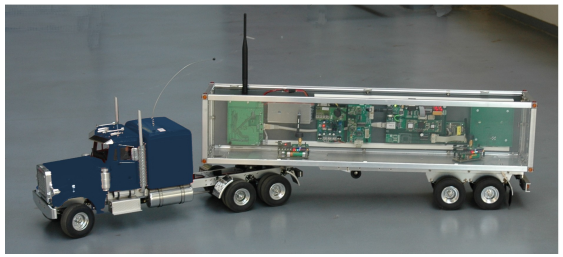
Transport Operator

Standard T&T



Quality Information





Transport Operator

Quality Modelling

Standard T&T + Processor

Local quality estimation

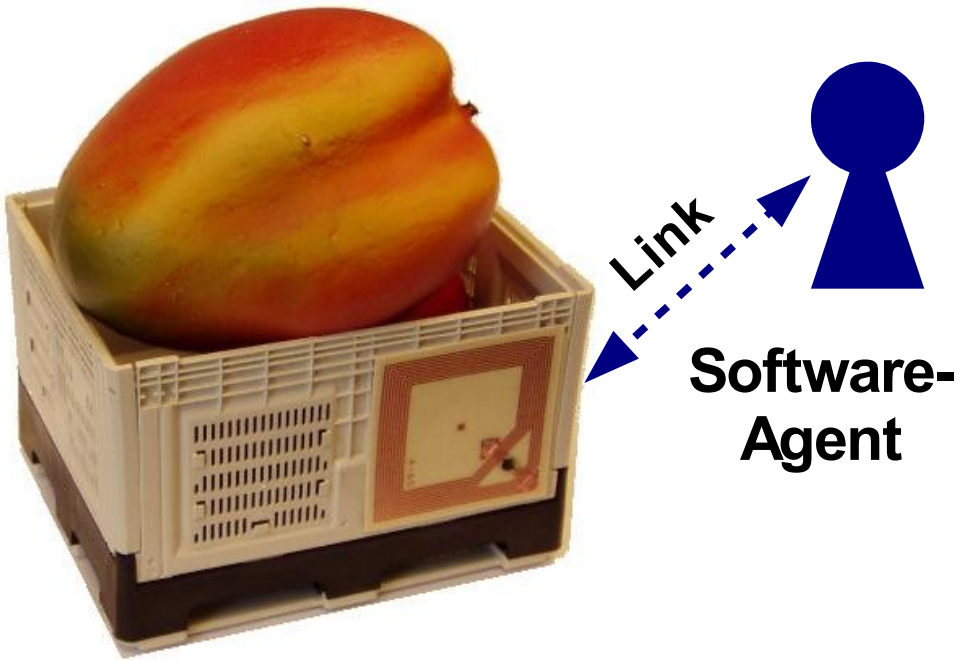
- Local calculation of dynamic quality models
  - Reduces communication volume and costs
  - Robust against communication failures
  - Advanced sensor supervision
- Technical implementation
  - Demonstrator
  - Extra hardware costs for processor ~ 100 €

Software Agents

- **Mobile quality models**
  - Electronic consignment note contains quality model
  - Accompanies freight item along the supply chain
  - Contains handling and supervision instructions

Software agents

- AI-Approach
- Informs the owner at emerging risks
- JAVA: dynamic and platform independent language



Linking RFIDs and Quality Models

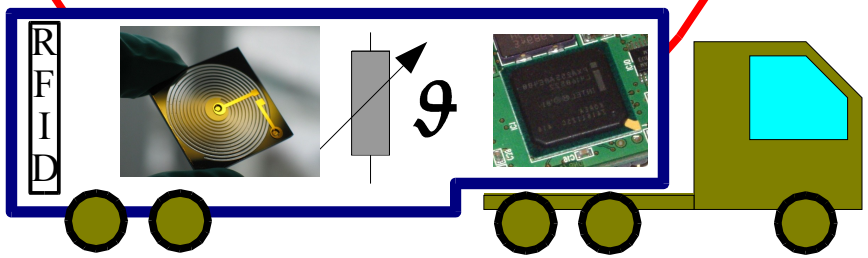
Logistical object
➔ Passive RFID-Label

Dynamic link

Intelligent Agent
➔ Software repre-sentation of the physical object
➔ Transport- and handling-instruction

