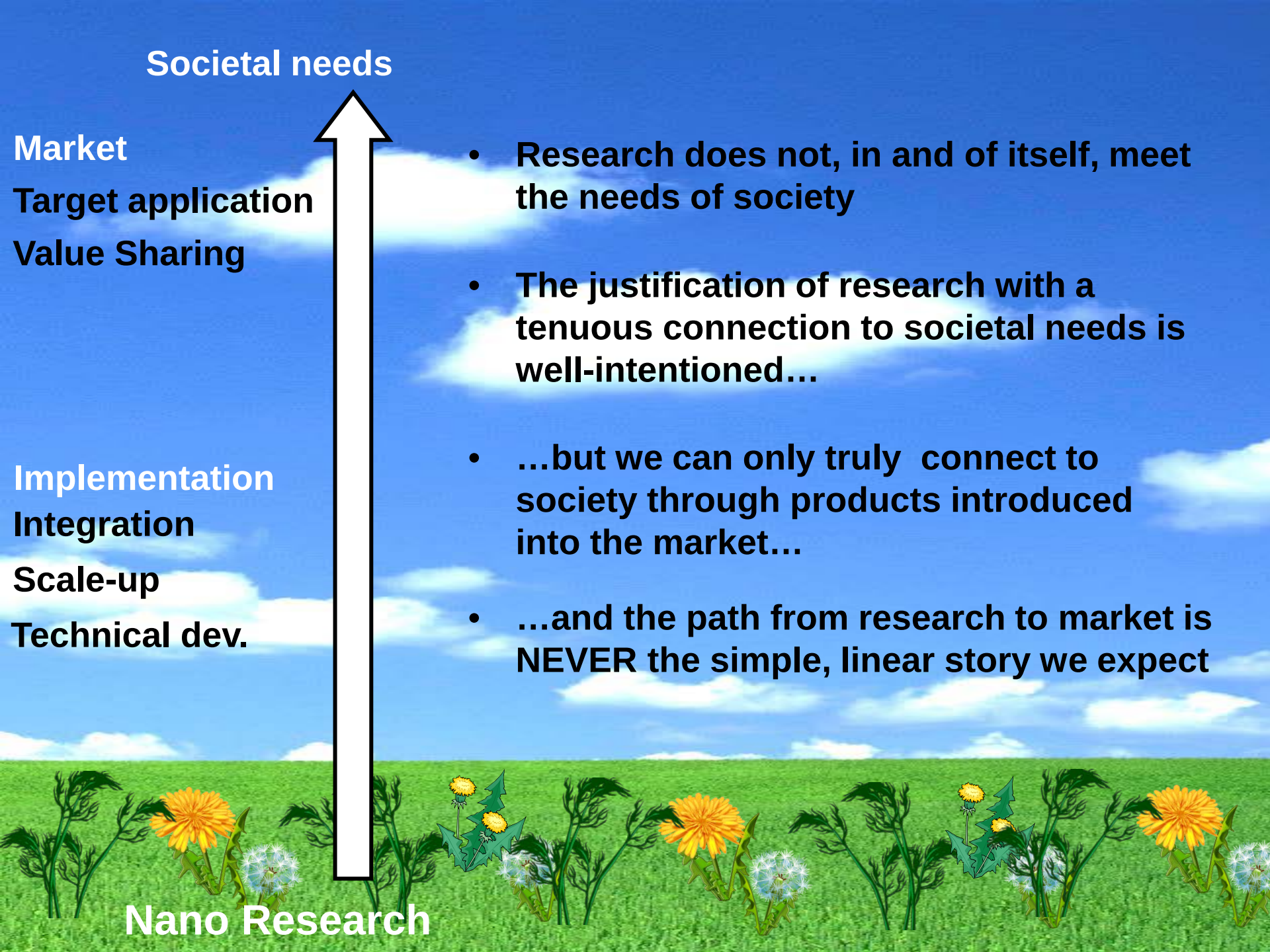
Commercializing Nanotechnology:

MIT Stories Connecting Basic Science to Market Impact

Christopher A. Schuh

Department of Materials Science and Engineering, MIT



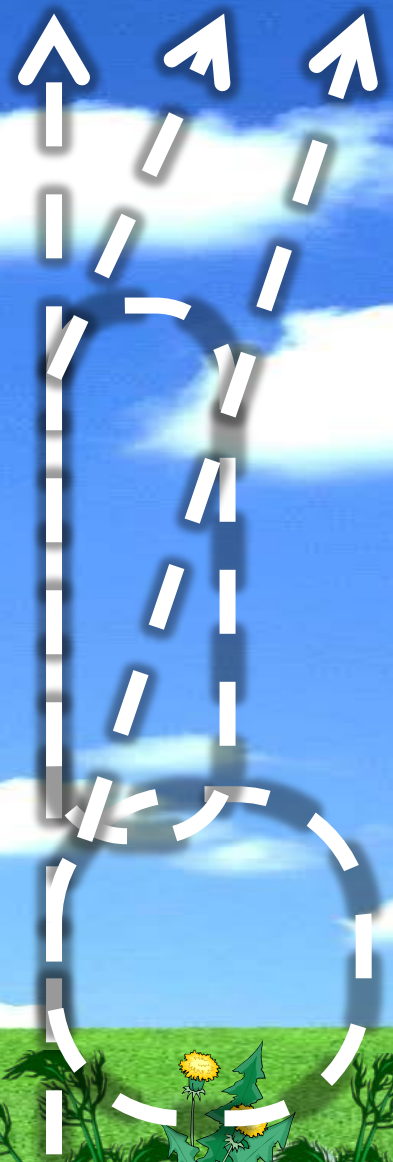
- Research does not, in and of itself, meet the needs of society
- The justification of research with a tenuous connection to societal needs is well-intentioned…
- …but we can only truly connect to society through products introduced into the market…
- …and the path from research to market is NEVER the simple, linear story we expect

Societal needs

Market

Target application

Value Sharing



Implementation

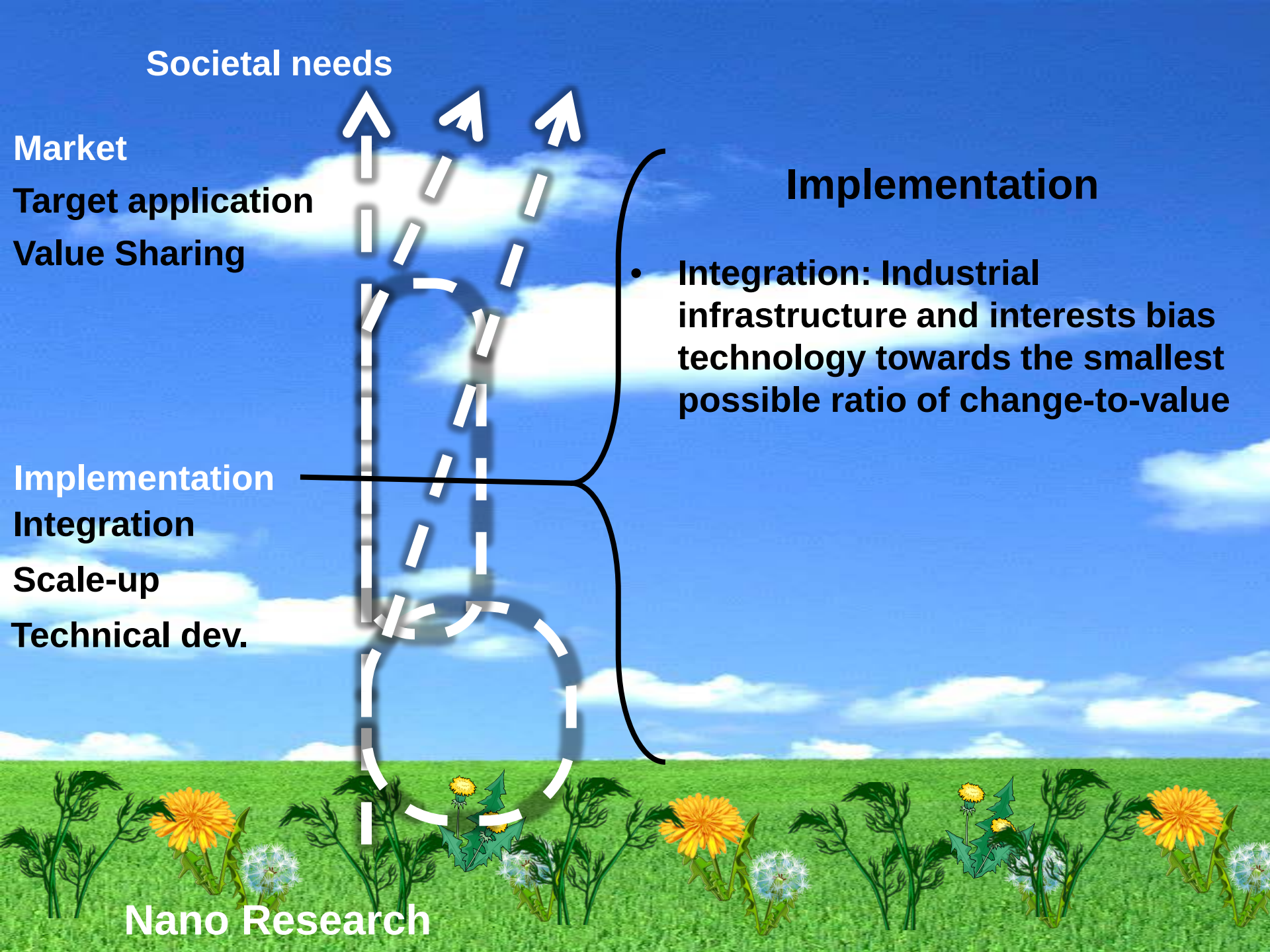
Integration

Scale-up

Technical dev.

