



# Energy issues in WSN for Aeronautics Applications: Harvesting and Scavenging, Power Management, Storage

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*with inputs from*

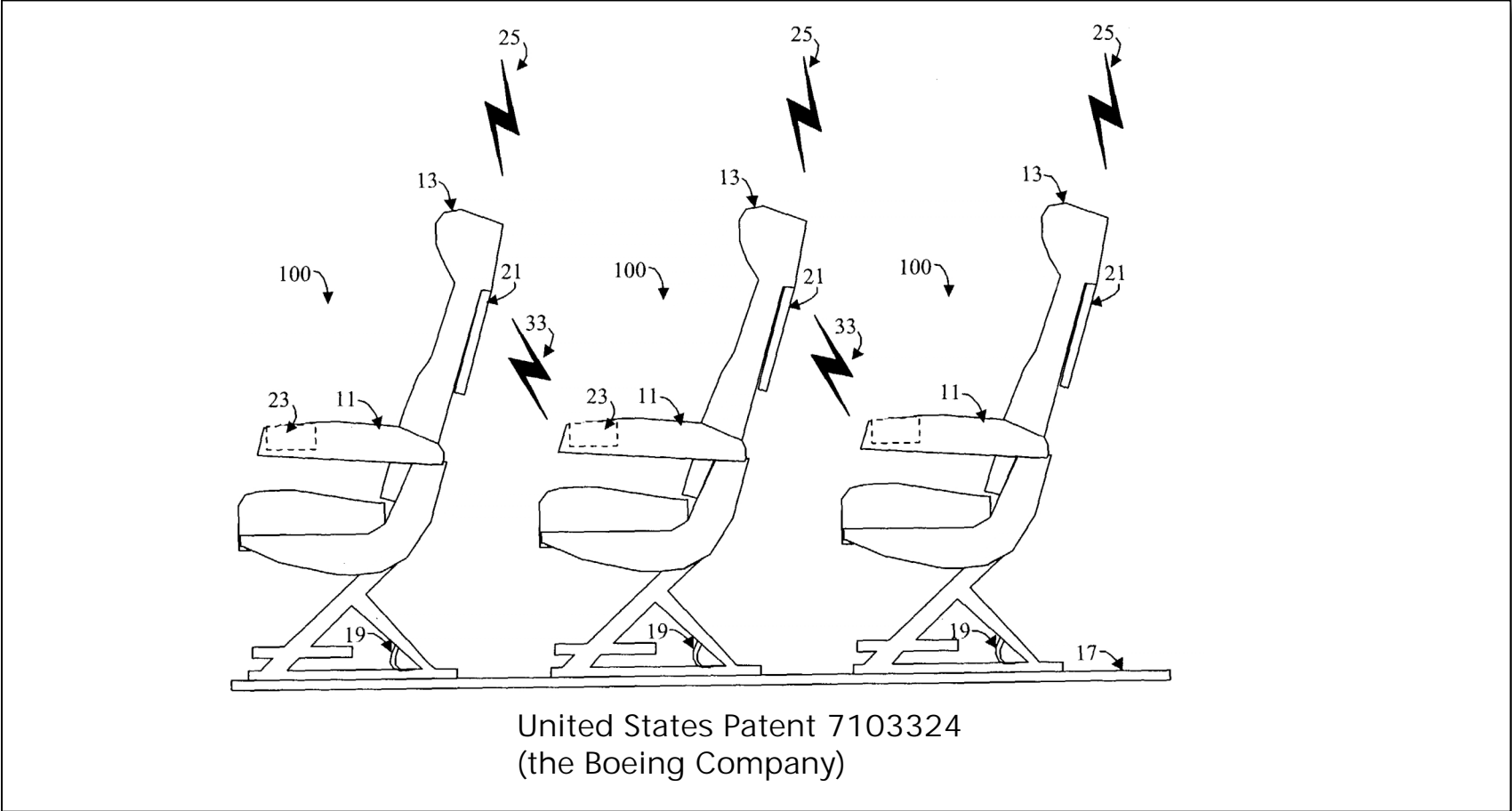
*Carole Rossi, Magali Brunet, Marise Bafleur,  
Claude Vanhecke, Nicolas Bailly, Christophe Escriba,  
Hugo Durou, Dariga Meekhun, Vincent Boitier,  
Jacques Collet, Piotr Zajak,  
Google...*



- Introduction: WSN and aircrafts
- WSN and SHM
- Energy issue: harvesting vs scavenging
- An example of energy capture:  
thermoelectricity
- Energy storage
- Energy management
- Network related considerations
- Conclusions



