SAFT

Battery Technologies in Traction Applications

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“Energy Efficient Components”
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Photos D.R.

A world leader in high technology batteries

- Saft is the world's leading designer, developer and manufacturer of advanced technology batteries for industrial and defence applications.

With 4,000 employees worldwide, Saft is present in 18 countries.

Batteries in traction application

- **Ecological awareness is one of the main drivers for the rail market in the coming years**

- **Battery based traction system are a solution to:**
  - Save energy, recover kinetic energy
  - Reduce gas emission
  - Reduce noise
  - Allow catenaries free sections
  - Provide Auxiliaries
    - Comfort
    - Equipment (Hydraulics, electronics, …)
  - Idling

- **Projects from other transportation applications are in progress and such experience will be beneficial for Railway applications as well**

Market segment 1 - Backup Traction

Slow driving mode in case of main power interruption

- **Metro & LRV**

Goal:

emergency autonomous mode
to restart from neutral section,
to reach next station,
for depot maneuvering

Market segment 2 - Autonomous Traction

Autonomous driving mode (no catenaries, no diesel engine)

- Hybrid tramways
- Freight Loco Diesel (slow driving mode)
- Freight Loco Electric (slow driving mode)

Goal:

local ZEV mode
on non electrified sections
(historical centers, urban areas for locos, warehouses / workshop)

Market segment 3 - Ecodriving Traction

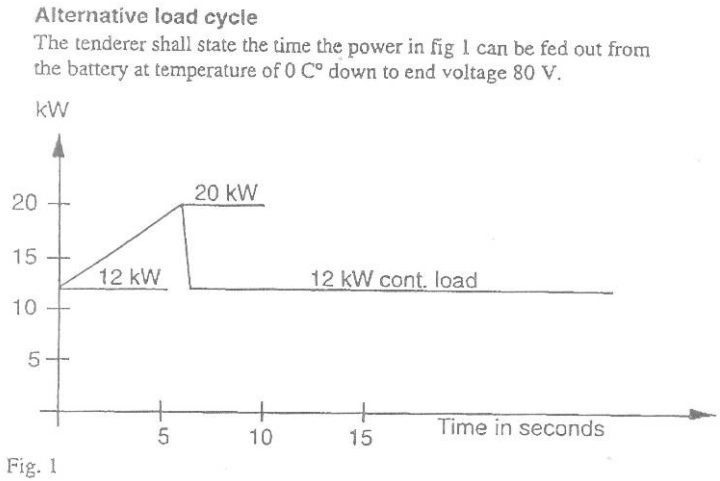
Regenerative braking & acceleration support

- **Regional EMU&DMU**
- **Diesel Loco/Shunting Loco**
- **Long distance Diesel Loco**

Goal:

Reduce infrastructure cost,
Reduce energy consumption,
limit gas emission,
reduce diesel engine size
regenerative crusing & support to maintain speed

Backup Traction - example



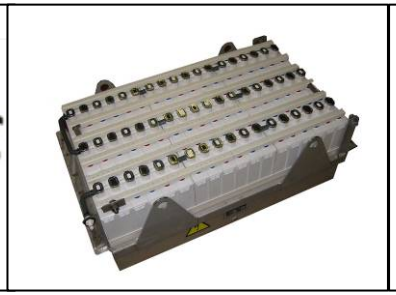
- **Emergency traction can be taken from the auxiliary battery (in service since 1999 for Stokholm metro), taking advantage of the energy installed for auxiliary back-up (here at 110V, on energy type battery)**

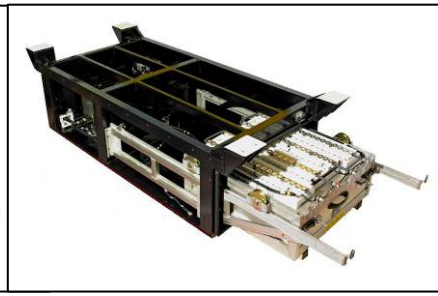
- **Profile is a power ramp up for less than 10 seconds, plus constant power to maintain the speed – with a frequency of few occurances a year.**