- All technologies meet this landscape
- Barriers are opportunities for course correction
- Six nano-commercialization stories from MIT offer insights on such course corrections

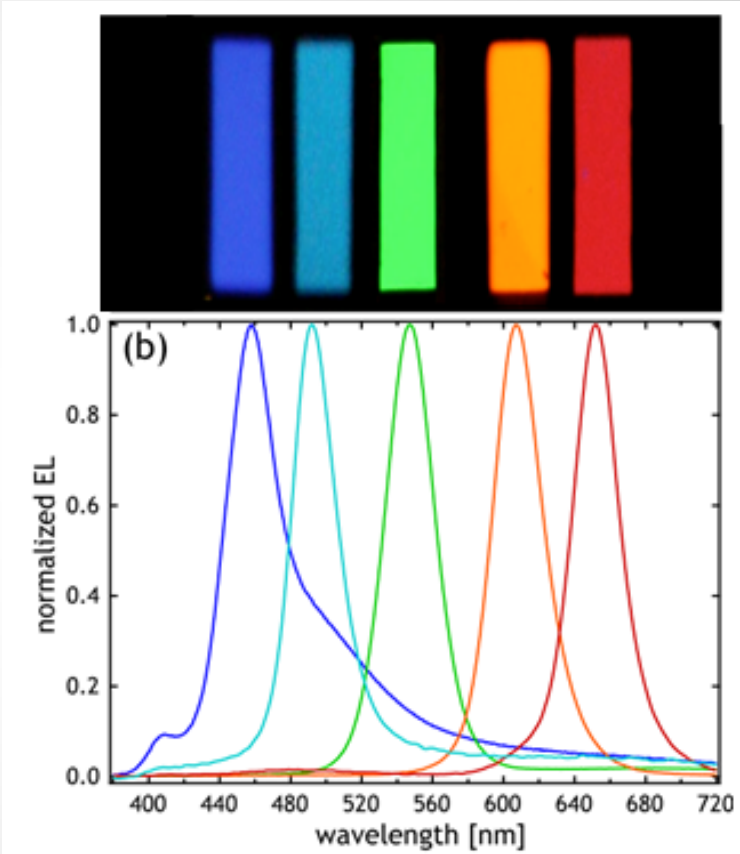
Nano Research



Implementation

- **Integration: Industrial infrastructure and interests bias technology towards the smallest possible ratio of change-to-value**

Example: Nanotech in Lighting/Displays
Quantum Dots and Prof. Vladimir Bulovic

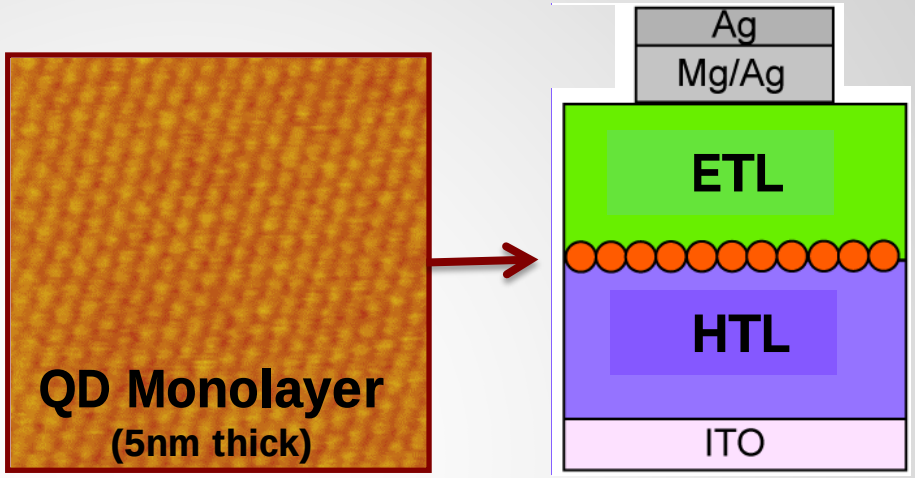


Quantum dots emit specific wavelengths of light, tunable by their size

Opportunity: control and sculpt the spectrum of light emitted from a display

QD VISION

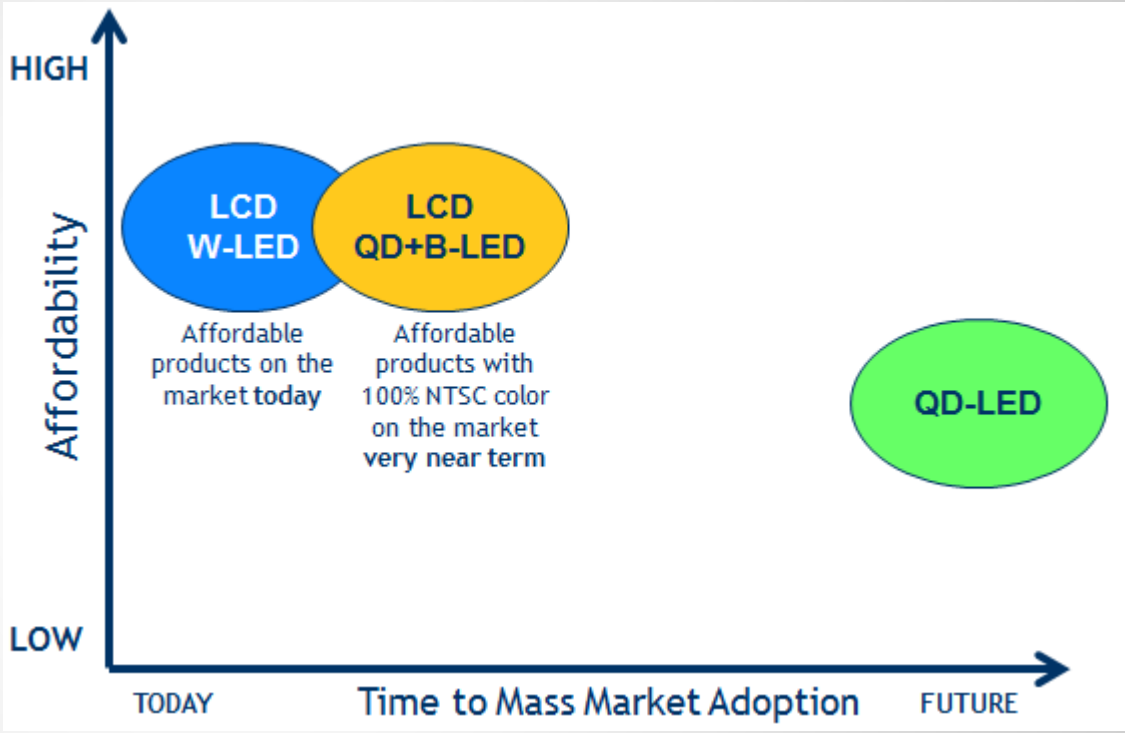
Example: Nanotech in Lighting/Displays
Quantum Dots and Prof. Vladimir Bulovic



Preferred implementation:

QD LED
Electrically activated

Example: Nanotech in Lighting/Displays Quantum Dots and Prof. Vladimir Bulovic



Preferred implementation:

QD LED
Electrically activated

significant change in infrastructure, slow adoption

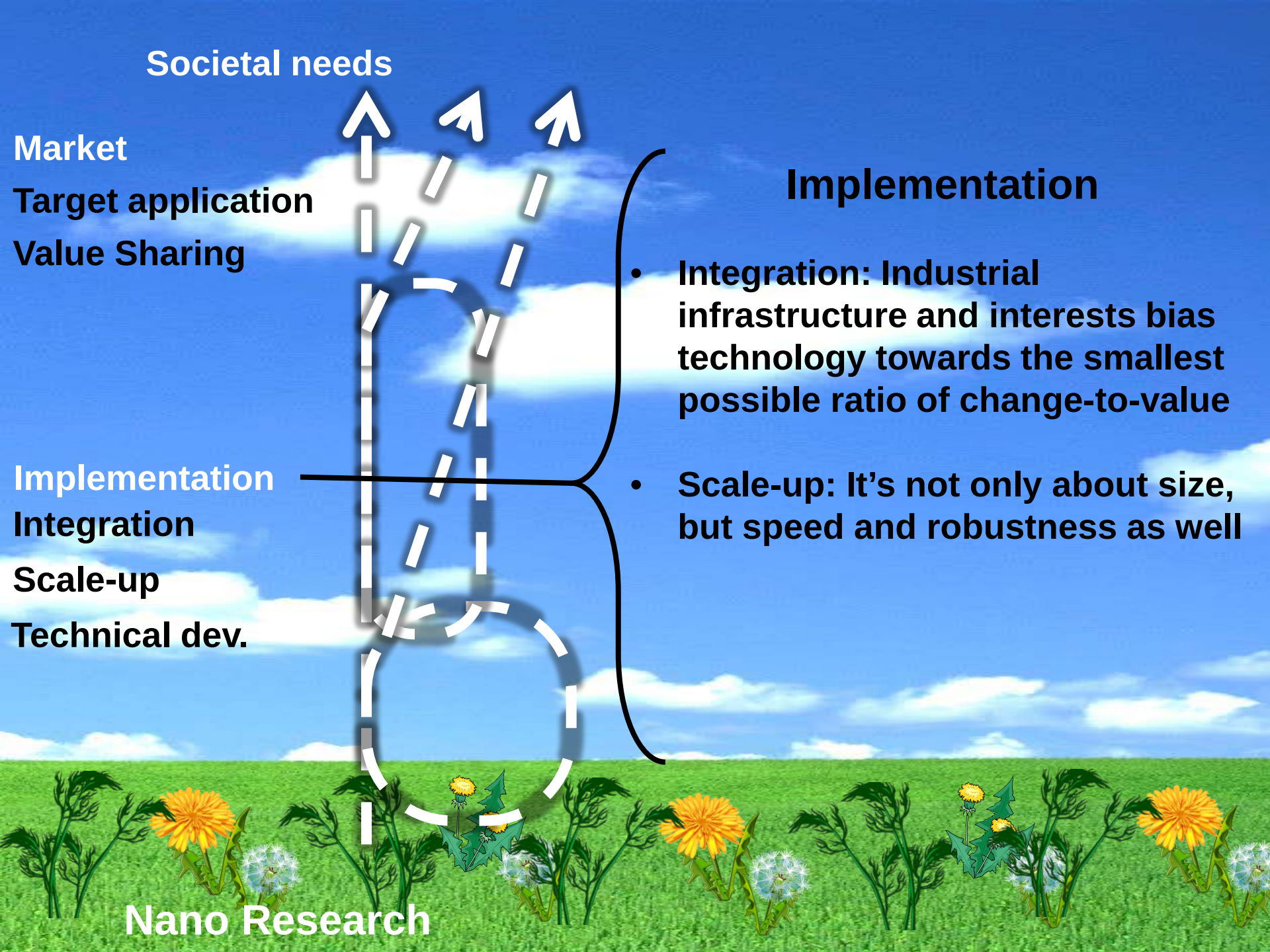
Example: Nanotech in Lighting/Displays
Quantum Dots and Prof. Vladimir Bulovic

