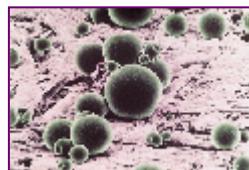




Use of Encapsulation Technology for NLW



Secondary delivery



Primary delivery



Wall material with properties specific to application

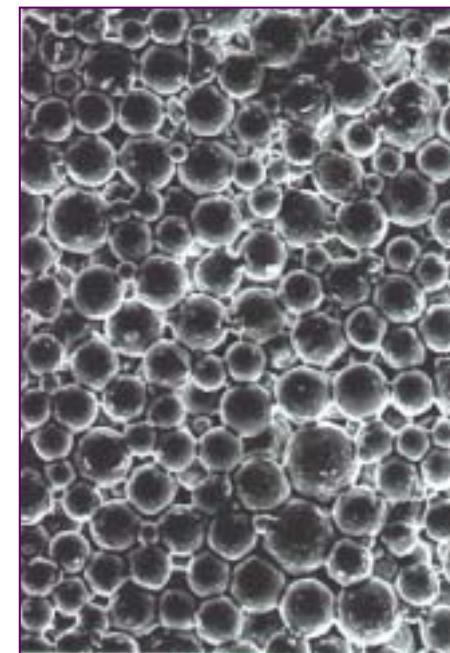


Active material



Why encapsulate NLW?

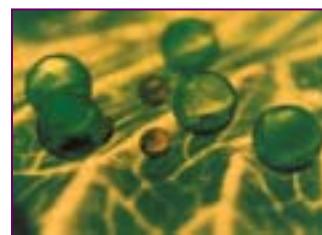
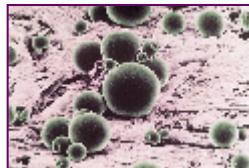
- To achieve controlled/remote-release.
- Make active materials easier/safer to handle.
- Compartmentalize multiple component systems.
- Protect sensitive materials from their environment.
- To turn liquids into powders/solids.





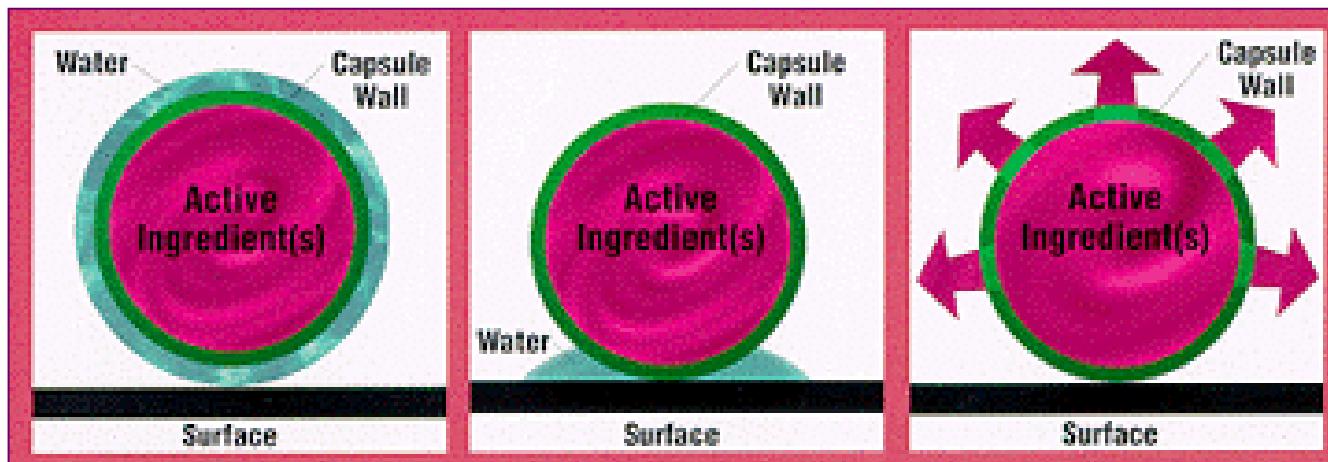
You are (very) familiar with microcapsules