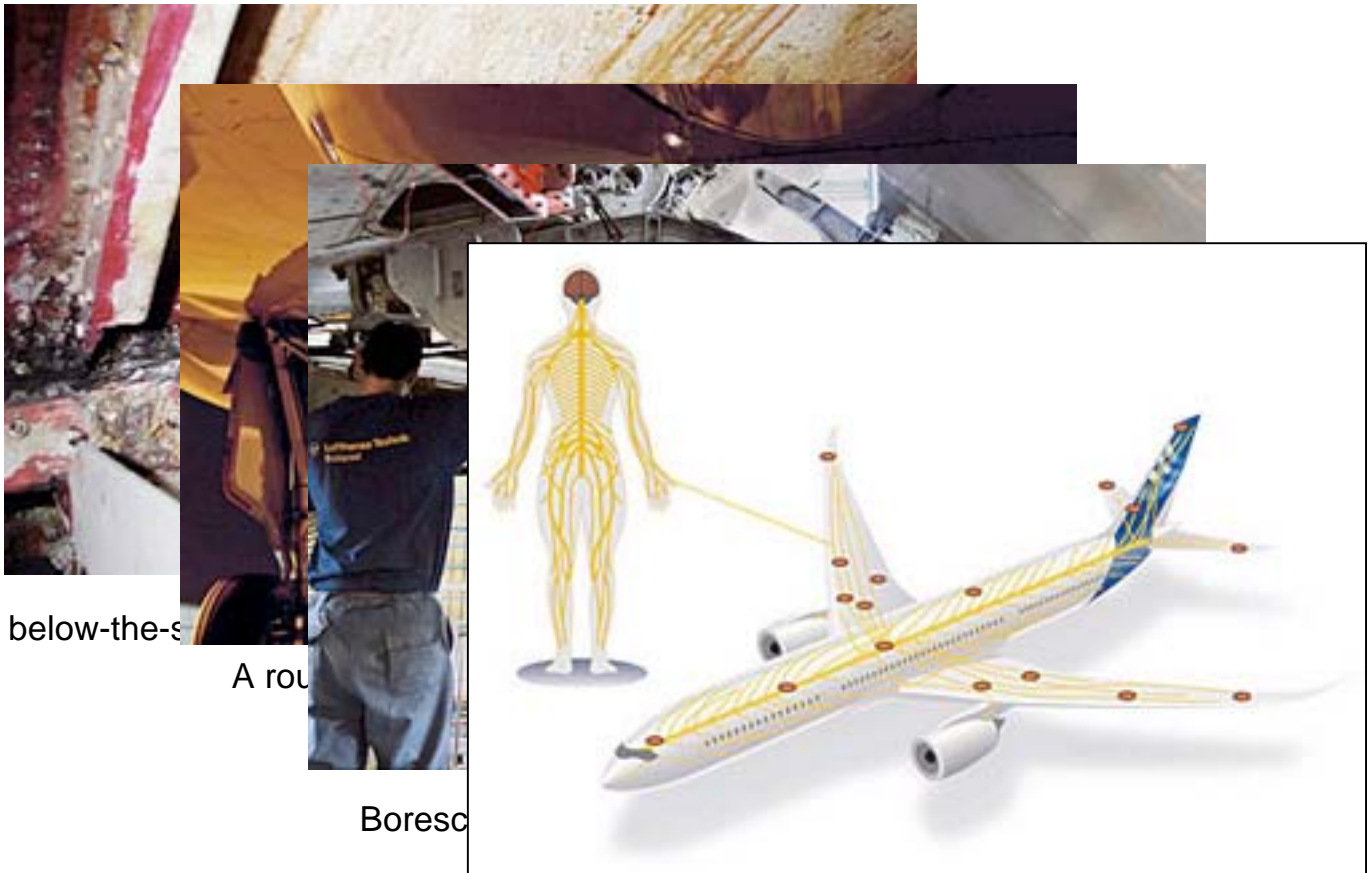
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**WSN for collecting passenger inputs** *(from passenger control units ("PCU") which are typically embedded in the armrest of the passenger seats)*



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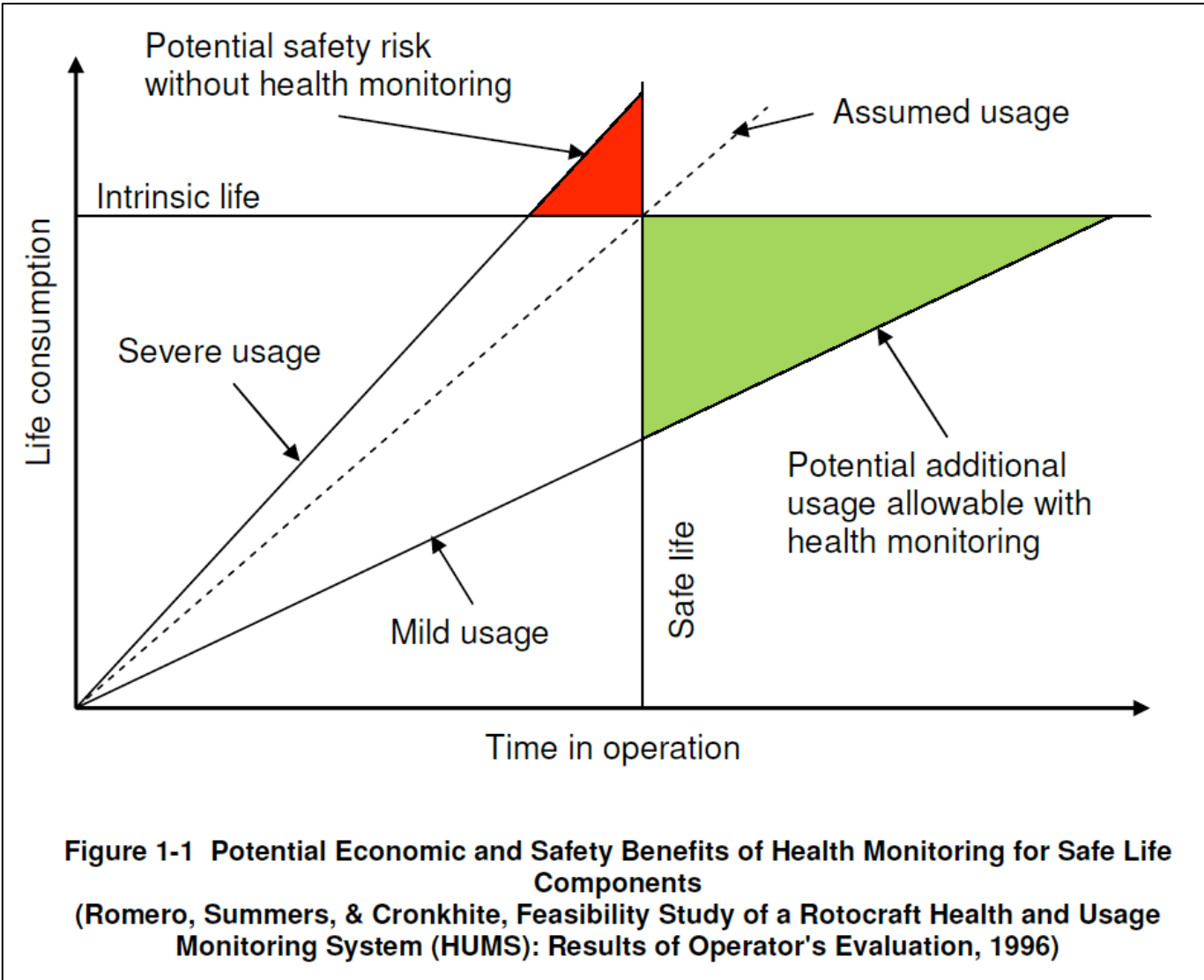
SHM (EADS)

- Level 1 (Detection).
- Level 2 (Localisation).
- Level 3 (Assessment).
- Level 4 (Prediction).

SHM: Structural Health Monitoring - sensors, some embedded in the airframe, detect cracks, corrosion, delamination and other damages and simplify their assessment while speeding their detection.