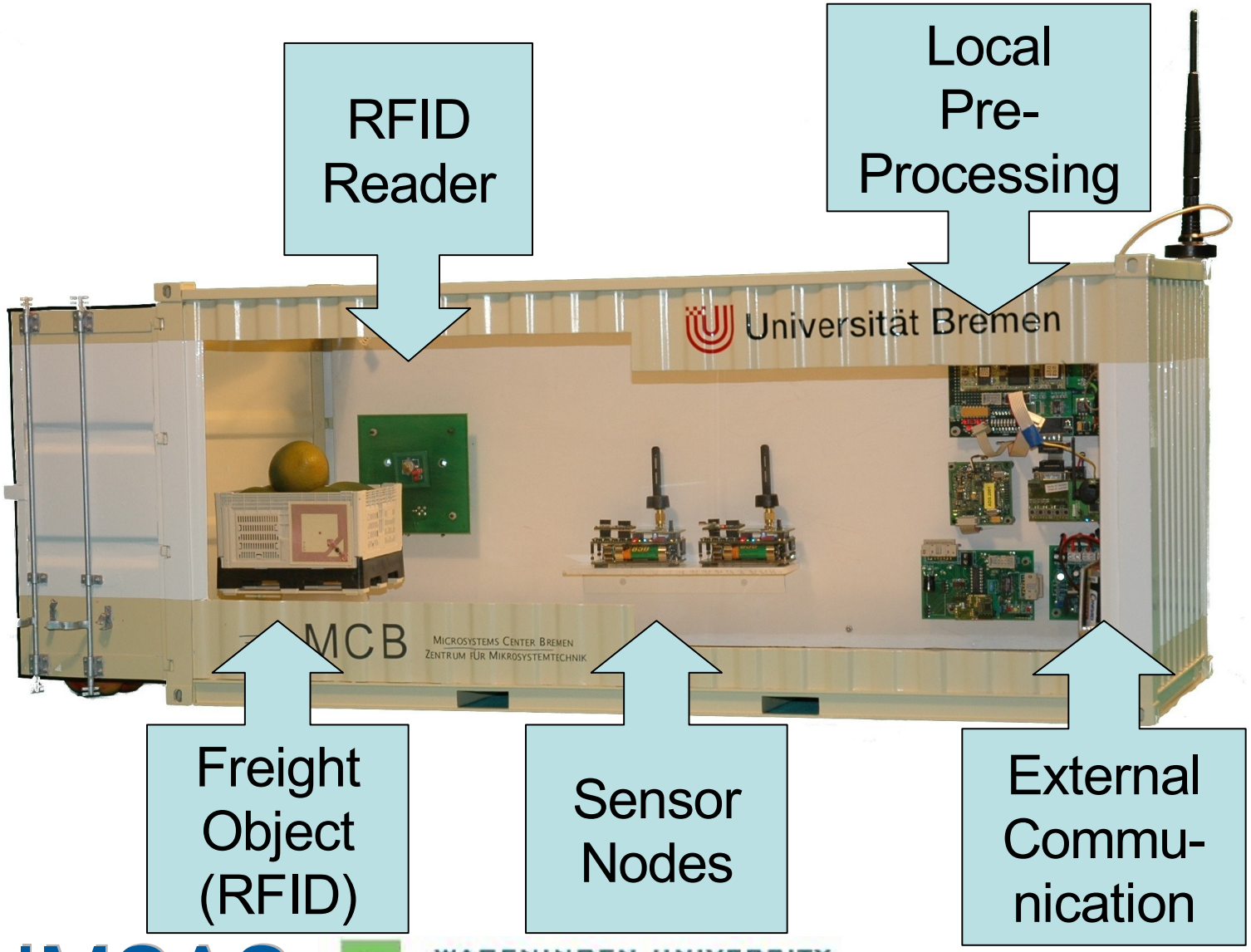
RFID-Tag is read at transshipment

Container requests agent at loading

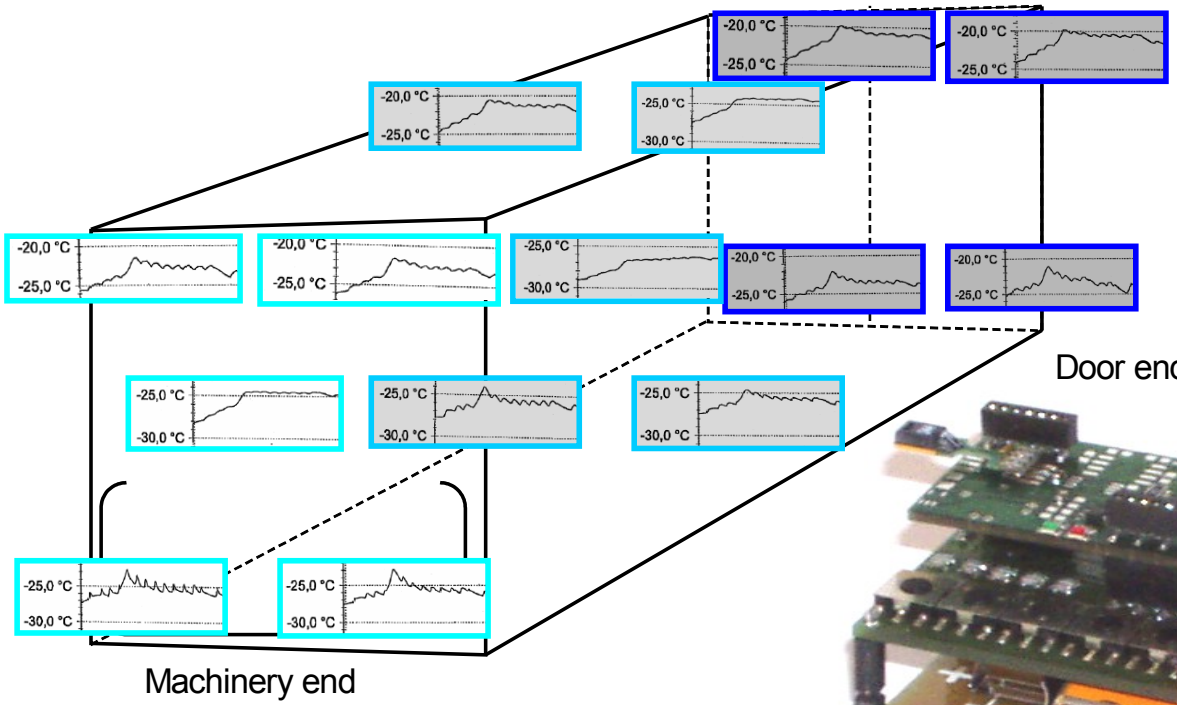