in SONY 2013 Bravia TVs

First implementation:

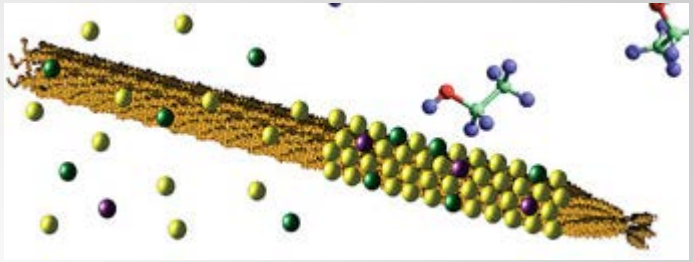
QD + Blue LED
Optically activated

Small change;
rapid adoption

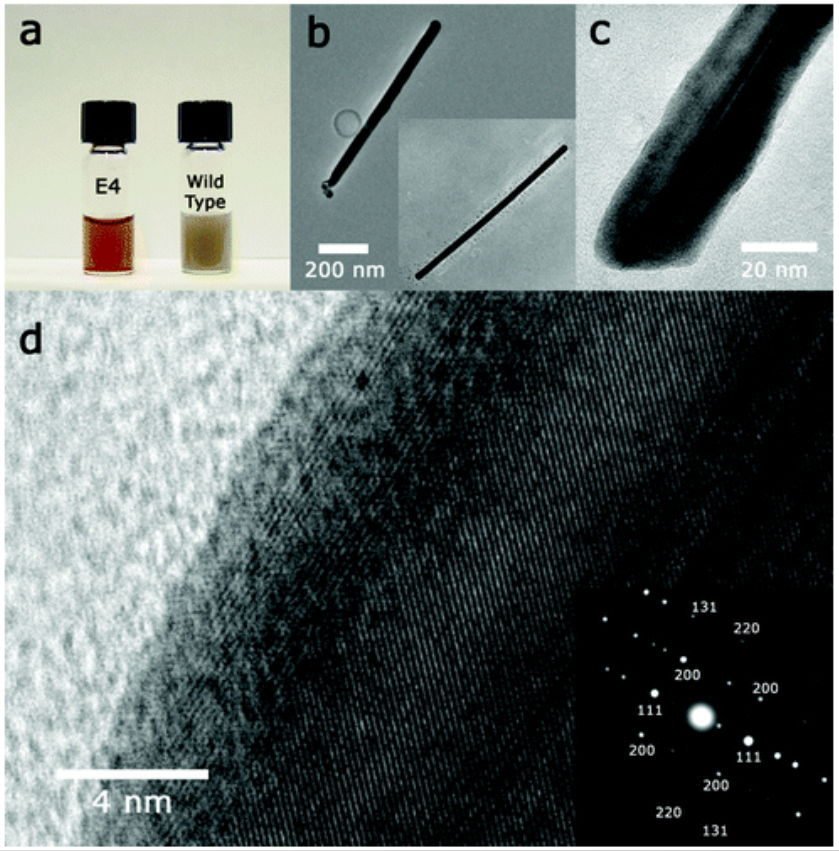

Societal needs
Market
Target application
Value Sharing
Implementation
Integration
Scale-up
Technical dev.
Implementation
• Integration: Industrial infrastructure and interests bias technology towards the smallest possible ratio of change-to-value
• Scale-up: It's not only about size, but speed and robustness as well
Nano Research

Example: Nanotech in Electronics
Ag nanowires and Prof. Angela Belcher

Target application:
Transparent touch sensors
(ITO replacement)



Proposed synthesis:
Bio-templating



CAMBRIOS

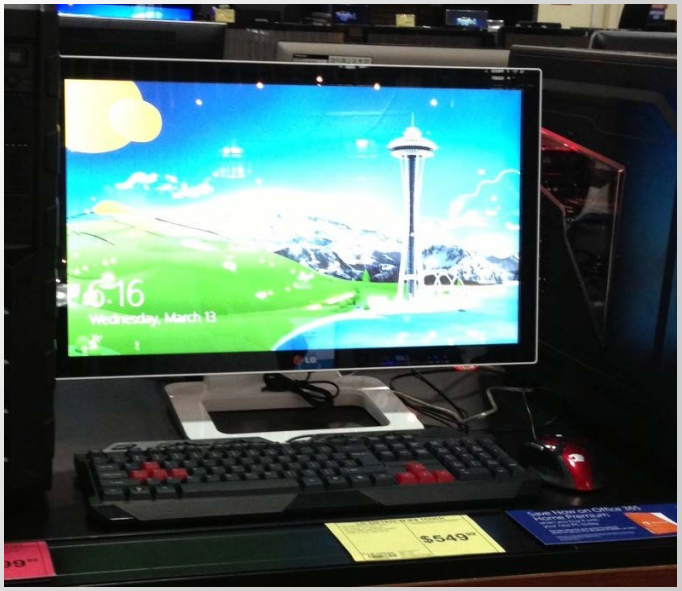
ACS Nano, **2008**, *2* (7), pp 1480–1486

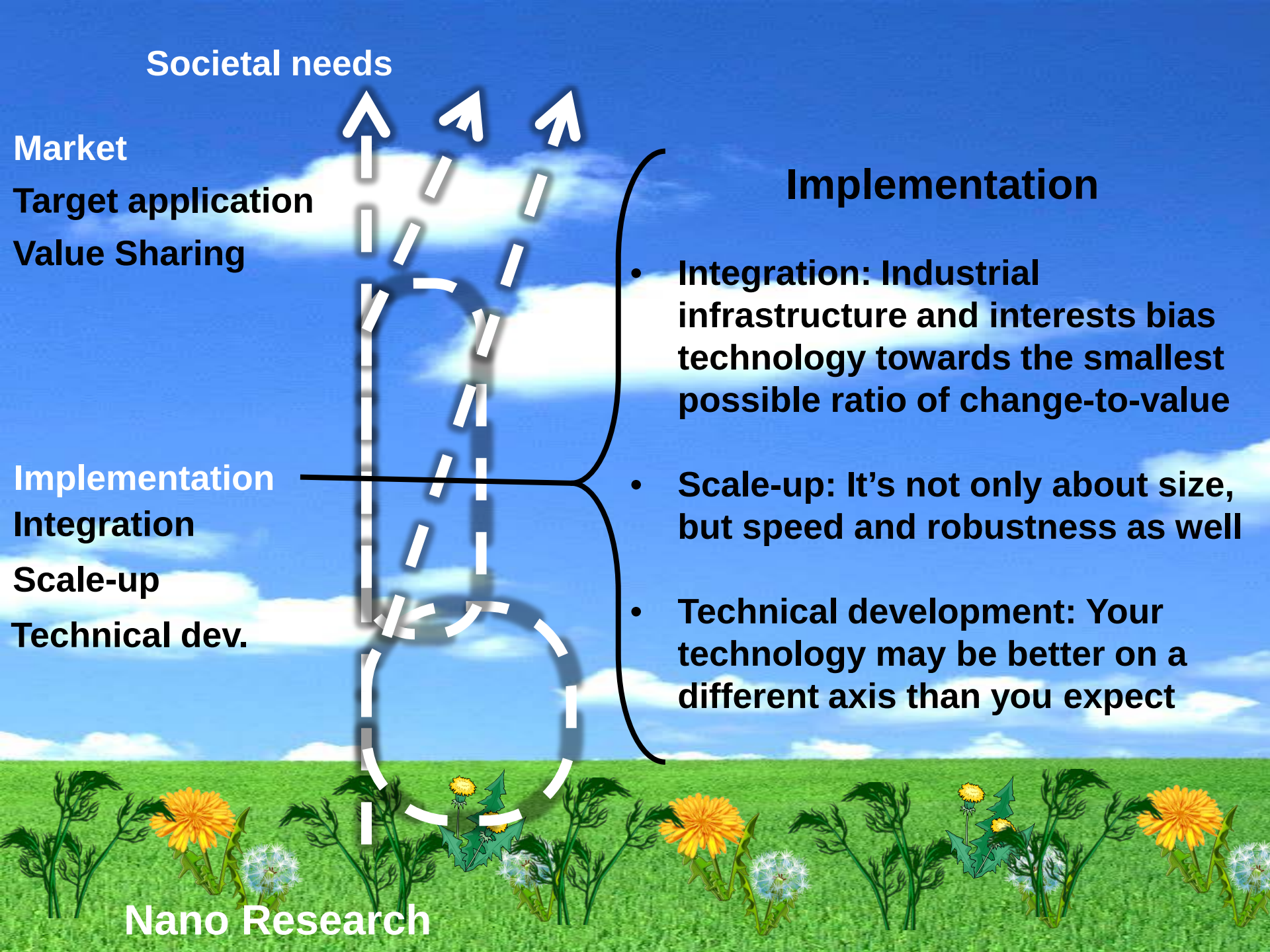
Example: Nanotech in Electronics
Ag nanowires and Prof. Angela Belcher