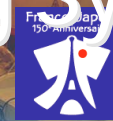


Def Stan 25-24 (UK MoD, 2004) defines health monitoring as “the automatic acquisition of data necessary to determine the potential failure or degradation of a system”, which is echoed in FAA policy (FAA, 1999) where a health monitoring system is defined as “equipment, techniques, and/or procedures by which selected incipient failure or degradation can be determined”

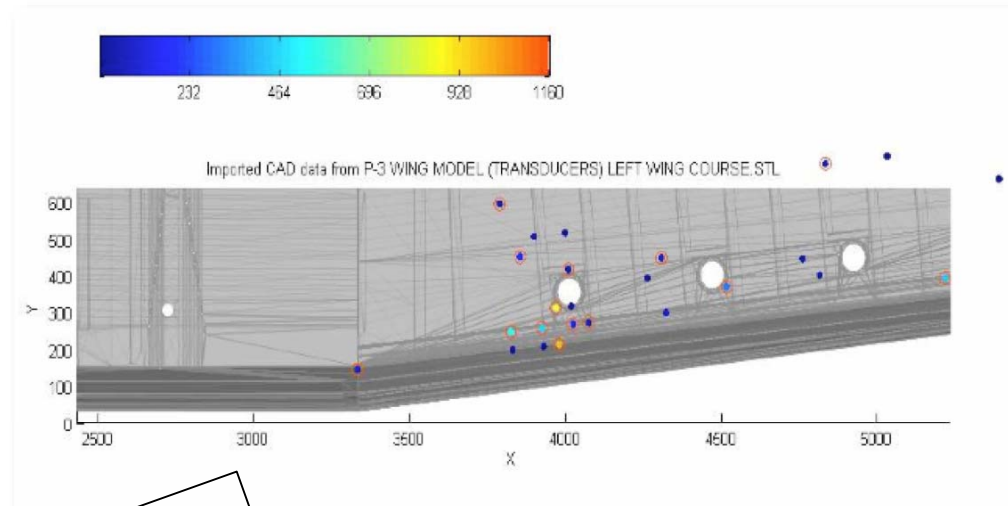




# Acoustic Airframe Integrity Monitoring System



Orion P3 - tanker



Wireless?



*Acoustic Airframe Integrity Monitoring System  
(similar to that used for A340 fatigue tests: Balrue system)*

(Aero Union Corporation / Ultra Electronics Ltd)



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# Energy capture from the environment



## Limited energetic autonomy:

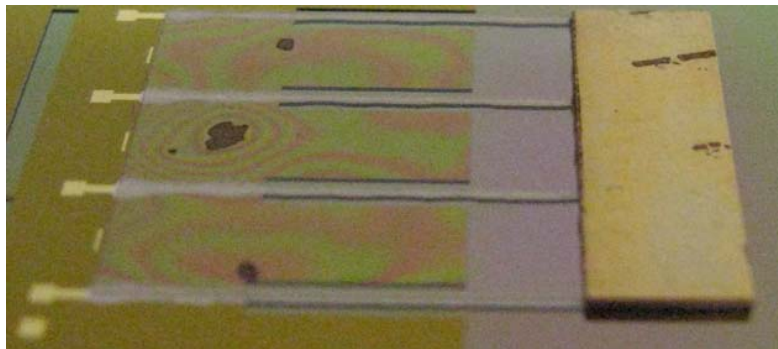
- application is limited in duration
- sensors/nodes are accessible
- pollution issue if abandoned

## Unlimited energetic autonomy:

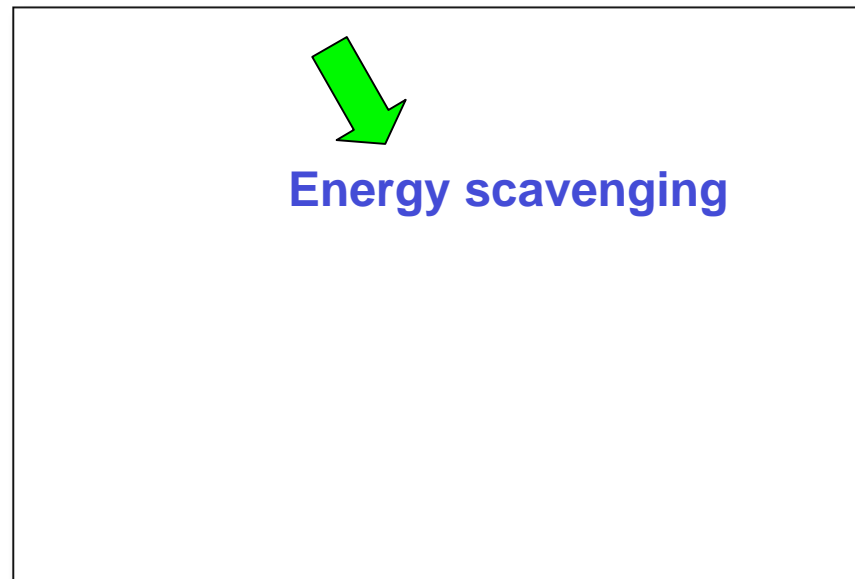
- long lifetime
- 'lost sensors' (or unaccessible) => energy capture from the environment



## Energy harvesting



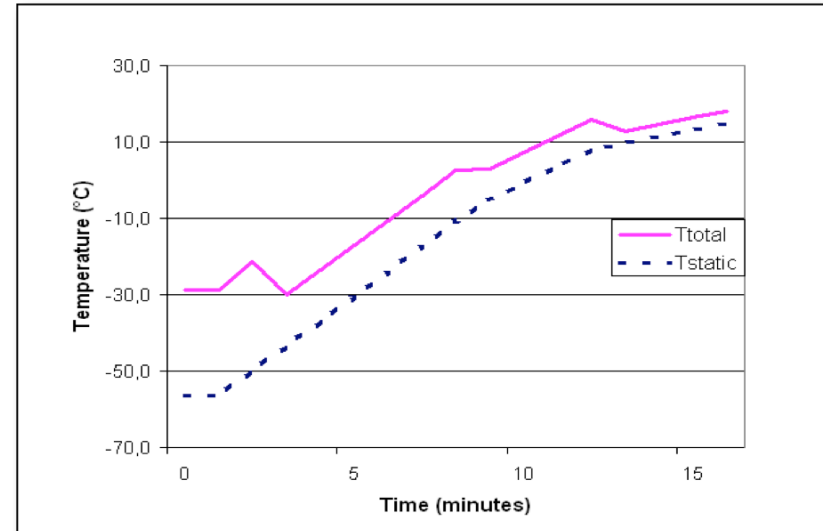
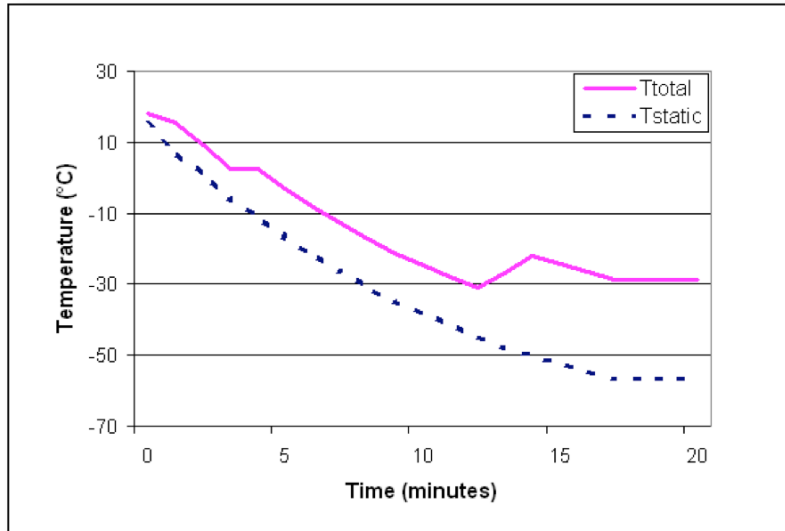
## Energy scavenging