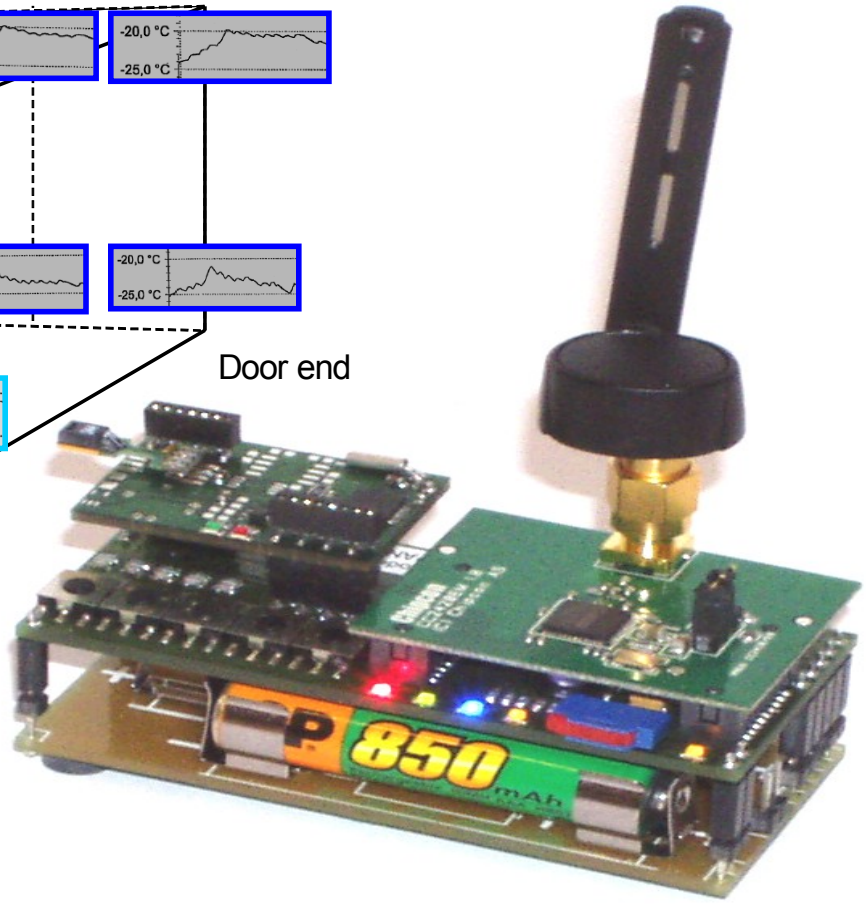
Warehouse or Means of Transport
➔ CPU platform
➔ Sensors
➔ RFID-Reader