This is based on Traditionnal Railway Integrated Batteries

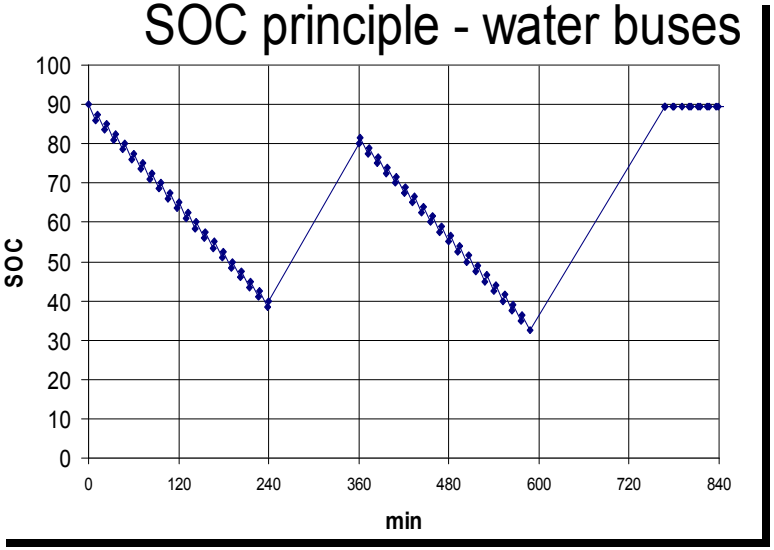
Saft is an integrated batteries supplier to all major rail OEMs in Europe, USA, Korea and Japan

- **Development & manufacture of integrated batteries (battery cells, mechanical and electrical components)**
- **Standard designs, a dedicated engineering department and project management team are the key for success in railway projects**





Autonomous Traction - example



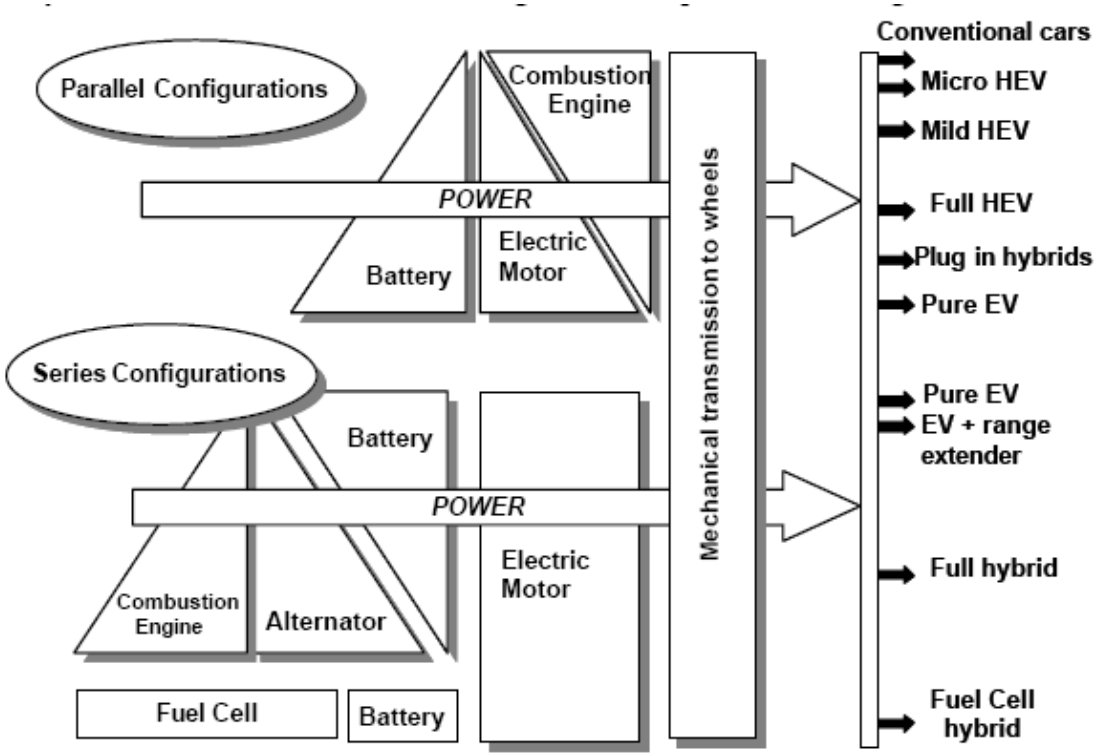
- **Non-stop operation throughout a full 6h shift (~30 return trips) on a single overnight charge. Possibility of fast-charge, so a short break enables battery to be recharged sufficiently for a second 3h shift.**