Razor Blades
Thread Lock Fasteners
Fertilizers
Pesticides
Toothpaste
Shampoo
Bath Salts
Sachets
Scratch-N-Sniffs
Scented Papers
Extended Relief Pharmaceuticals
Carbonless Paper
Detergents & Bleaches
Antiperspirants
Air Fresheners
Vacuum Cleaner Bags
Fire Retardants
Waste Disposal Systems
Kitty Litter
Facial Tissues



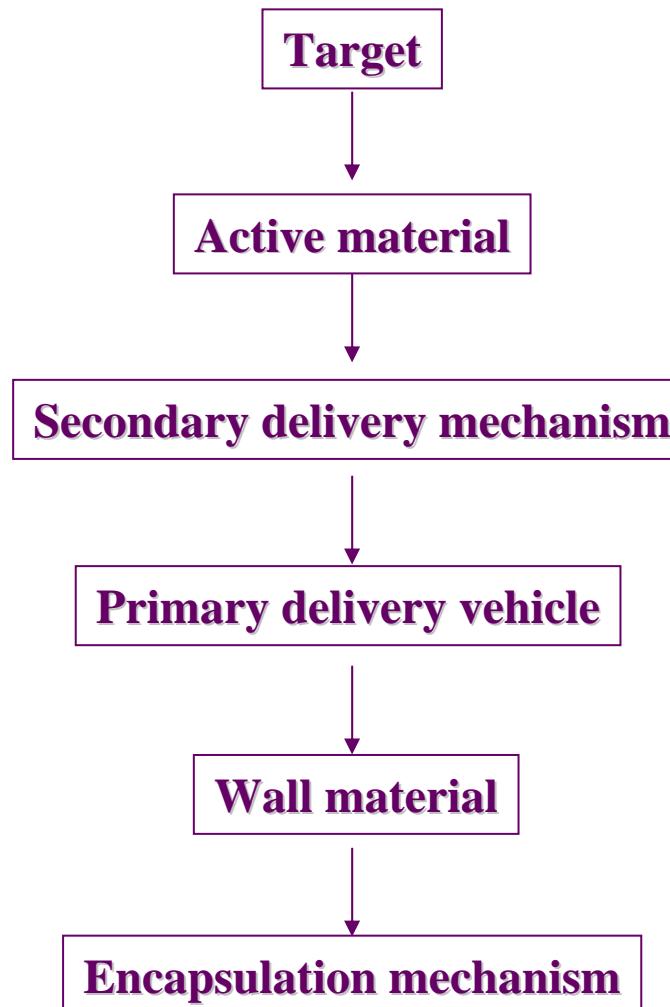


Example of release





Selection process

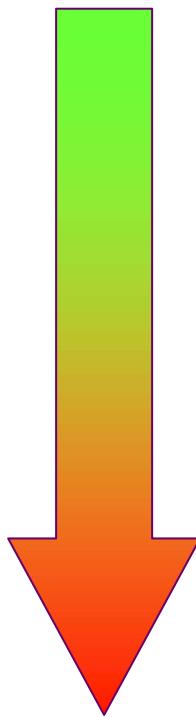




Target / Potential active materials

Anti-Material

- Combustion modifier
- High viscosity polymers



Anti-Personnel

Color dyes

Mark the opponent for easy identification (chase situation)