“The chemistry method just came out faster”
—Mike Knapp, CEO

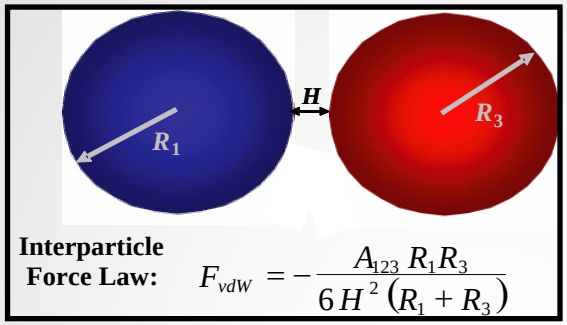
Solution Processed, Roll-to-Roll or printing
Capacity to produce TC for 100 million laptops/yr

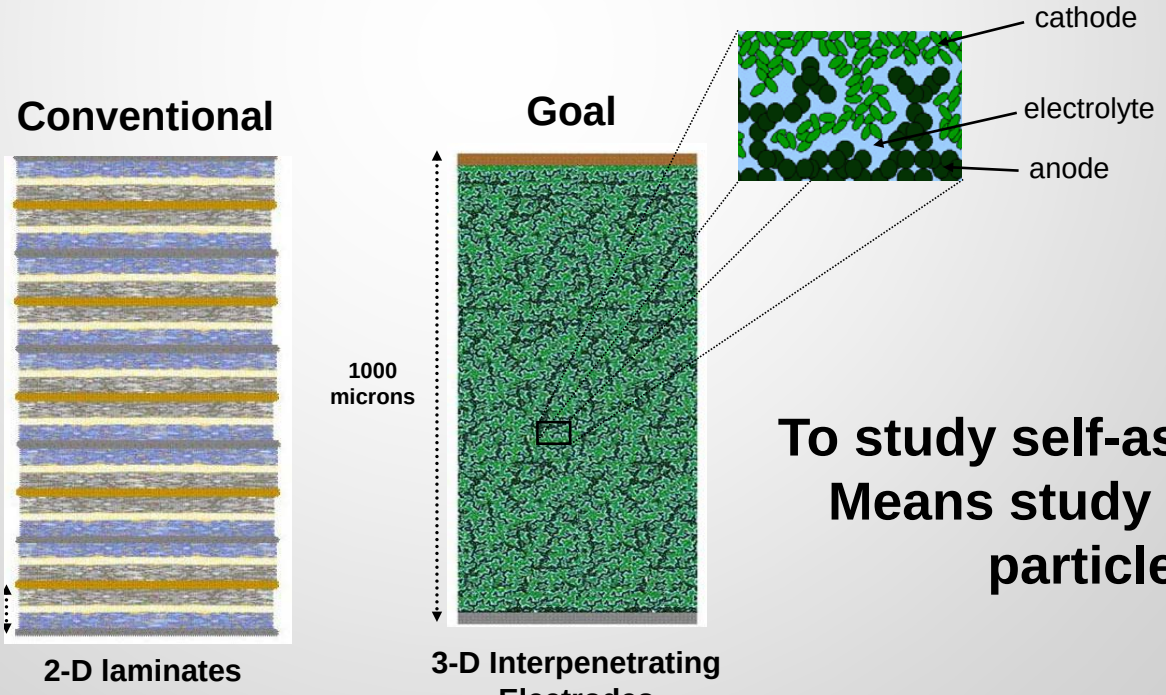
CAMBRIOS




Societal needs
Market
Target application
Value Sharing
Implementation
Integration
Scale-up
Technical dev.
Implementation
• Integration: Industrial infrastructure and interests bias technology towards the smallest possible ratio of change-to-value
• Scale-up: It's not only about size, but speed and robustness as well
• Technical development: Your technology may be better on a different axis than you expect
Nano Research

Example: Nanotech in Energy
Nano-spinels and Prof. Yet-Ming Chiang

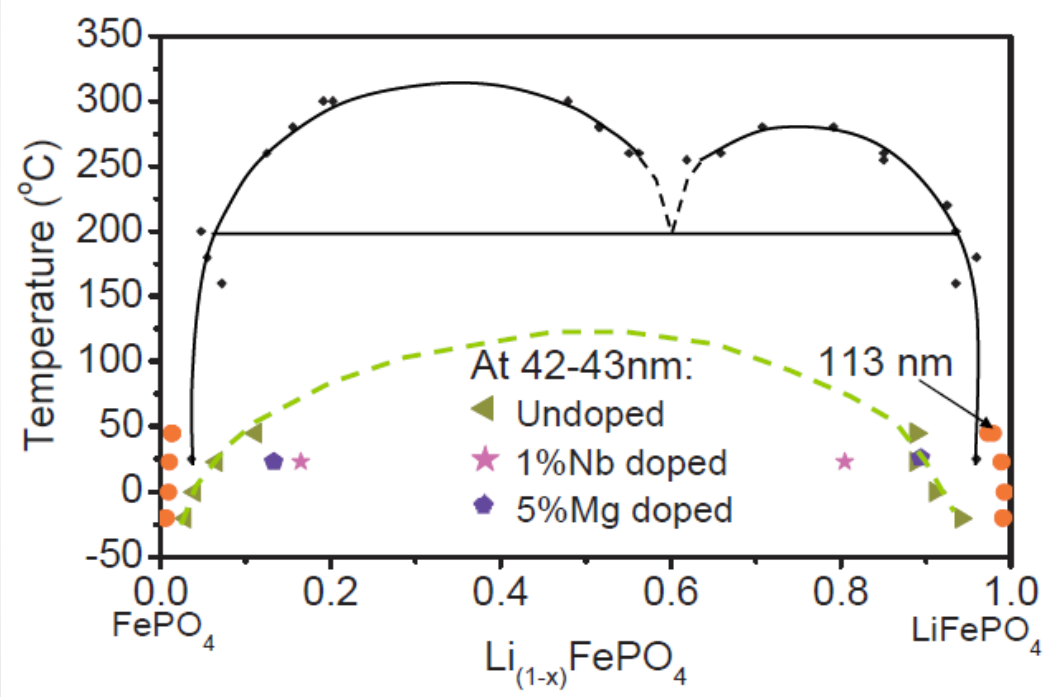




To study self-assembly…
Means study of small particles

Example: Nanotech in Energy
Nano-spinels and Prof. Yet-Ming Chiang

Unexpected nanoscale effects: thermodynamic, mechanical, and kinetic



These amount to a key advantage in energy delivery rate

Change in: implementation mode, target markets

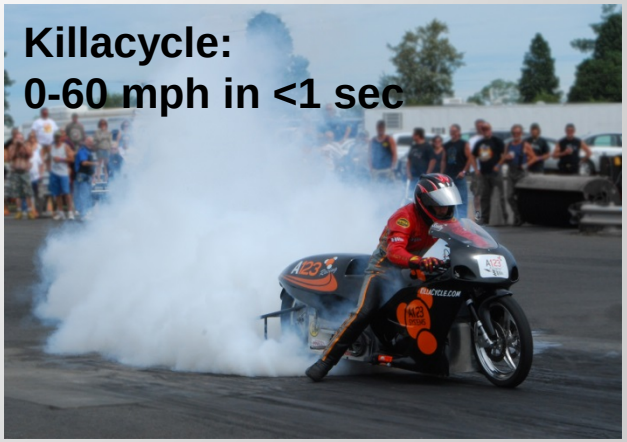
Example: Nanotech in Energy
Nano-spinels and Prof. Yet-Ming Chiang