- **Also advantage of 'opportunity charging' to top up the charge level when the boat stays in dock for longer than normal, even if just for a few minutes, such as outside peak travel times.**

Autonomous & Ecodrive Traction
Road Public Transportation in operation

- **Hybrid & Pure Electric Buses: > 200 vehicles in daily services in Europe & USA (Ni-Cd & Ni-MH battery systems)**
- **More than 11 000 EVs In Europe fitted with Ni-Cd batteries (production line in Bordeaux for 5000 EV's battery packs per year)**
- **Demonstration programs with Li-ion (VEDELIC 106, VE 2000 Scenic, Ford e-Ka, Volkswagen Bora, Fiat Seicento, DaimlerChrysler Voyager, Audi)**
- **Johnson Controls-Saft Opens World's First Production Facility for Lithium-ion Hybrid Vehicle Batteries**
- **Johnson Controls-Saft : production contracts on 3 continents :**
  - Europe : Mercedes S Class, BMW 7 series ActiveHybrid,
  - Asia : Chery
  - U.S. : Azure, Ford

What's a « Hybrid » ?



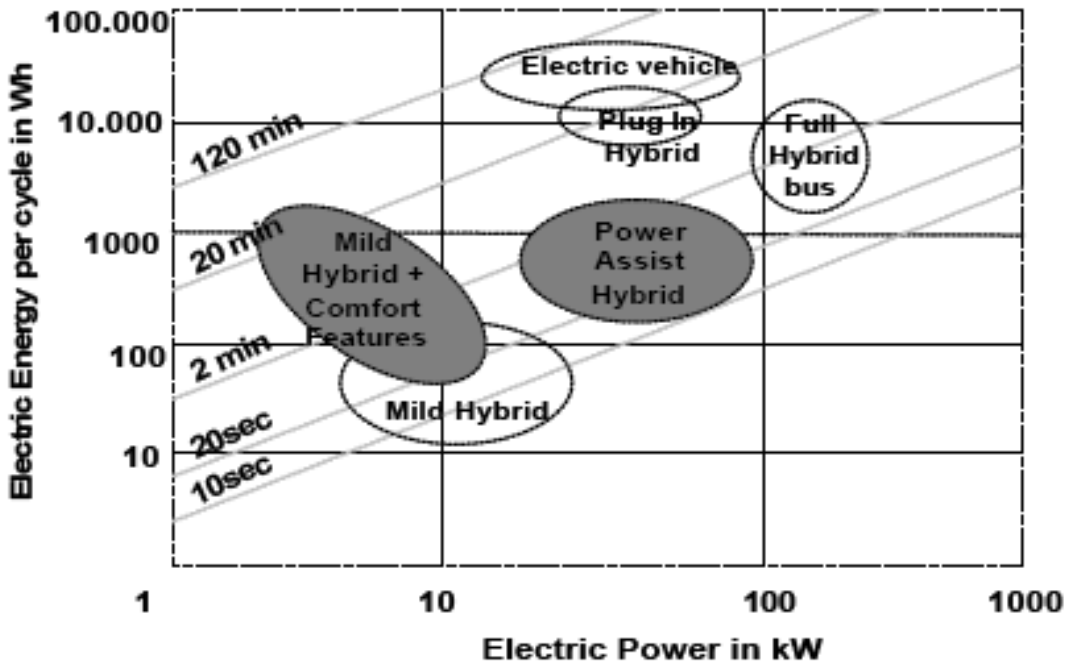
- Distance
- Acceleration
- Regenerative braking
- External recharge