The intelligent container



Wireless Sensors





- Ultra low power design for extended service intervals
- Autonomous configuration

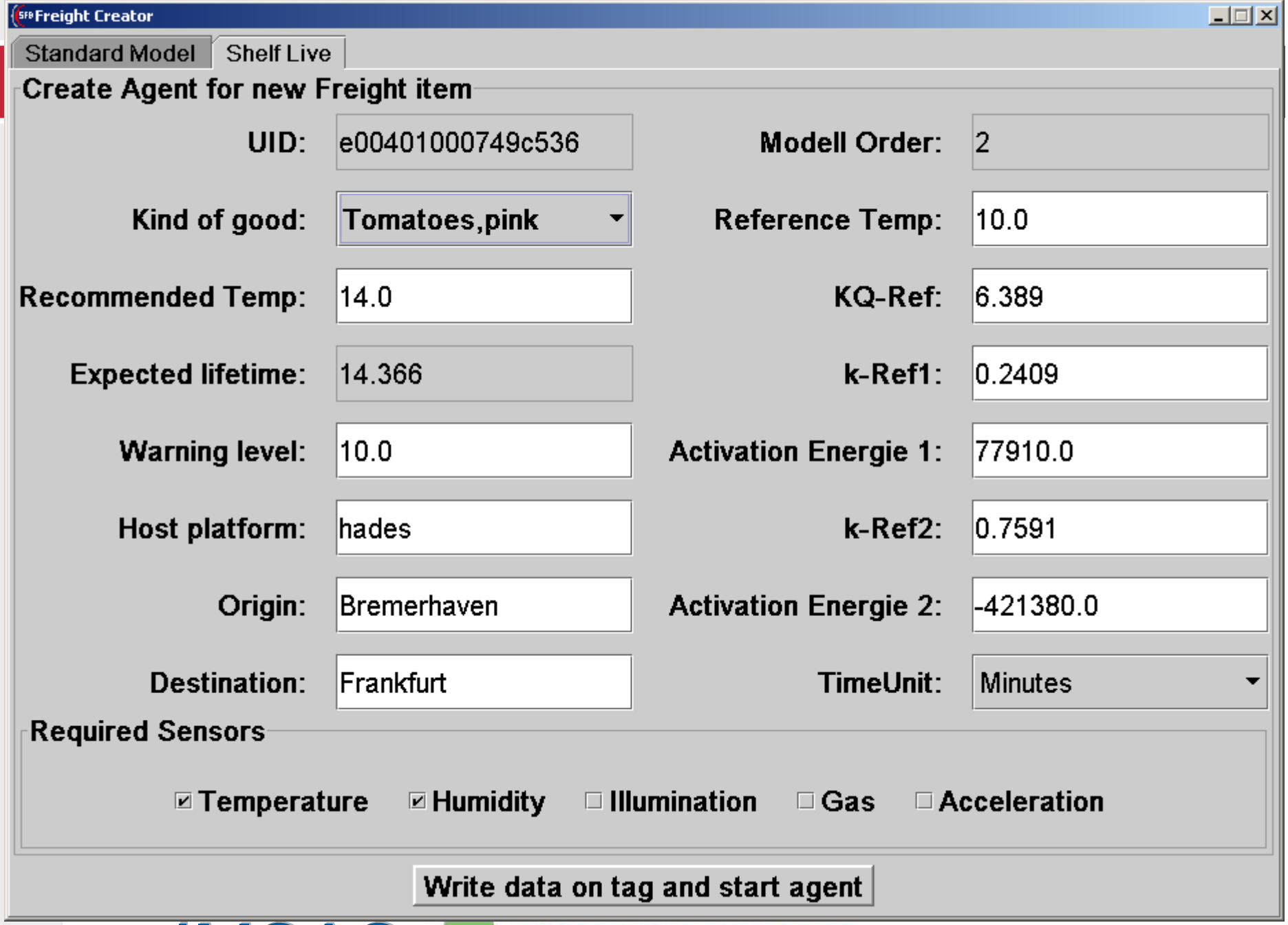
Sensor Node
ITEM, University of Bremen