Pheromones

Discomfort inducers

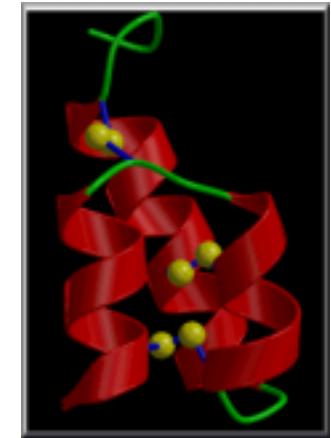
Loss of vision

Coughing

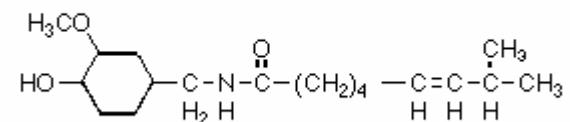
Disorientation

Vomit

Anesthetic
Paralytic



Capsaicin



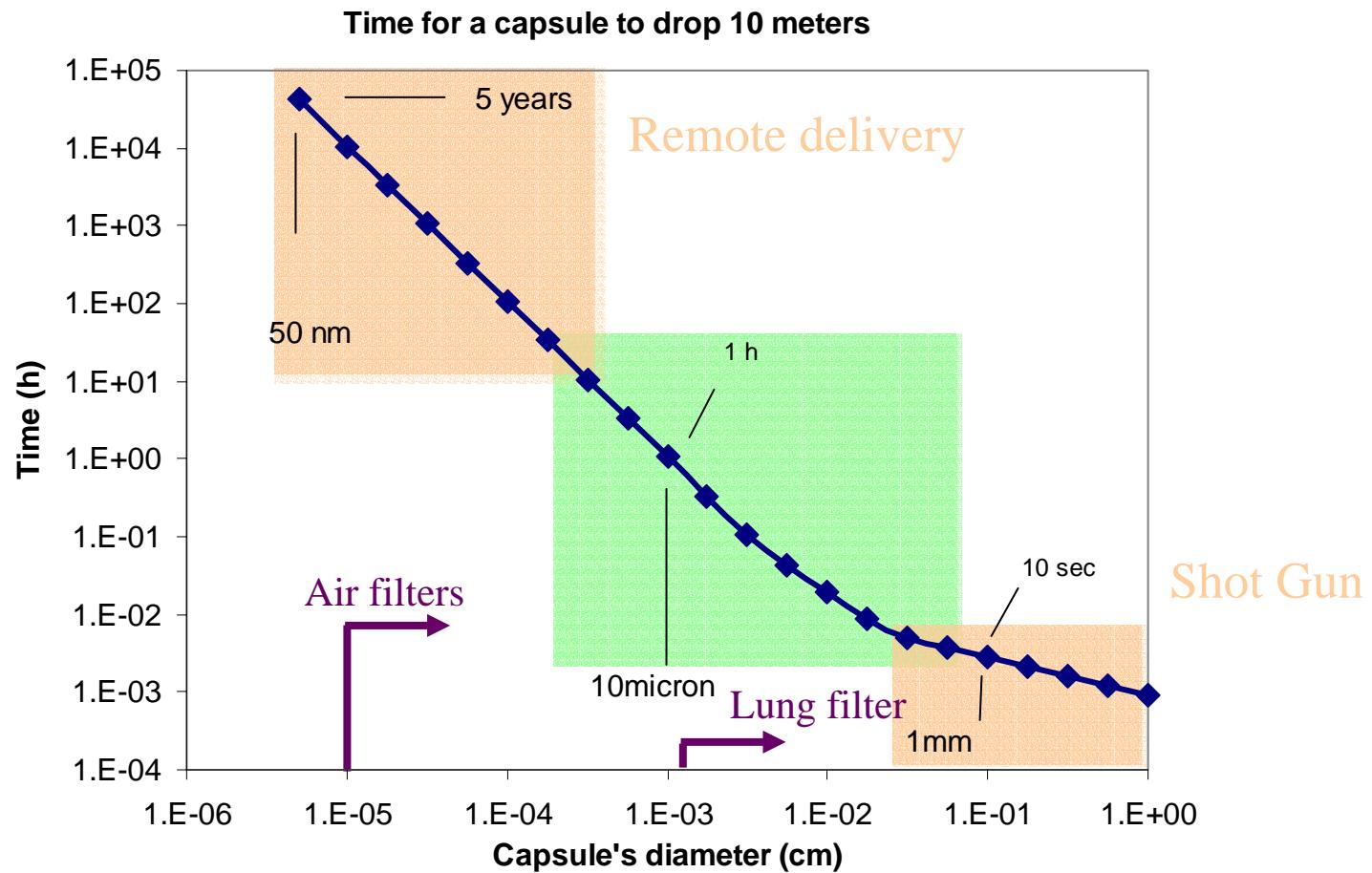


Secondary delivery (release mechanism)

- Mechanical rupture (weight of a human)
- Thermal release (activation temperature)
- Shell dissolution (presence of water)
- Photolytic release (exposition to (Sun)light)
 - Osmotic and pH-dependent release
 - Enzymatic release
 - Electric current



Capsule sedimentation.... Fog or sand ?