Battery use

- Only hybrid
- Pure electric

} or both

Battery : always a compromise
Clear vision of the vehicle needs is Key



- **Energy**
- **Power**
- **Charge acceptance**
- **Number of cycles**
  - Frequency
  - Life time
- **Depth of discharge**

Autonomous & Ecodrive Traction
Typical profiles depends on usage

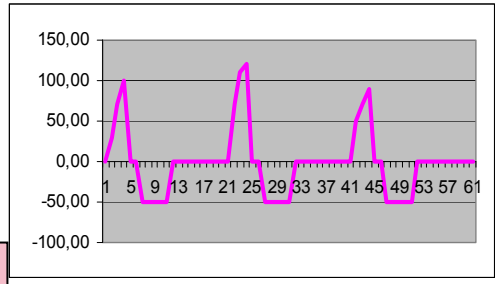
- **Mild Hybrid**
  - Electric driving up to given speed, plus power boost
  - Downsize Primary Energy Source
  - Avoid unefficient operation of Primary Energy Source
- **Full Hybrid**
  - Both Energy Sources are operating together
  - Permanently
- **All Electric**
  - Battery only energy source
  - For limited time / distance

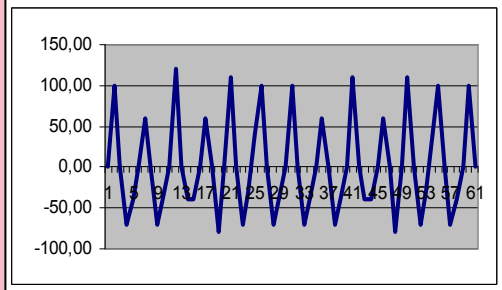
In practice:

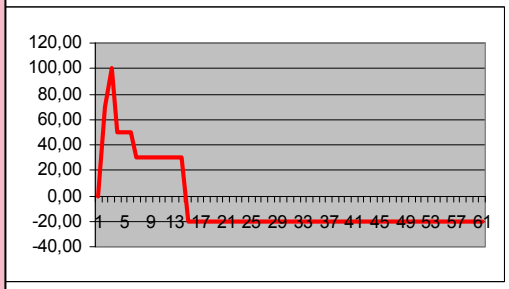
Profiles are often mixed

Full Hybrids include mild hybrid functions

Full Hybrids can be with all electric portions







Autonomous Traction
Hybrid tramway – Ni-MH Battery system

- **Dual mode Tramway**

Power ratio(7C)

Battery	68 NHP 10-340
Nominal Voltage	816 V
Battery energy	28 kWh
Battery System Weight	1,1 t
Battery Power	200 kW

Operation Modes

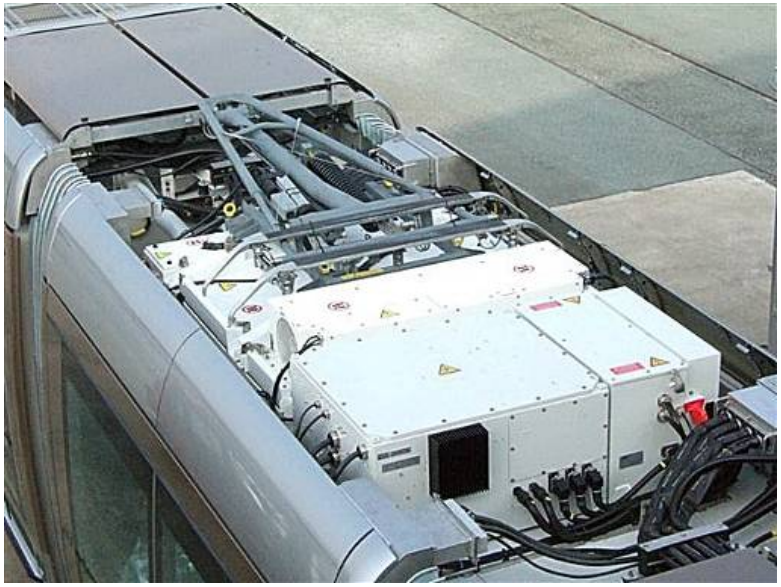
- **On catenary**
- **Without catenary**
  - 500m every 30 min
  - Several stop-start