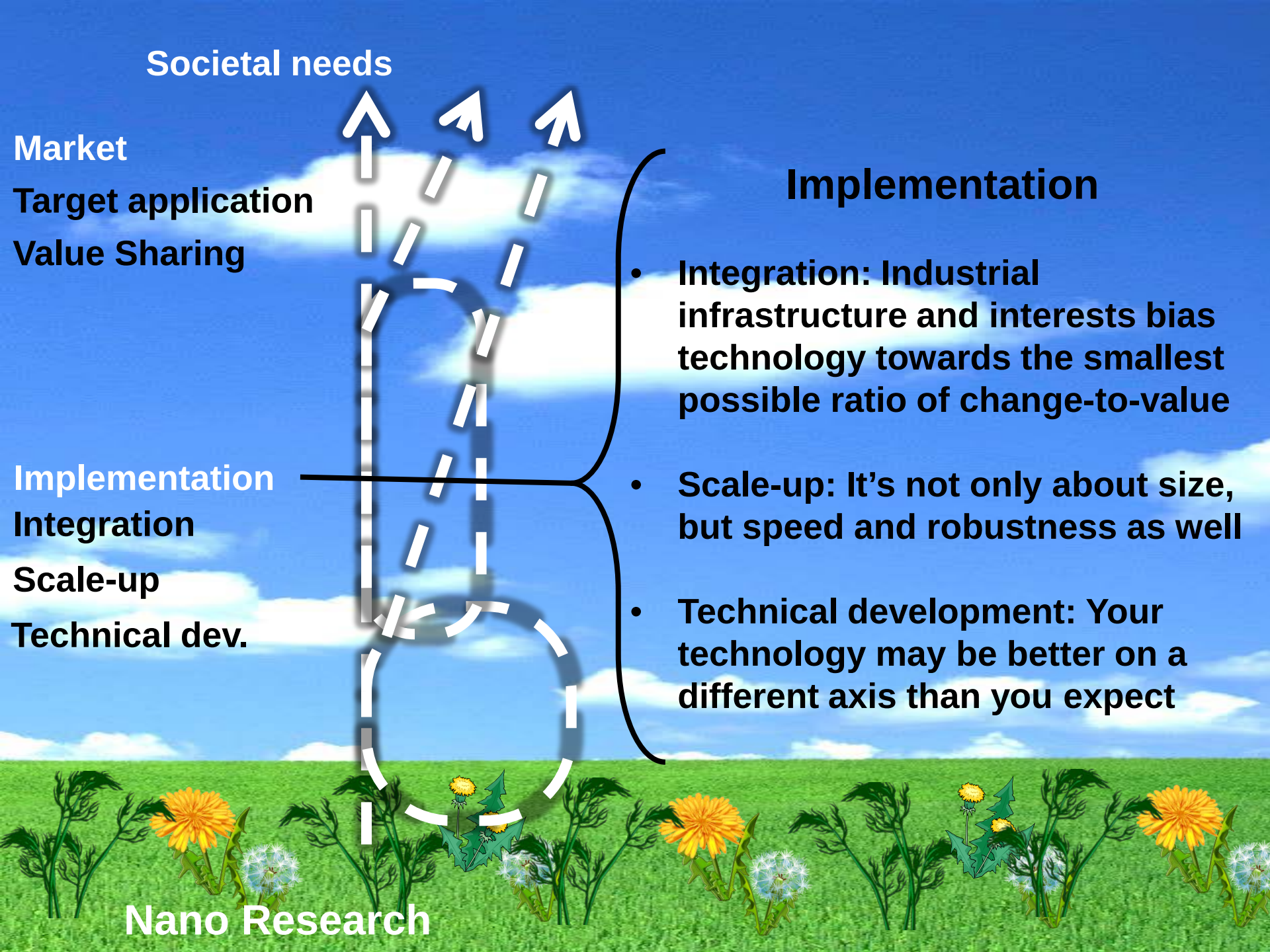
From 600-700W in 1.1kg
(18V NiCd battery pack)

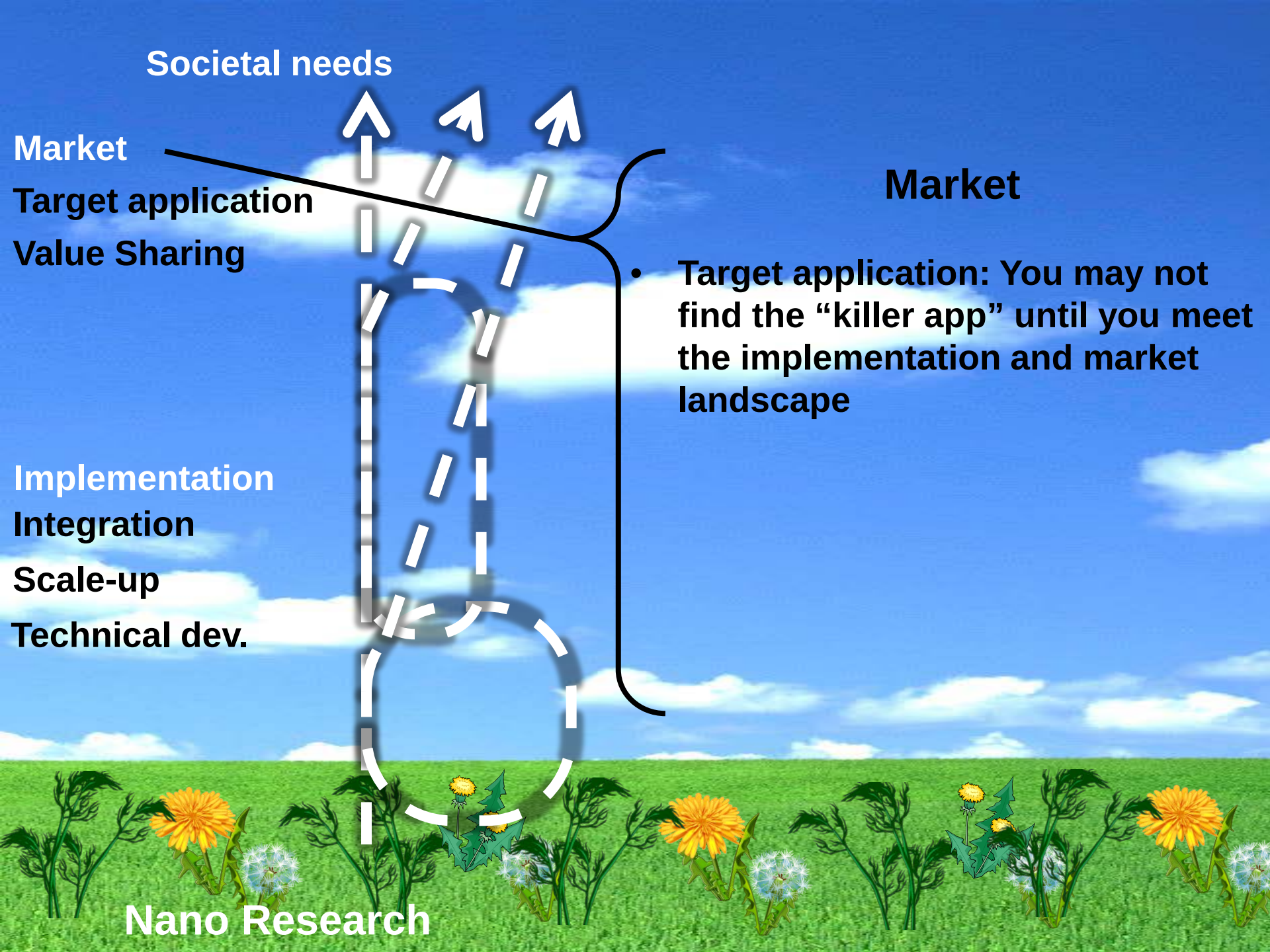
to 3000W in 1.1 kg
(36V Li-ion battery pack)

→ 2x the peak power of corded power tools

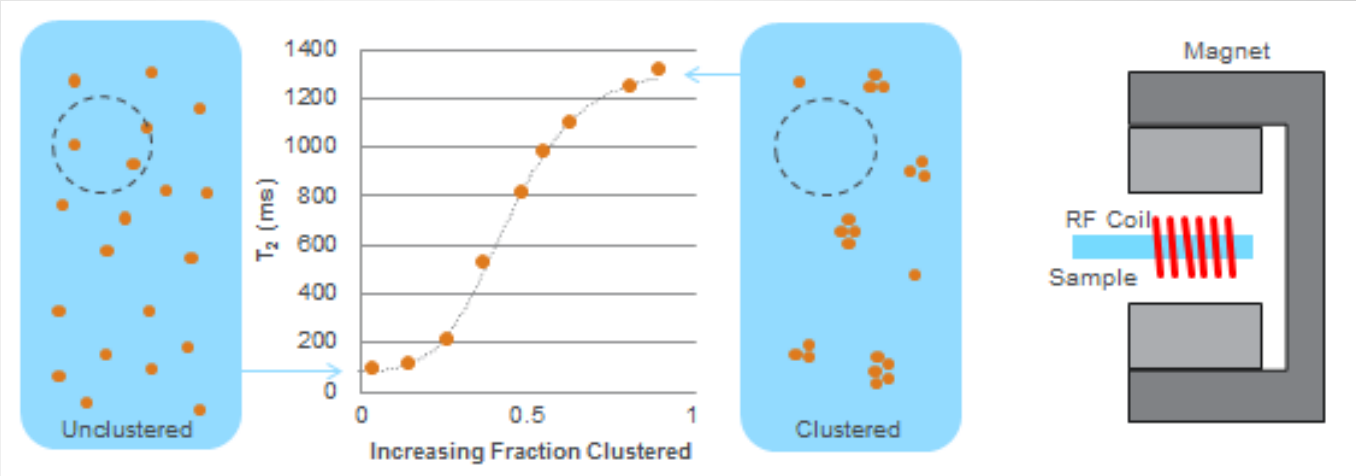
3000 lb weight savings on >3000 buses;
> 400 million cumulative miles




Societal needs
Market
Target application
Value Sharing
Implementation
Integration
Scale-up
Technical dev.
Implementation
• Integration: Industrial infrastructure and interests bias technology towards the smallest possible ratio of change-to-value
• Scale-up: It's not only about size, but speed and robustness as well
• Technical development: Your technology may be better on a different axis than you expect
Nano Research