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# Thermo-electric generation

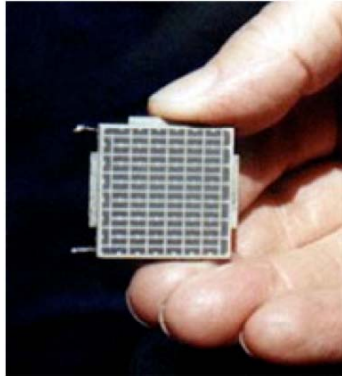


$$T_t = (1 + 0.2 M^2) T_s$$

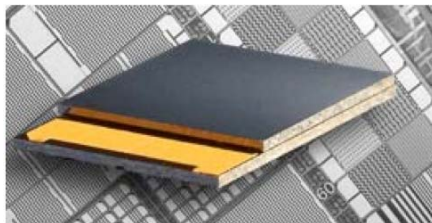
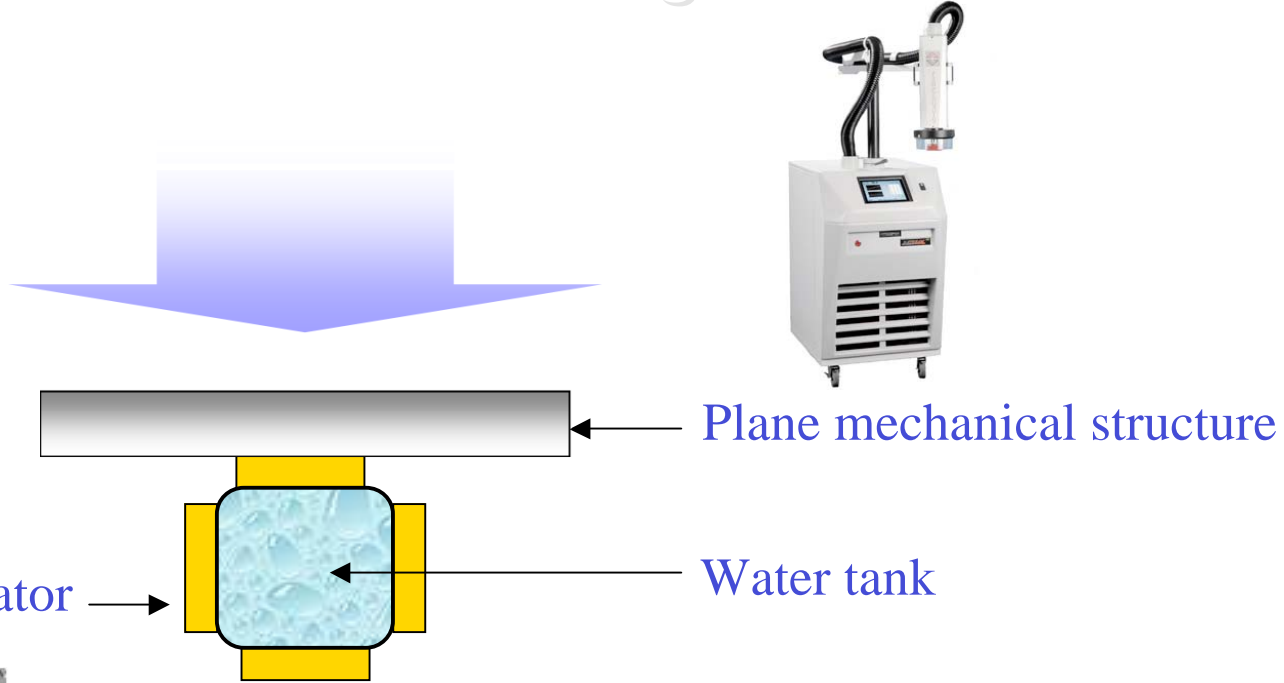


$$W_T = \Delta T \times C + H_f = 645 \text{ J/g}$$

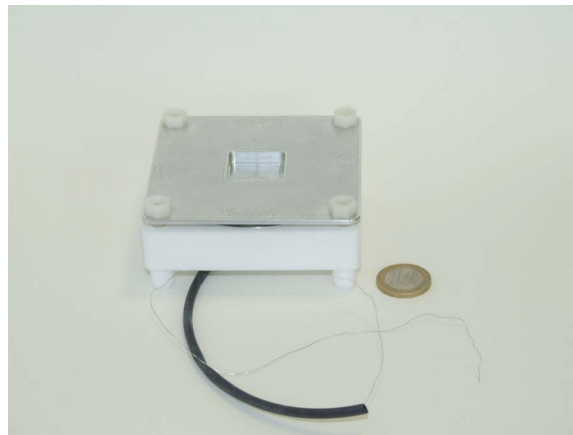
# Thermal Gradients: experimental arrangement