ITEM
INSTITUT FÜR THEORETISCHE ELEKTROTECHNIK UND MIKROELEKTRONIK

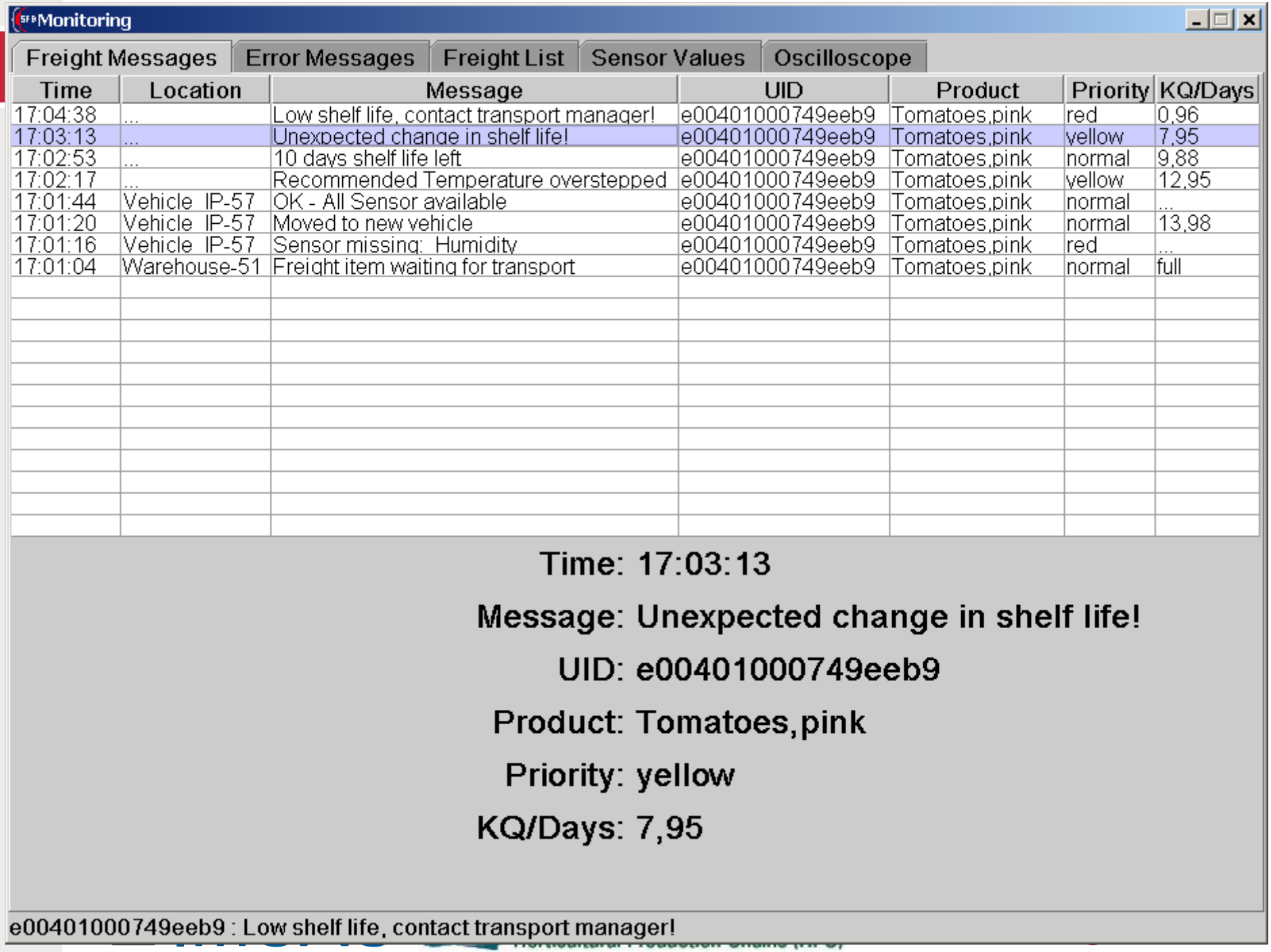
IMSAS

WAGENINGEN UNIVERSITY
PLANT SCIENCES
Horticultural Production Chains (HPC)