Societal needs
Market
Target application
Value Sharing
Market
Target application: You may not find the “killer app” until you meet the implementation and market landscape
Implementation
Integration
Scale-up
Technical dev.
Nano Research

Example: Nanotech in Medicine
Nanoparticles and Prof. Michael Cima



Magnetic resonance is a sensitive probe of magnetite nanoparticle clustering

Functionalizing the nanoparticles triggers clustering in the presence of target chemicals

Therapeutic Drugs, Metabolites, Chemistries

T2 Biosystems

Initial application: Antirejection drug monitoring in transplant patients

Example: Nanotech in Medicine Nanoparticles and Prof. Michael Cima

New opportunity upon interaction with the market: systemic fungal infections

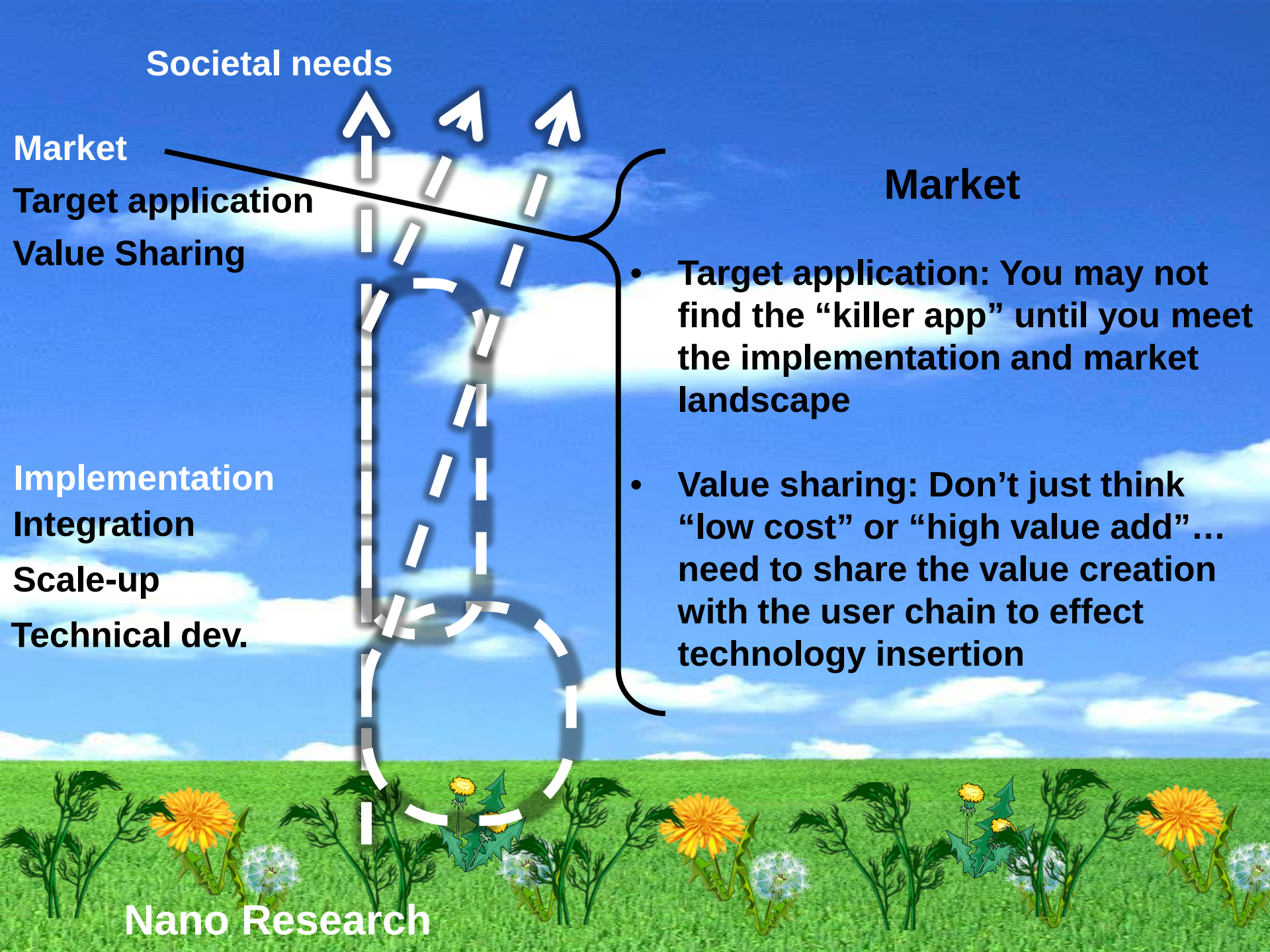
- **4th leading cause of hospital acquired infections.**
- **Standard diagnosis (blood culture) takes four days.**
- **Mortality is 20% at two days.**

Magnetic resonance is a sensitive probe of magnetite nanoparticle clustering

Functionalizing the nanoparticles triggers clustering in the presence of target chemicals

Microbial Pathogen in Blood Specimen	**# of samples/ # correct**	# of incorrect results
C. albicans	2/2	0
non-*albicans**	6/6	0
Gram-negative bacteria**	4/4	0
Gram-positive bacteria**	7/7	0
Negative control	8/8	0

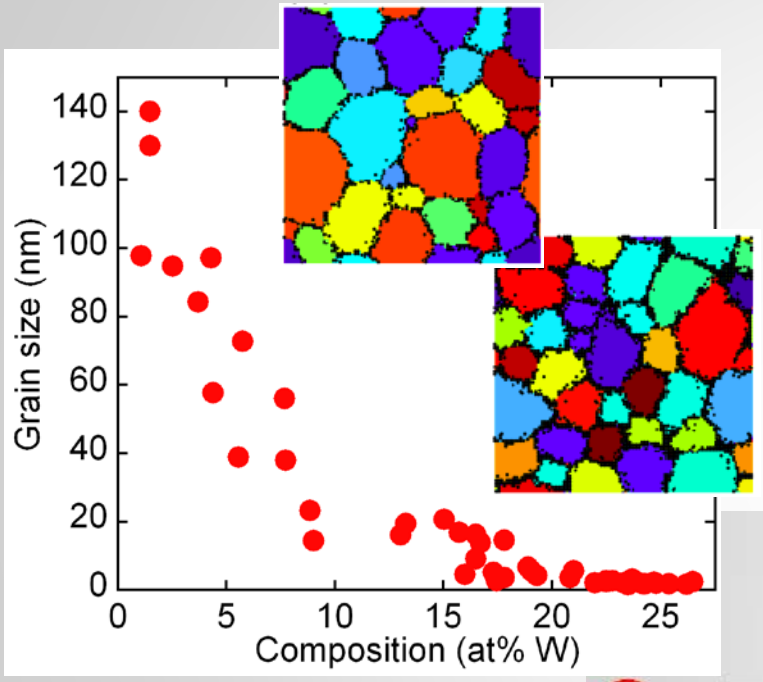
*2 samples *C. parapsilosis*, and 4 *C. krusei*
**8 total samples with bacteremia were analyzed, and 3 contained more than one bacterial species.



Market

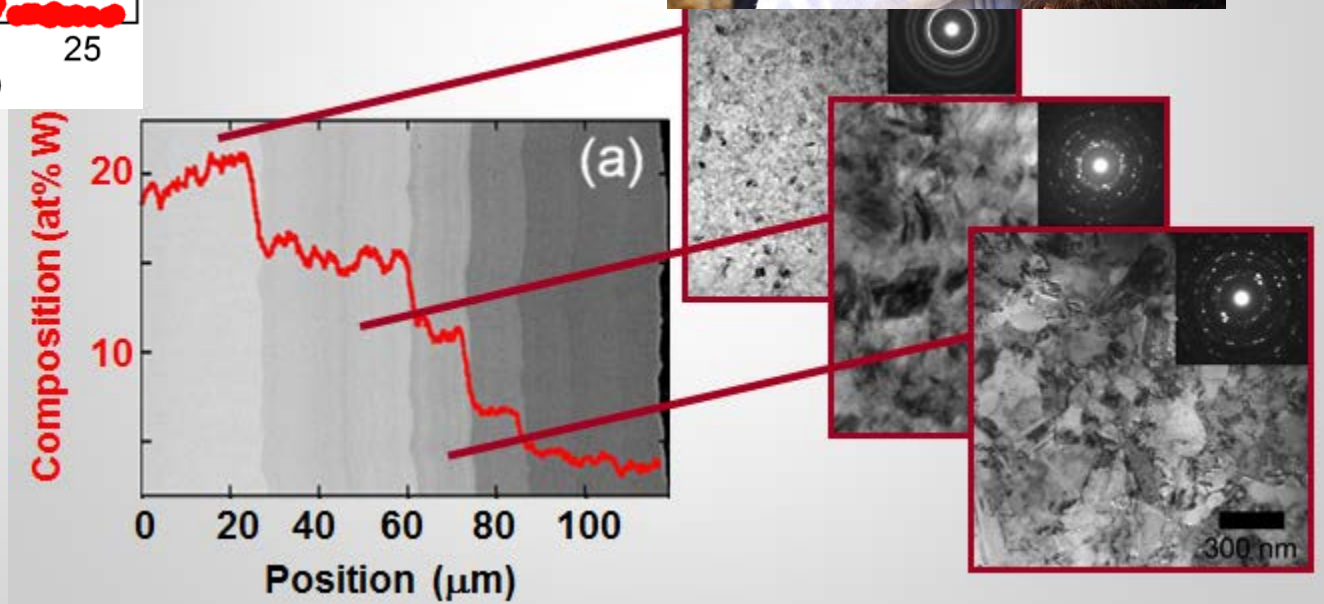
- Target application: You may not find the “killer app” until you meet the implementation and market landscape
- Value sharing: Don’t just think “low cost” or “high value add”… need to share the value creation with the user chain to effect technology insertion