Primary Delivery

Shotgun

Hand grenade / grenade launcher
with very small explosive load

Objective Individual Combat Weapon (OICW)

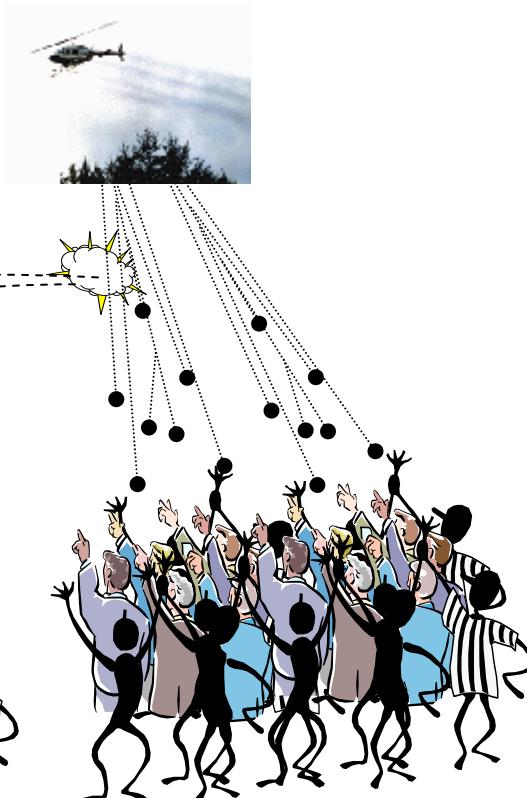
Planned to have a 20mm high-explosive (HE) air-bursting ammunition, with range and fuse delay controls

Mortar / gun with fragmentation shell.

Unmanned Aerial Vehicle (UAV)

Missiles

with modified release - drop and exit strategy





Capsule wall material

- Natural Polymers
 - Proteins (gelatine, albumin, casein...)
 - Carbohydrates (gum arabic, agar, starches, xanthan...)
- Semi-synthetic polymers
 - Cellulose esters and ethers
 - Fatty acid derivatives
 - Fatty alcohol derivatives
- Synthetic polymers
 - Vinyl (co)polymers (polyacrylamide, polymethacrylate...)
 - Polyamides and polyesters
 - Poly condensation type polymers (polyurethanes, epoxy...)
 - Polyolefines (paraffin, hydrocarbon wax...)



Encapsulation methods



Physical methods

- Spray drying
- Rotating disk
- Stationary extrusion nozzle
- Centrifugal extrusion nozzle
- Submerged extrusion nozzle
- Air suspension
- Pan coating

Size, micrometers

- 5-500
- 5-1,500
- 500-4,000
- 250-2,500
- 500-6,000
- > 75
- > 1,000

Chemical methods

- Simple and complex concentration
- Interfacial polymerization
- Phase separation
- Solvent evaporation
- In situ* polymerization
- Super swelling polymerization
- Mini emulsion polymerization

Size, micrometers

- 2-1,200
- 2-2,000
- 0.5-1,000
- 0.5-1,000
- 0.5-1,000
- 0.5-500
- 0.1-0.4



Selection chart - anti material

Target — Ship at sea / cooling system



Active material —

- Poly(N-isopropyl acrylamide) (NIPAM) becomes very water soluble at $T>62^{\circ}\text{C}$
- Bicomponent polyisocyanate / polyol creates a polyurethane foam

Secondary delivery —

Temperature release, low density (0.8g/cm^3),
1 micron diameter, biodegradable (1 month)