Universität Bremen

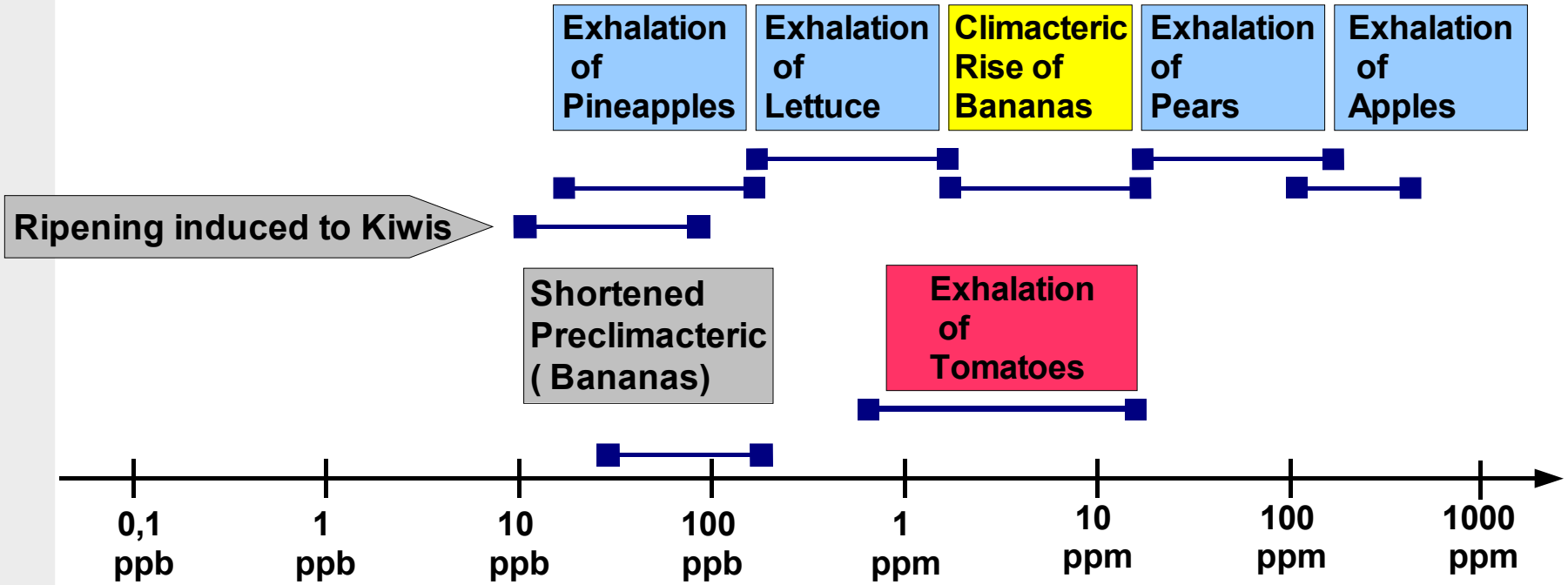

Freight Creator
Standard Model
Shelf Live
Create Agent for new Freight item
UID:
e00401000749c536
Modell Order:
2
Kind of good:
Tomatoes,pink
Reference Temp:
10.0
Recommended Temp:
14.0
KQ-Ref:
6.389
Expected lifetime:
14.366
k-Ref1:
0.2409
Warning level:
10.0
Activation Energie 1:
77910.0
Host platform:
hades
k-Ref2:
0.7591
Origin:
Bremerhaven
Activation Energie 2:
-421380.0
Destination:
Frankfurt
TimeUnit:
Minutes
Required Sensors
Temperature
Humidity
Illumination
Gas
Acceleration
Write data on tag and start agent


Monitoring
Freight Messages
Error Messages
Freight List
Sensor Values
Oscilloscope
31 °C
Temperature
13 °C
-5 °C
100 %
Humidity
Acceleration
Light
50 %
0 %
14
Shelf Life
7
0
Status Line



Time	Location	Message	UID	Product	Priority	KQ/Days
17:04:38	...	Low shelf life, contact transport manager!	e00401000749eeb9	Tomatoes,pink	red	0,96
17:03:13	...	Unexpected change in shelf life!	e00401000749eeb9	Tomatoes,pink	yellow	7,95
17:02:53	...	10 days shelf life left	e00401000749eeb9	Tomatoes,pink	normal	9,88
17:02:17	...	Recommended Temperature overstepped	e00401000749eeb9	Tomatoes,pink	yellow	12,95
17:01:44	Vehicle IP-57	OK - All Sensor available	e00401000749eeb9	Tomatoes,pink	normal	...
17:01:20	Vehicle IP-57	Moved to new vehicle	e00401000749eeb9	Tomatoes,pink	normal	13,98
17:01:16	Vehicle IP-57	Sensor missing: Humidity	e00401000749eeb9	Tomatoes,pink	red	...
17:01:04	Warehouse-51	Freight item waiting for transport	e00401000749eeb9	Tomatoes,pink	normal	full