Example: Nanotech in Materials
Nanocrystalline Coatings and Prof. Schuh



Scientific premise:
Alloying as a thermodynamic control on grain size in the nanoscale

Implemented as an electrodeposition Technology



Example: Nanotech in Materials
Nanocrystalline Coatings and Prof. Schuh

Before: 19 miles
After: >200 miles

Early technical wins:

- High wear components
- Corrosion and impact resistance
- "Green" substitutions

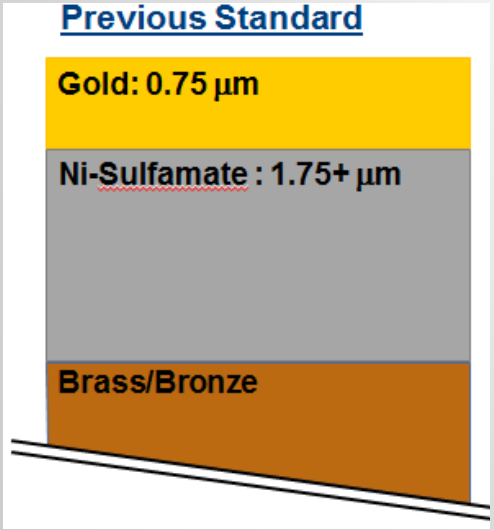
XTALIC

Business challenges:

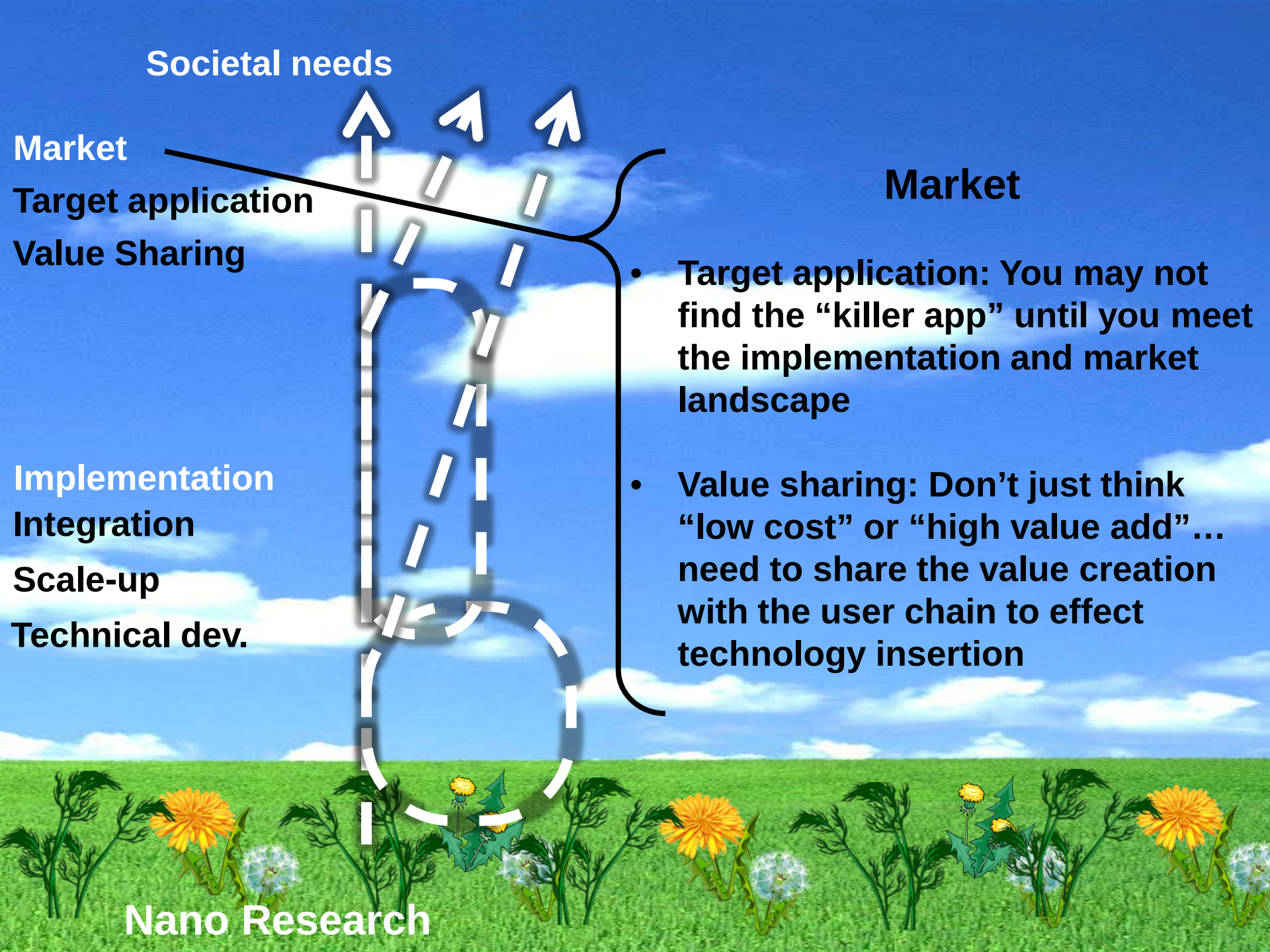
- Commodity spaces, premium products
  - Value sharing requires cost sharing
- "Green" value in $ is unclear
- Net result: slow moving