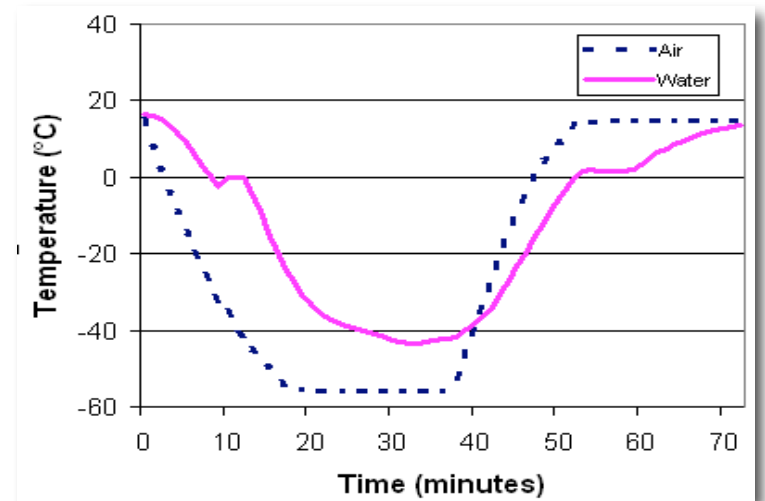
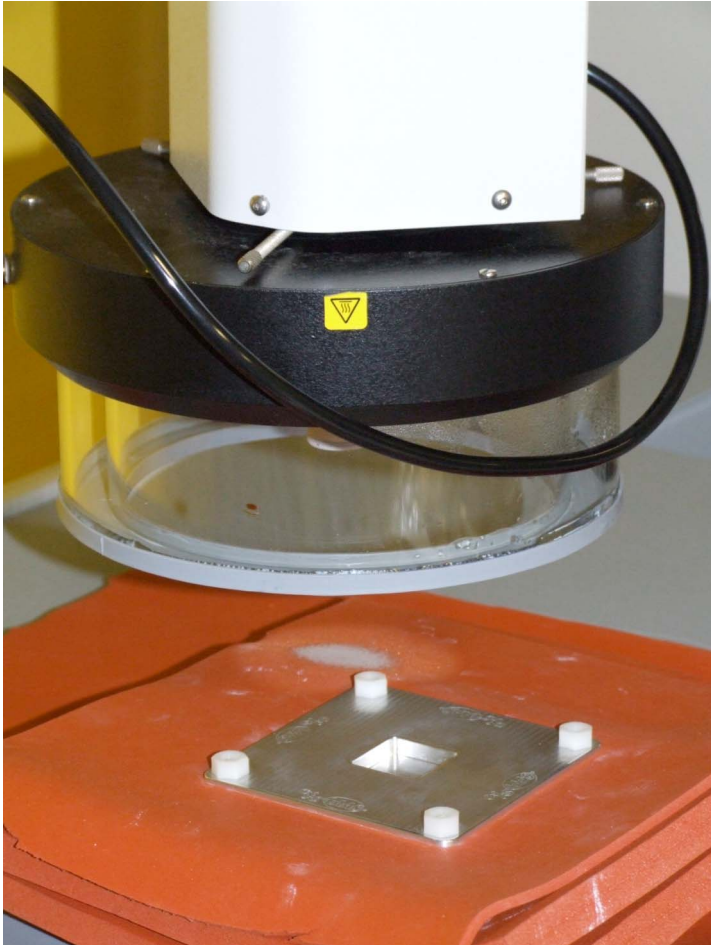


Thermoelectric generator

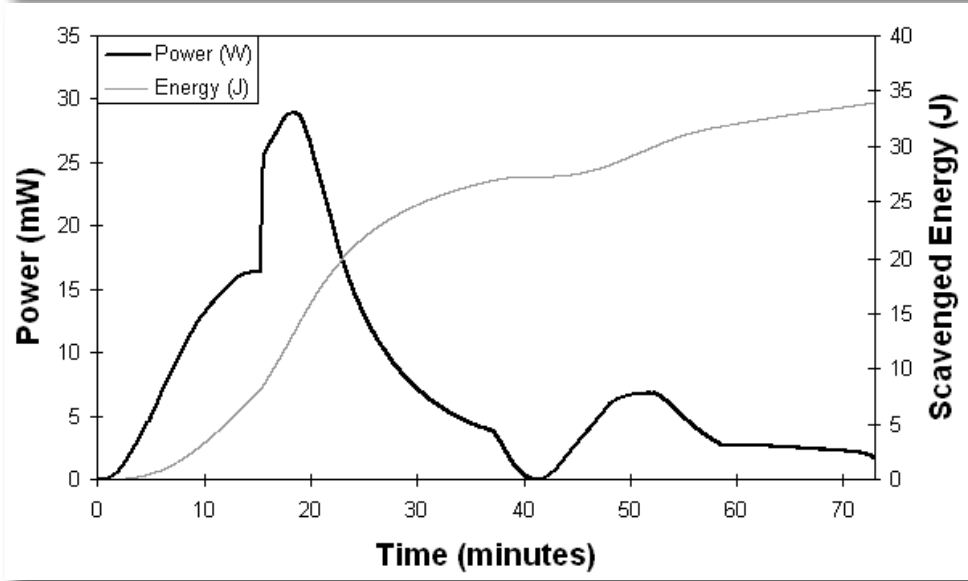
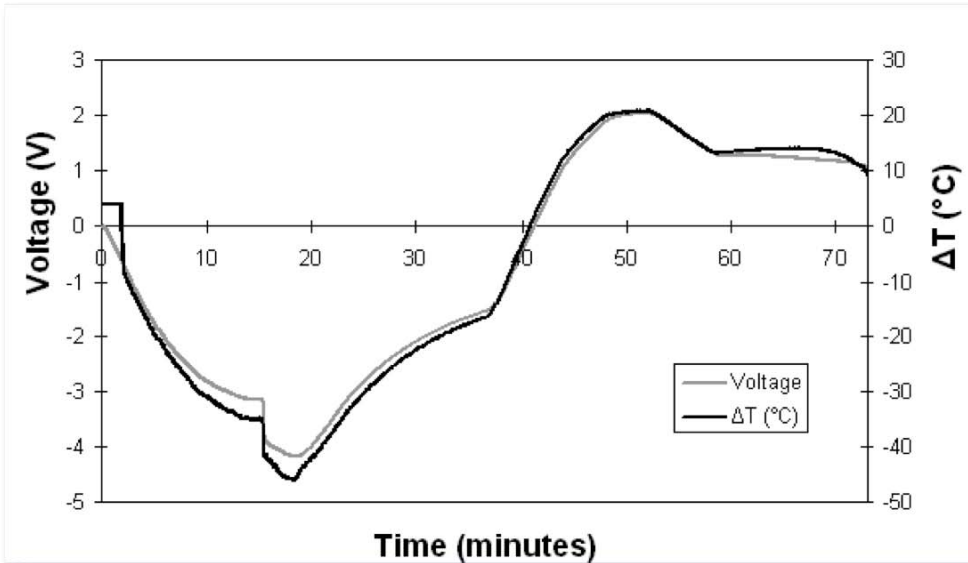