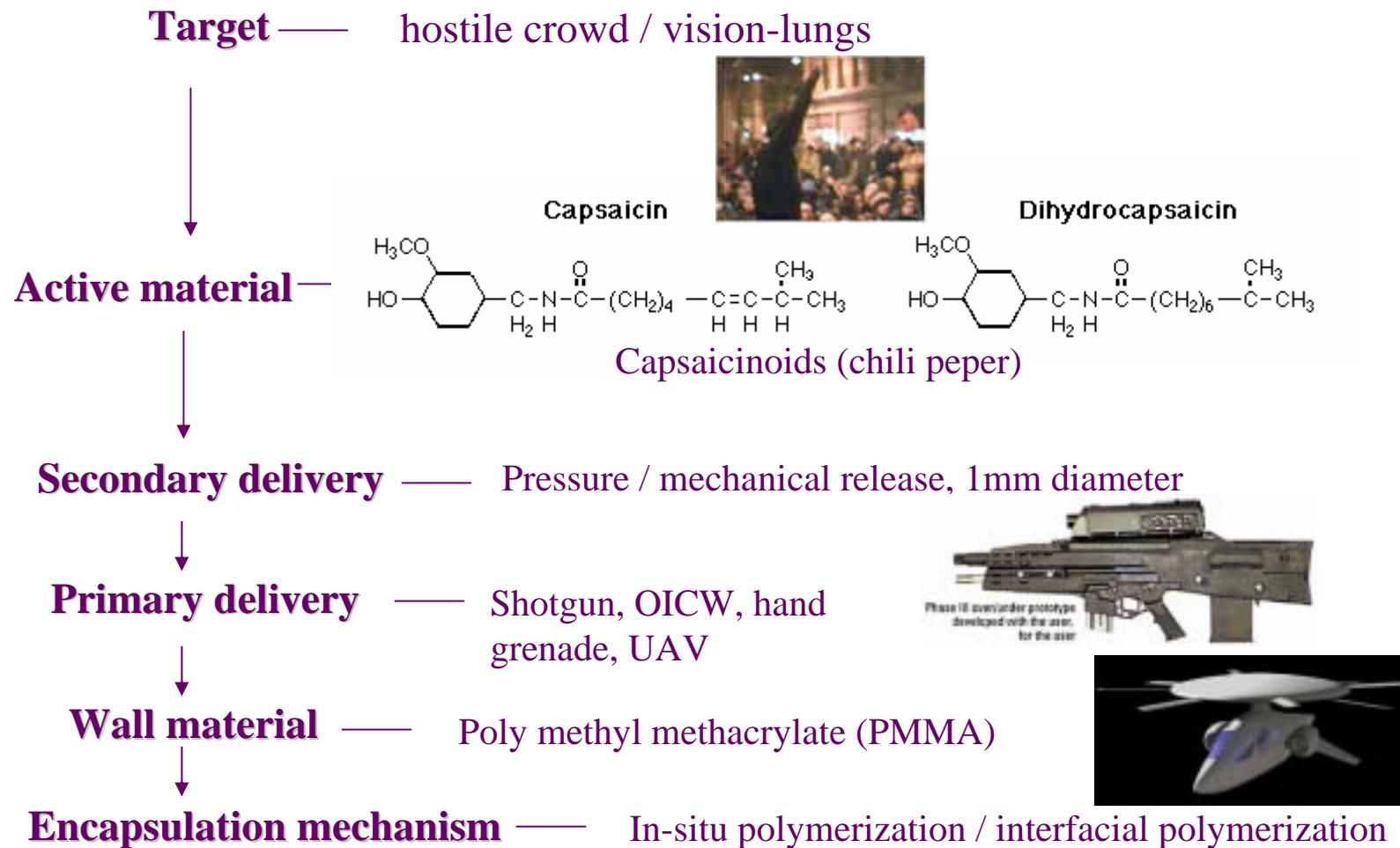
Primary delivery — Air/sea-sea missile, UAV

Wall material — Low molecular weight polyolefine (wax)

Encapsulation mechanism — Meltable dispersion process

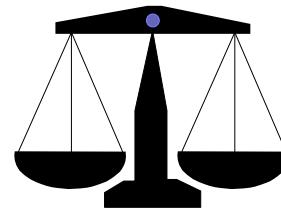


Selection chart - anti personnel





Pros



Cons

- Projectable at long ranges
- High flexibility
- Multi chemical mix
- Prevent redirection
- No restriction of offensive / defensive capabilities
- Use existing delivery vehicles
- Light weight
- Safe to handle
- Biodegradable
- Local area exposure
- Potential for strategic NLW

- Reaction time
- Multiple countermeasures can be developed
- Vulnerable human organs exposure (lungs / eyes)
- Individual exposure control