The Ethylene Scale



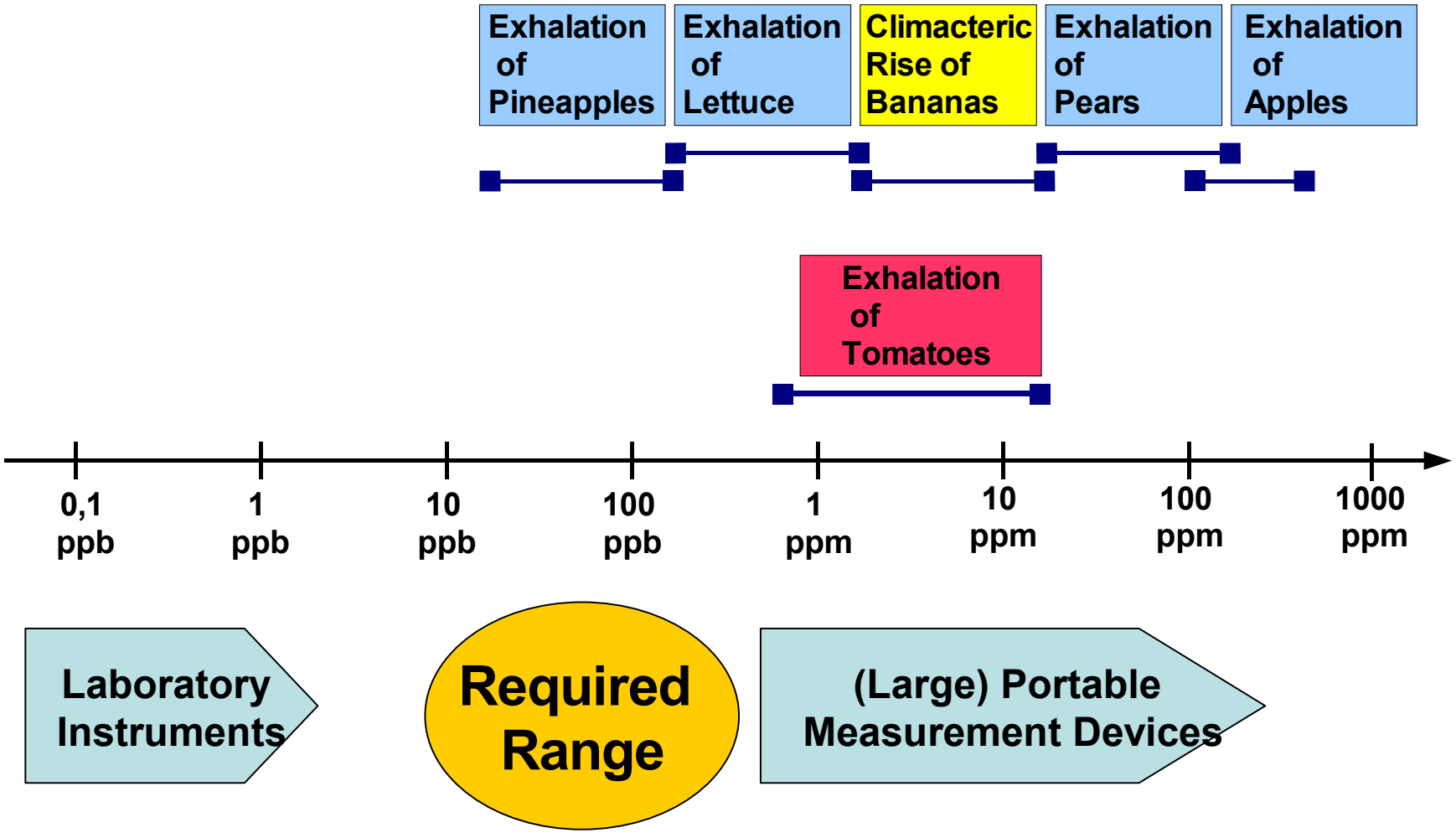
$$\frac{1\ \mu l}{kg \cdot h} \sim 1 \ldots 2\ ppm$$