Battery Systems =

Cells & their management +

Thermal management +

mechanical integration

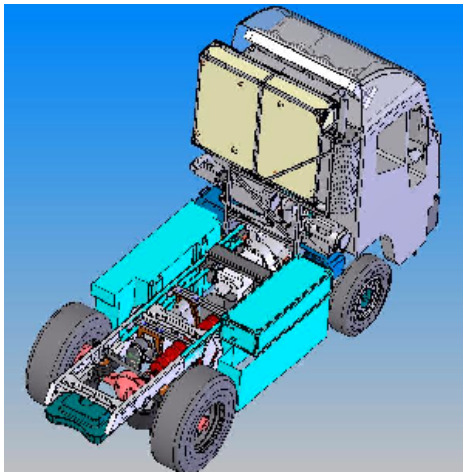


Autonomous & Ecodrive Traction
Garbage trucks

- **Garbage Truck**

Power ratio(1.5~2.5C)

Battery	45 NHE 10-100
Nominal Voltage	540 V
Battery System Weight	1.500 kg
Battery energy	54 kWh
Battery Power	80 to 130 kW



Operation Modes

- **Hybrid**
  - 10 sec peak power
  - Regenerative Braking
- **All electric**
  - 3km ➡ 5 kWh
- **Auxiliaries**
  - Hydraulics ➡ 13 kWh

Autonomous & Ecodrive Traction
Very High Power Li-Ion - Armoured Vehicles

- **AHED (Advanced Hybrid Electric Wheel Drive Vehicle)**

Power ratio(14.5C)

Battery	Very High power Li-ion
Nominal Voltage	216 V
Battery System Weight	110 kg
Battery energy	7 kWh
Battery Power	100 kW
Cycle life	1.000.000 shallow HEV Cycles
Life duration	> 15 years

Operation Modes

- **Hybrid**
  - Peak Power
  - Regenerative Braking
- **All electric**
  - Limited drive range
- **Auxiliaries**
  - Specific military equipment

Importance of clear profile definition

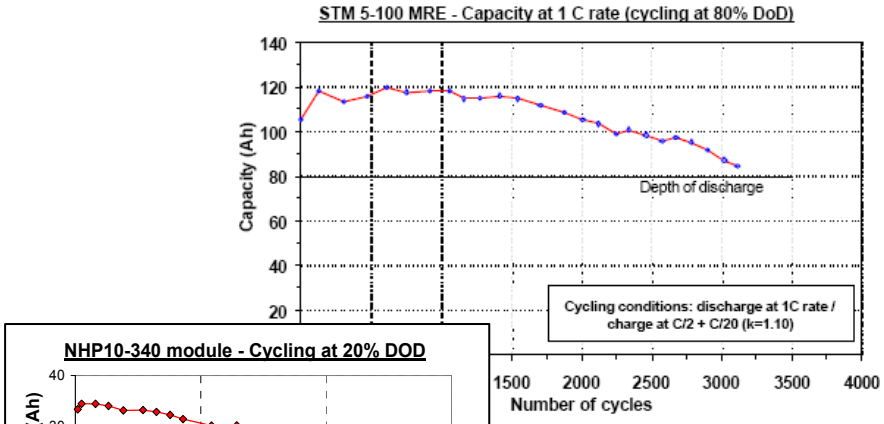
For the same usable cycle

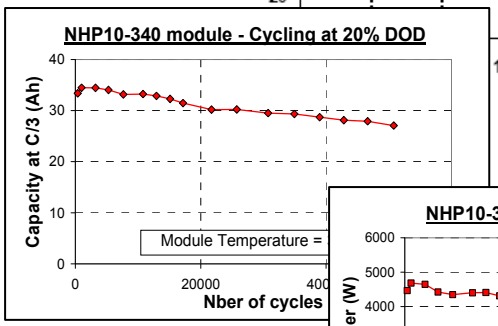
- **Backup traction**
  - Slow charge between cycle
  - Deep DOD happens seldom
  - Non optimal efficiency acceptable battery voltage as for auxiliary
  - “Add on” battery is possible
  - Thermal behaviour is average
  - Only max. cycle can be studied
  - Performances characteristics for the cycle allow to size battery