**micropelt**  
Thin film thermoelectrics.





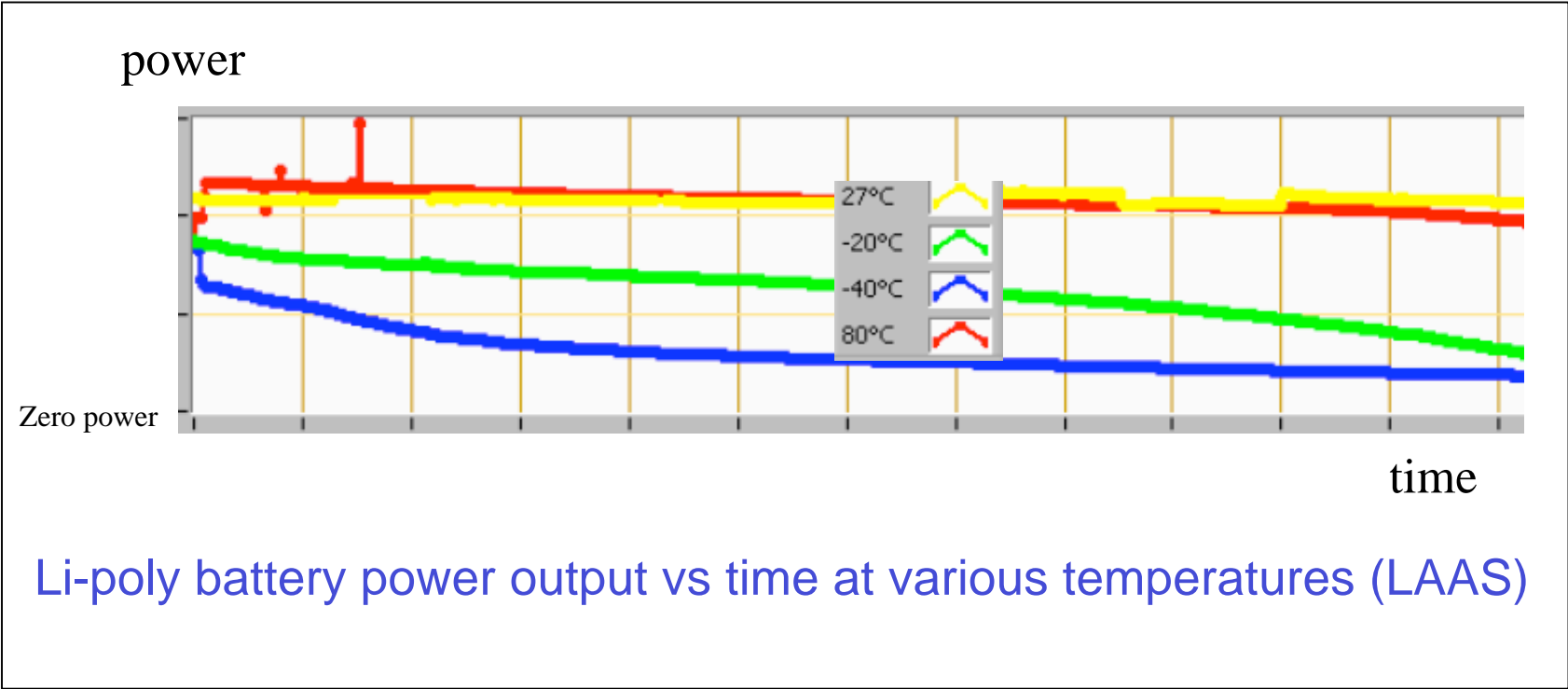
# Thermal Gradients



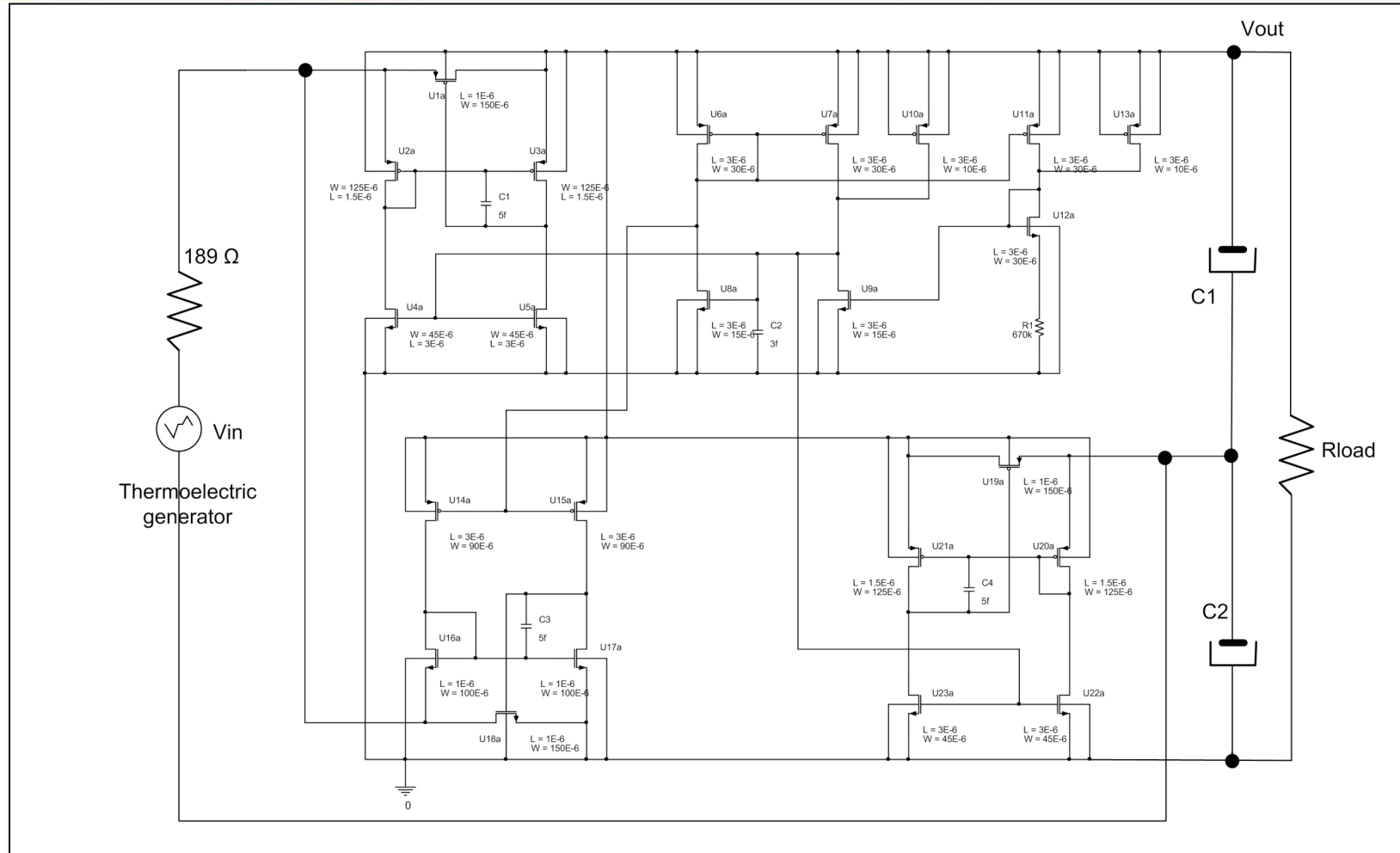




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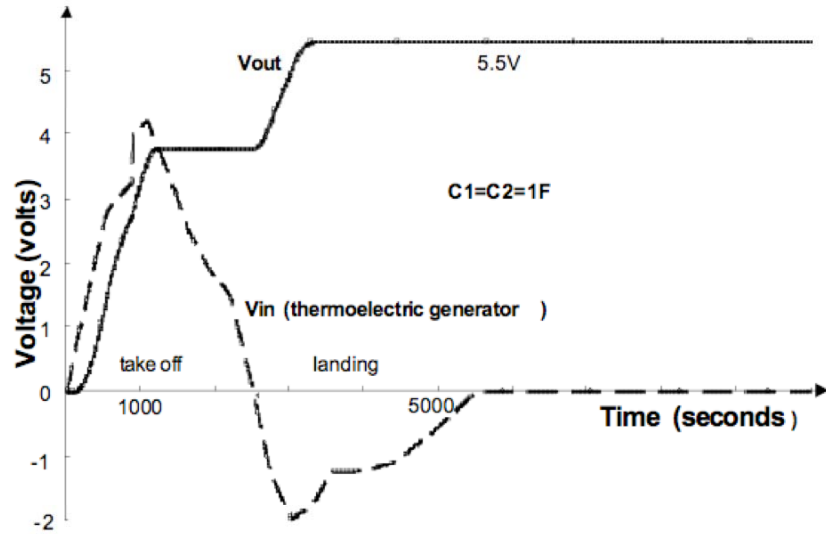
# Voltage Booster Details



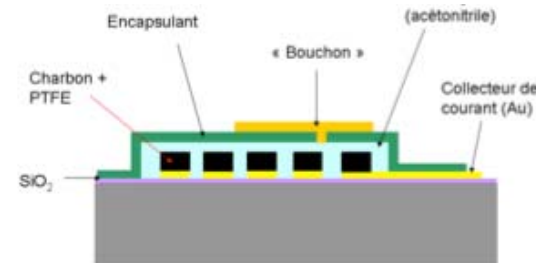
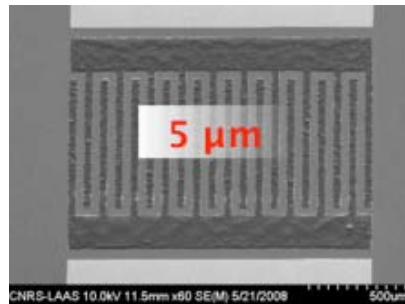