1 ton of fruits in 0.5 ... 1 m³ free air volume after one hour

Ethylene sensors

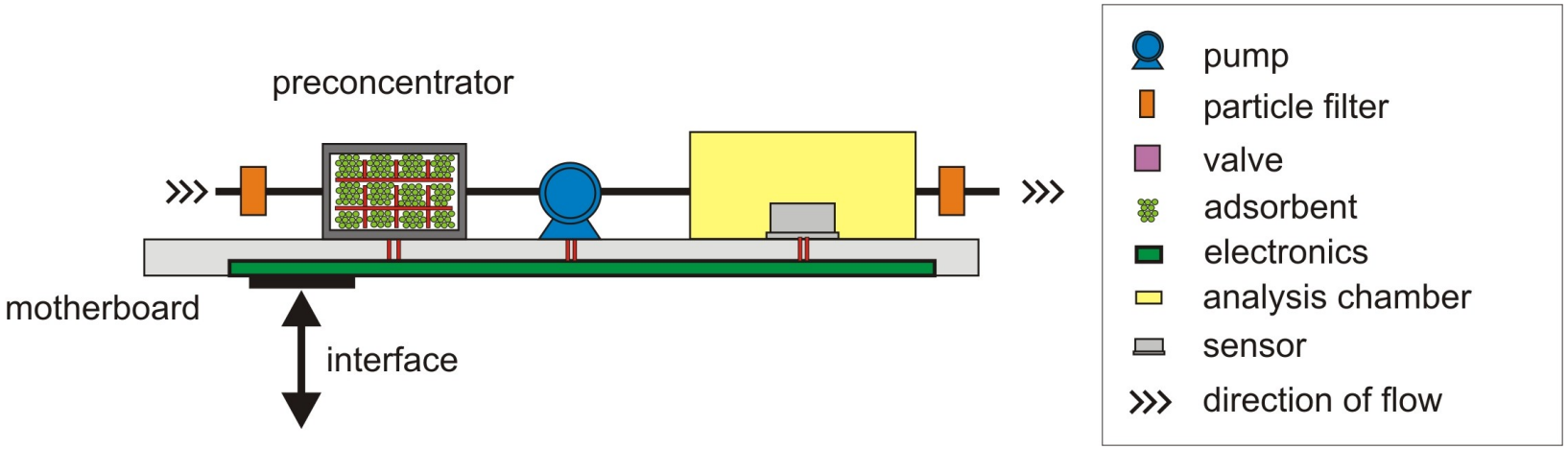
- Requirements for improved ethylene measurement
  - Detection of pre-climacteric states
  - Detection of small changes over time
  - Selective
  - Mobile
  - Maintenance free
  - Cost effective

The Ethylene Scale

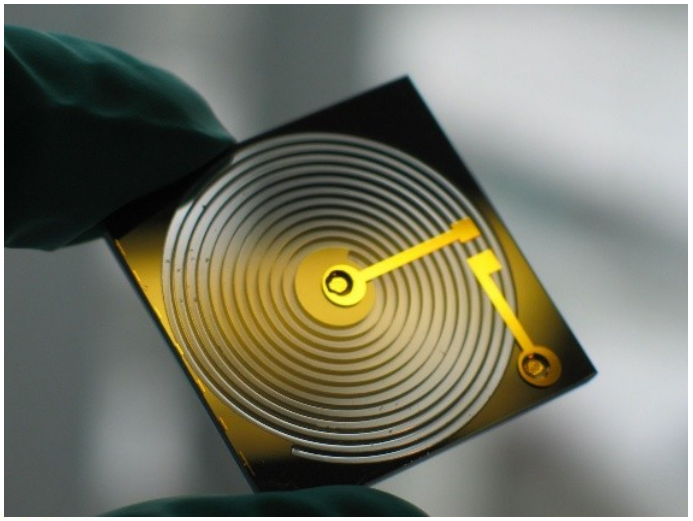


Concept for sensitive and selective sensor

- Increased resolution by pre-concentrator



- Increased selectivity by gas chromatography



Summary

- Current state
  - KQ-Model for tomatoes / different maturity states
  - Prototype for an autonomous quality supervision system (intelligent container)

- Further research
  - High sensitive mobile ethylene sensor
  - Extend KQ-Library for influence factors like humidity, ethylene and maturity
  - Integration into commercial T&T systems

Contact

- Thank you for your attention
  - For further information please contact:

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