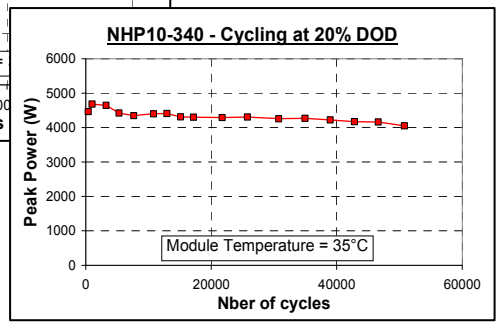
- **Autonomous / Ecodrive traction**
  - Balanced status for day cycles
  - Low DOD happens often
  - Global system efficiency is key battery voltage can be higher
  - Integrated architecture is requested (& communication…)
  - Thermal behaviour should be stable on cycling
  - Spread of cycles should be descrides (eg. slope) in the day
  - Behaviour over life duration should be checked to size the battery

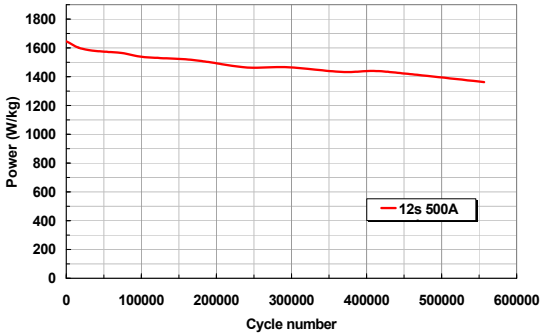
Nickel-Cadmium, Ni-MH & Li-Ion Products

- Ni-Cd: Deep cycle life
  >3000 full cycles
  - at 1C discharge rate
  - and C/2 charge rate
- Ni-Cd: Shallow cycle life
  >1,000,000 shallow cycles
  - neutral sections on HST
  - every 5 min. 16h a day for 15 years
- For Ni-MH & Li-Ion, if the reference is Ni-Cd, target is to have more
- Ni-MH: More than 50,000 cycles proven at 20% DOD
- **Li-Ion power cycling**
  - 500 000 cycles demonstrated
  - 500 A / 12 sec
    = 2.2% DOD on 20 Ah cell