SPICE Simulation (0.35  $\mu\text{m}$  technology):  
 Rectifier threshold voltage = 10 mV  
 Total Bias Current = 530 nA



# Energy Storage



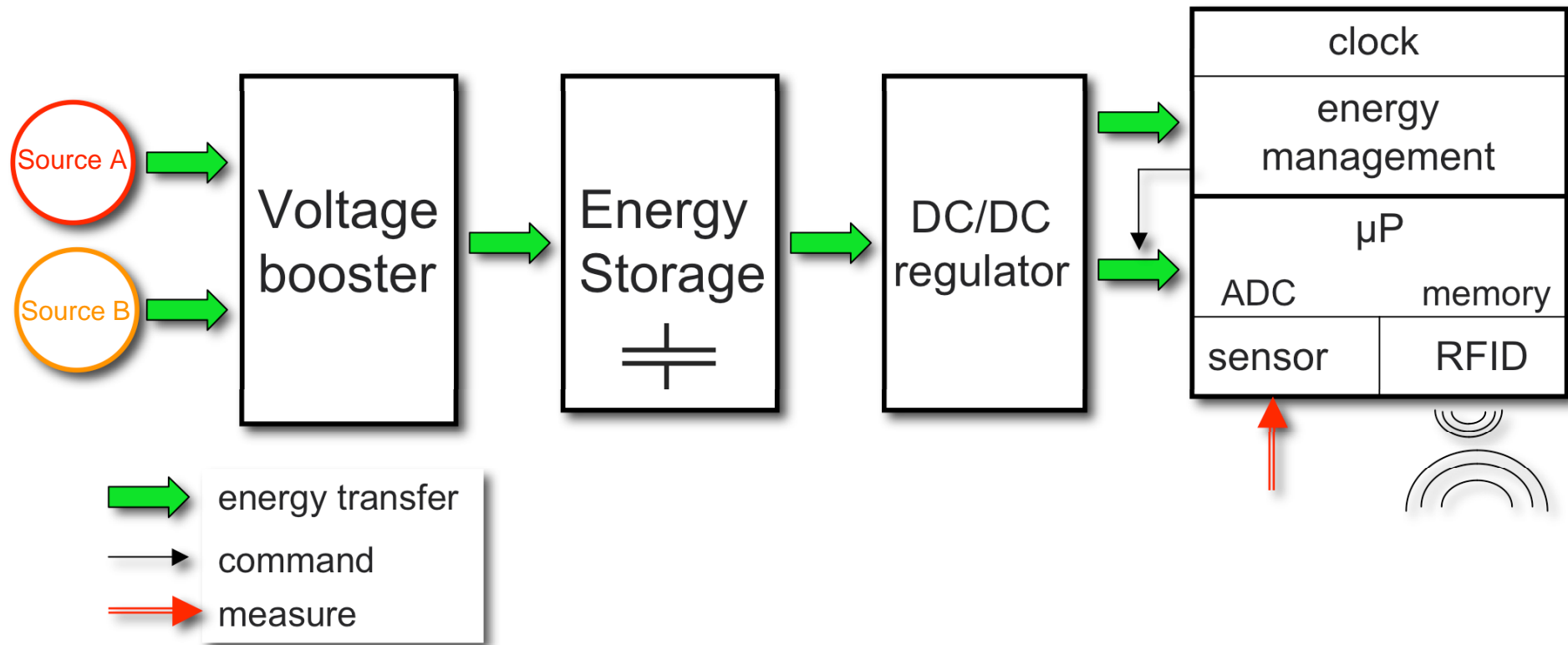
CMOS 0.35  $\mu\text{m}$   
 Active diodes  $V_t=10\text{ mV}$   
 Self-bias activated at  $t=2\text{min}$   
 DC/DC activated at  $t=9\text{min}$  (1V output)  
 Total bias current is 530 nA





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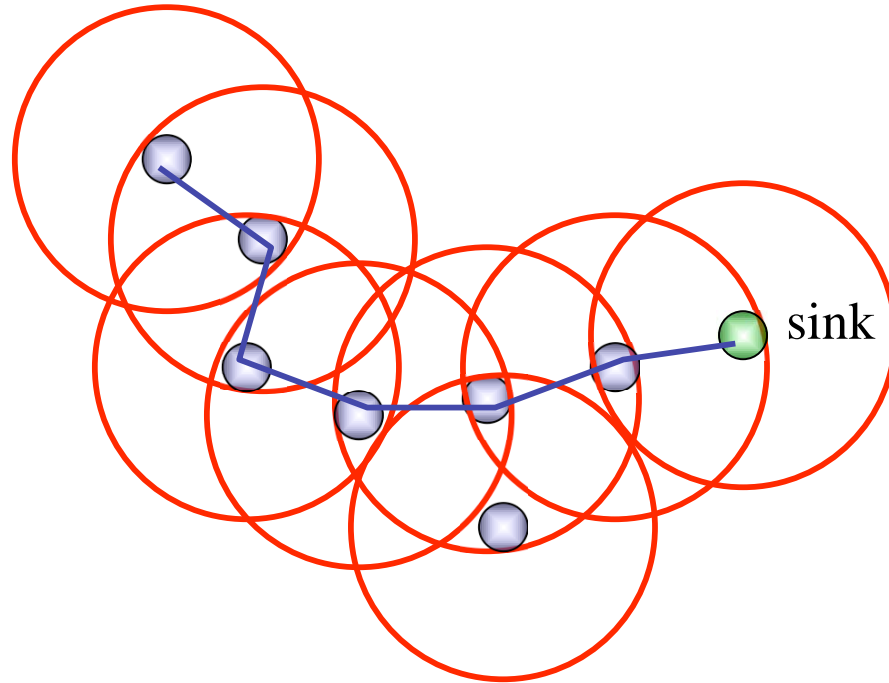
# Structural Health Monitoring





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# Network/energy related issues





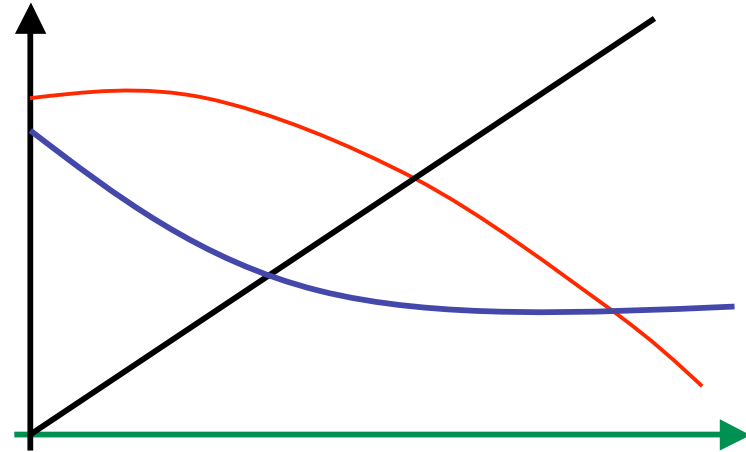
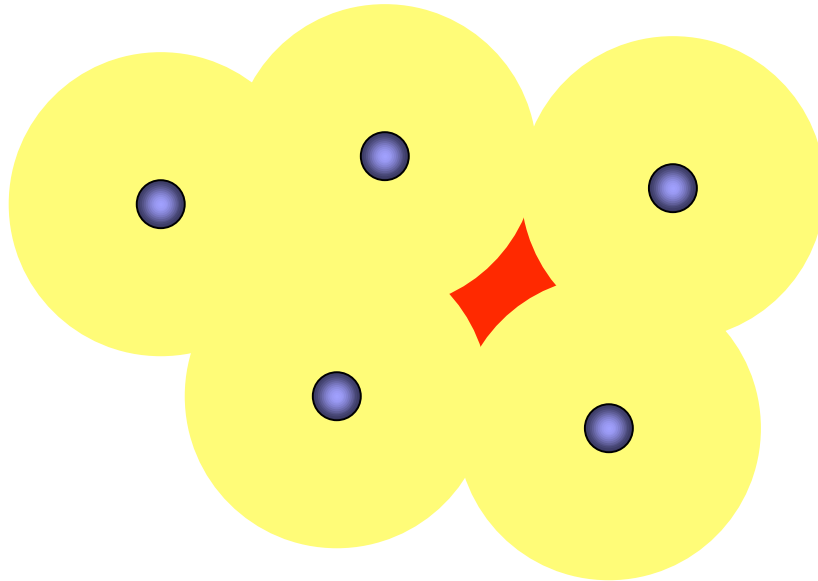
# Network/energy related issues

## Network related issues:

- none of the connectivity problems associated with multi-hop transmission found in WSN...
- ... but a different approach no more based on the spatial distribution of nodes and their transmission range, but the spatial distribution of nodes and their measurement range

# Network/energy related issues

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INSTITUT  
CARNOT  
LAAS

*what is the relationship between*

- *sensor distribution density,*
- *captured power per sensor,*
- *sensor power consumption,*
- *total weight of the network?*

*... with the added perspective of short and long term resilience of network.*



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