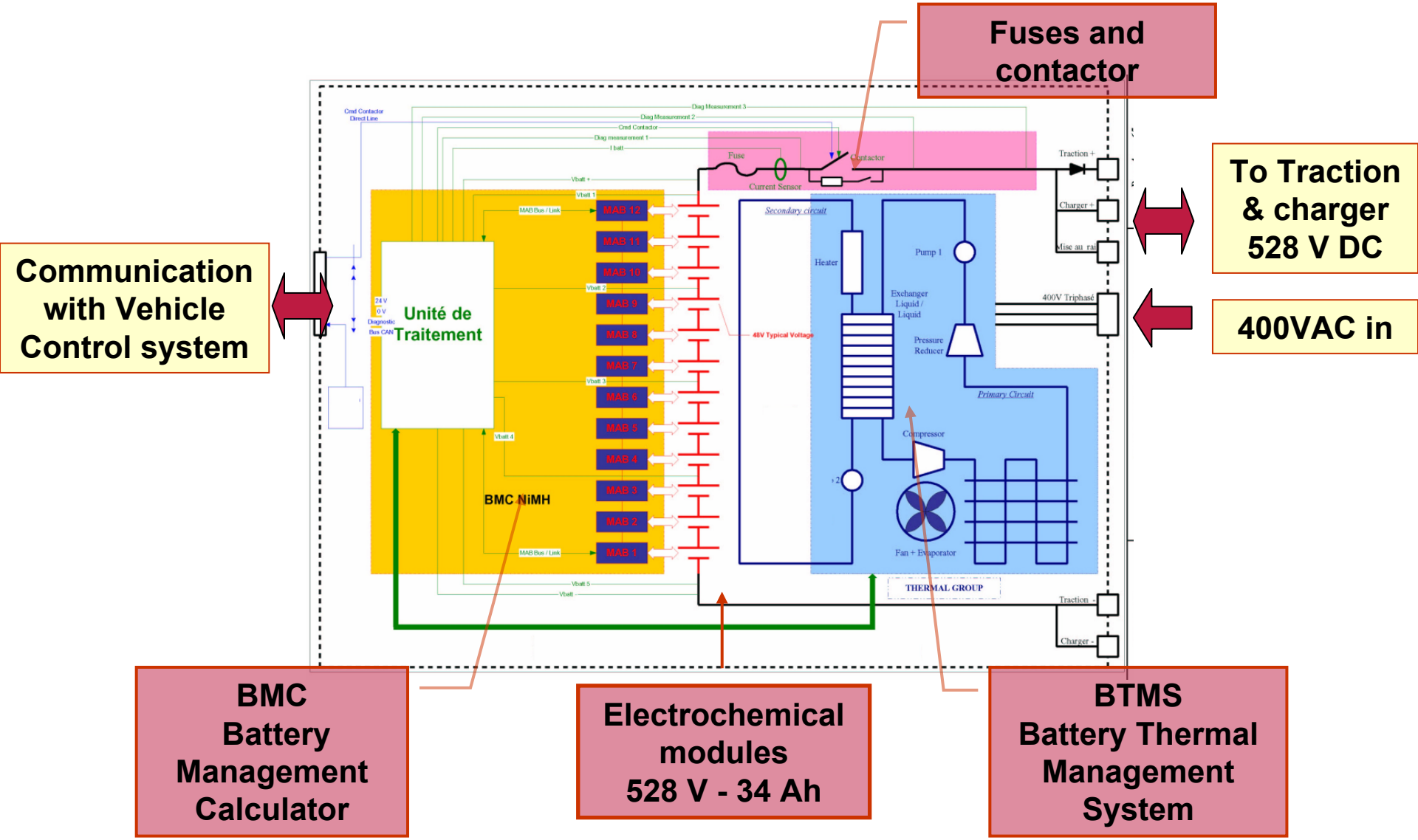








More concentrated energy implies more battery System: example for a HEV



General principles

- **System design**
  - Selection of optimum electrochemistry
  - Design to meet application needs (clear specification required)
    - Performance
    - Life
    - Electrical and mechanical interfaces
    - Safety
- **Qualification**
  - Application-specific!
  - Testing under expected operating conditions
  - Specific abuse situations
- **In close cooperation with OEM**
  - Intelligent charging and control
  - Two-way communications are vital!

Rail applications: opportunities

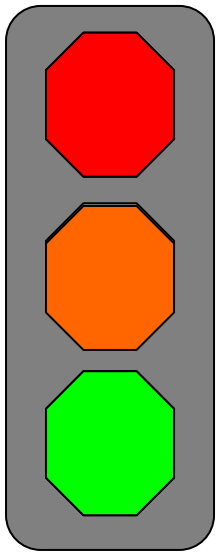
- **Opportunities for diesel-powered hybrid vehicles**
  - Fuel & NOX savings
  - Emission free operation for short distances (in & out of station)
- **Important to separate project types**
  - **Commercial**: warranty needed …on time for actual revenue service
  - **Exploratory:** test & qualification as per Railways standards are required

➔ **Ni-MH (eg Nice, Padova) as for today**

- **Electric-powered vehicles may also benefit from power-assist and regenerative braking**
  - onboard & on trackside
  - in combination with an auxiliary battery as today

Rail applications: current situation

- **Batteries are large (18 to 200 kWh)**
- **Batteries are complex (Thermal mgt., BMS, safety aspects)**
- **SAFT manufactures Ni-Cd, Ni-MH & Li-ion**
- **SAFT understands the Railways market requests**
- **Risks need to be evaluated**
  - Architecture & system integration
  - Transportation qualification
  - Fire & Smoke (EN 45545 standard)
  - High Voltage battery onboard (safety)
  - Operation in tunnels
  - Evolution in legislation



Willing to do the move

…

when all lights are green

Thanks for your attention

Photos D.R.