Example: Nanotech in Materials
Nanocrystalline Coatings and Prof. Schuh

>2.5B parts in service

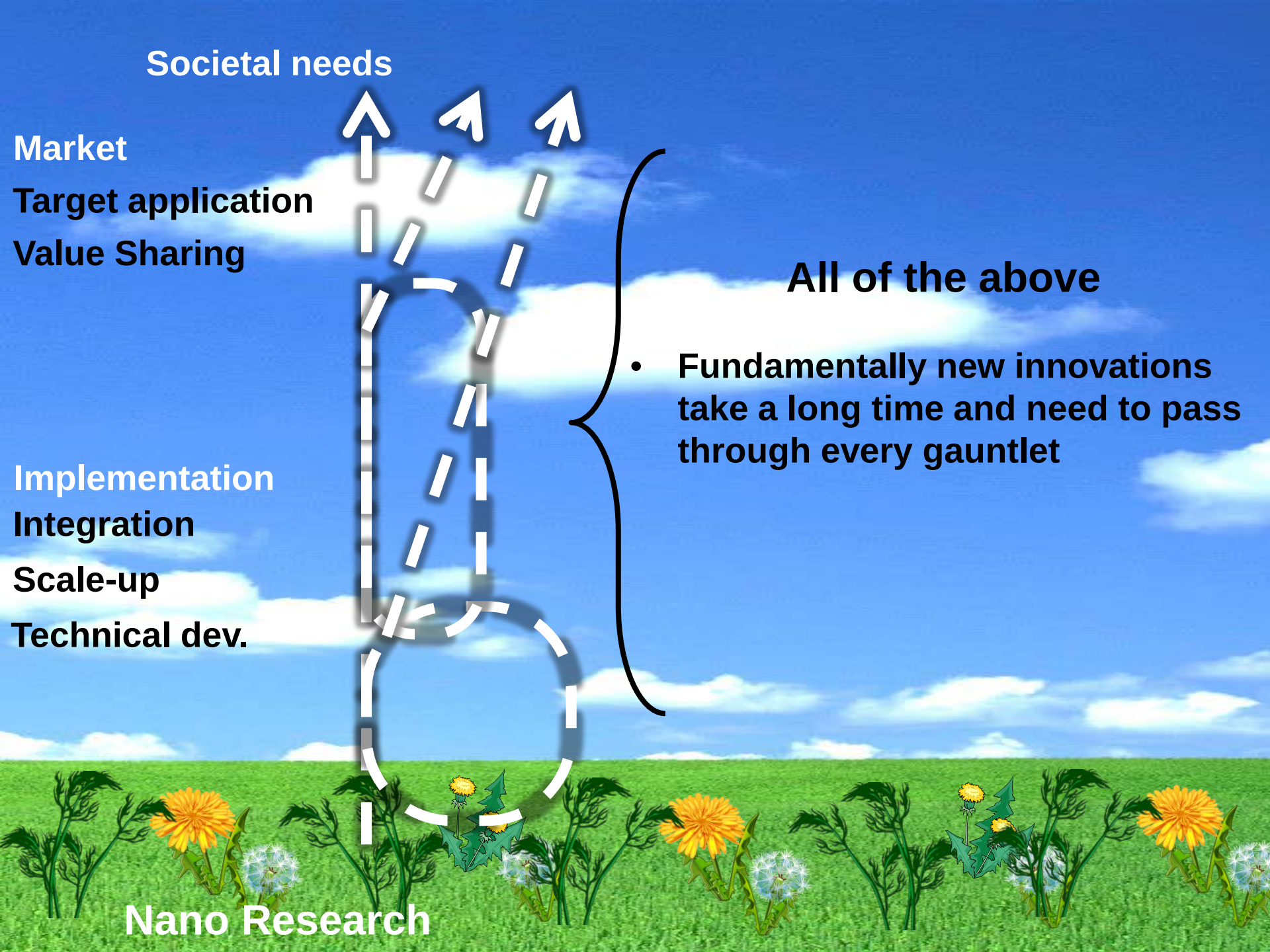


value sharing =
savings sharing

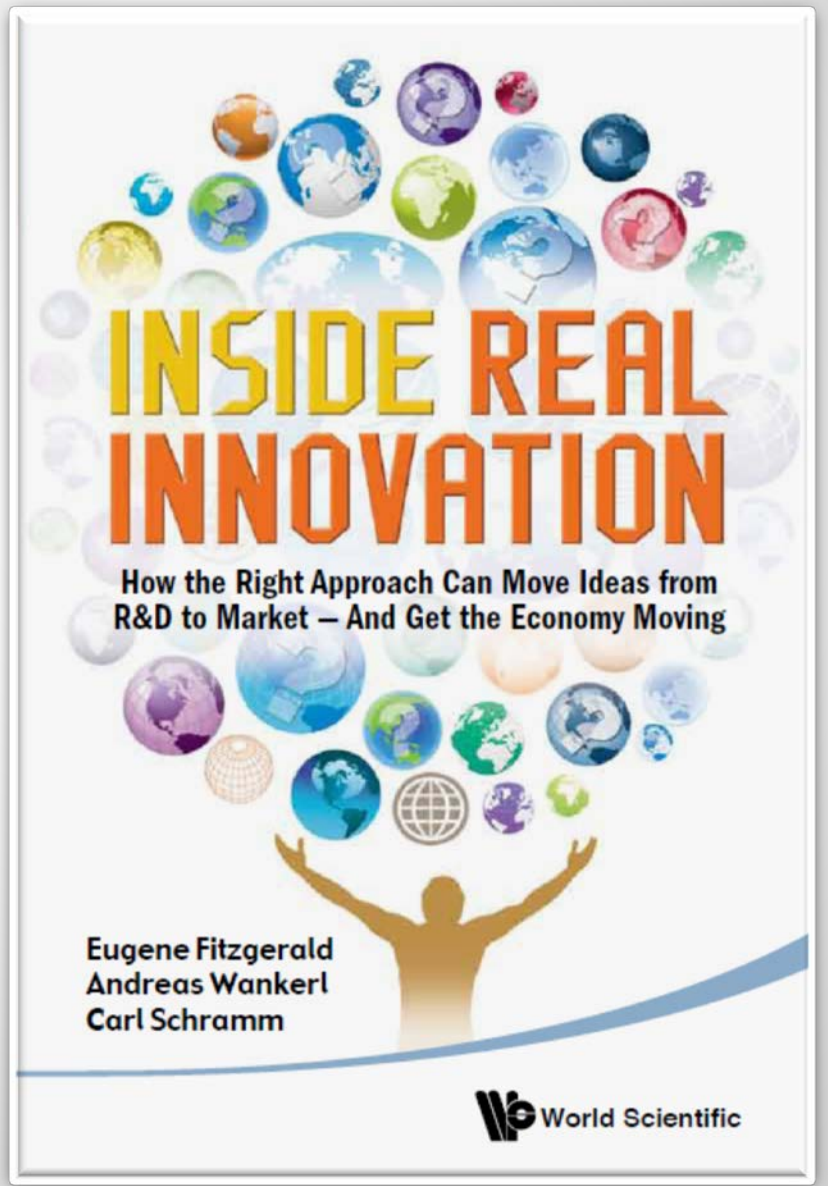


Market

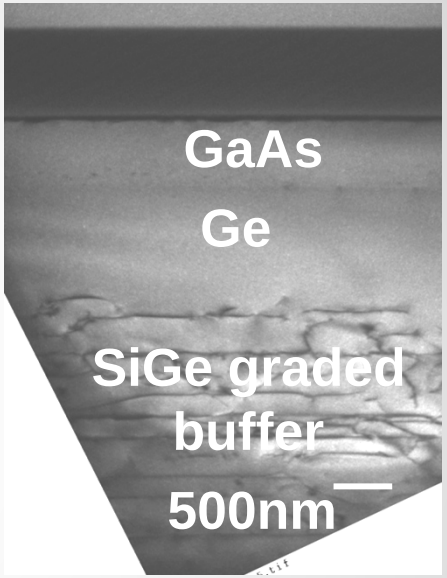
- Target application: You may not find the “killer app” until you meet the implementation and market landscape
- Value sharing: Don’t just think “low cost” or “high value add”… need to share the value creation with the user chain to effect technology insertion


Societal needs
Market
Target application
Value Sharing
Implementation
Integration
Scale-up
Technical dev.
All of the above
• Fundamentally new innovations take a long time and need to pass through every gauntlet
Nano Research

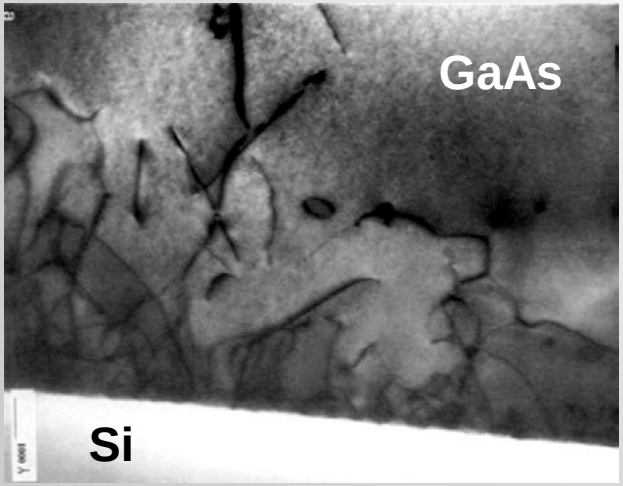
Example: Nanotech in Computing
Strained silicon and Prof. Gene Fitzgerald



Example: Nanotech in Computing
Strained silicon and Prof. Gene Fitzgerald



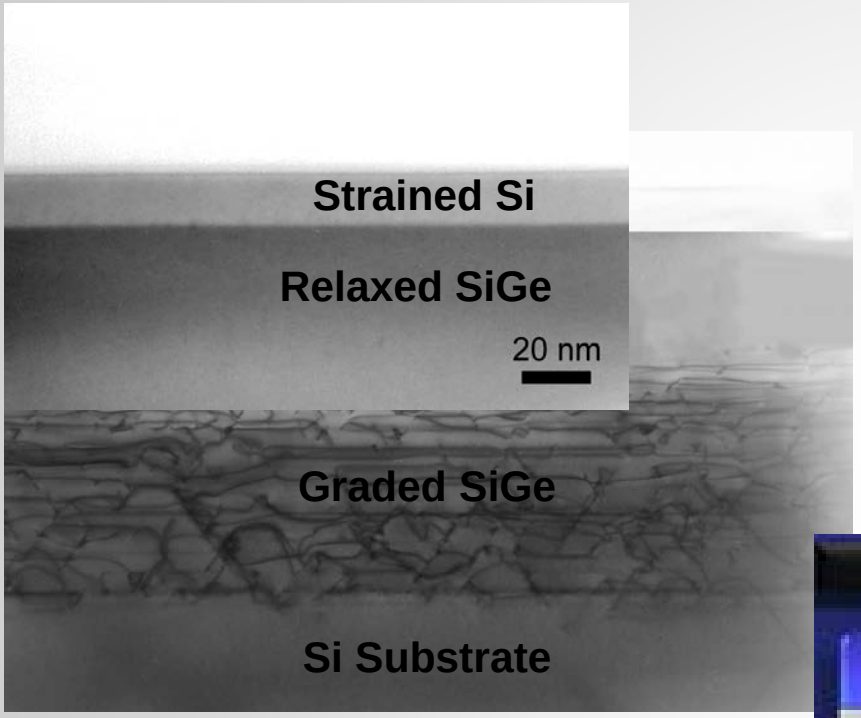
Relaxed Mismatch Epitaxy:
Prototypical Problem: GaAs on Si



Target applications:
III-V integration
Optoelectronics
Digital wireless
Etc.

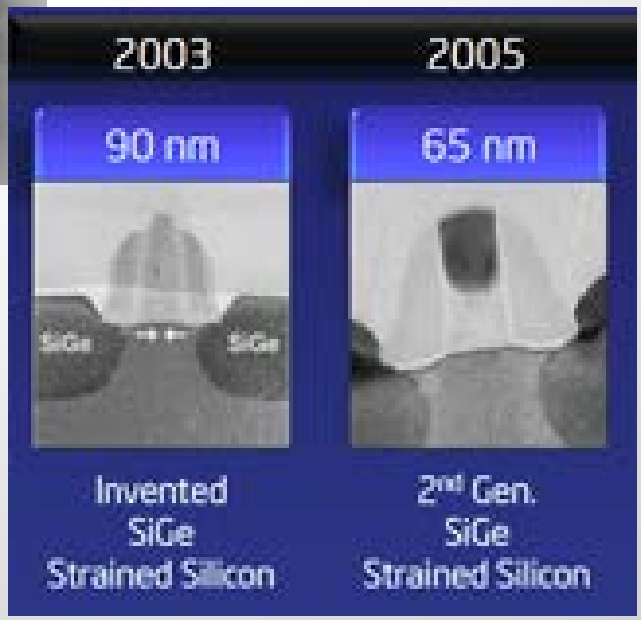
Tech pathway:
Bell labs
MIT
AmberWave

Example: Nanotech in Computing
Strained silicon and Prof. Gene Fitzgerald



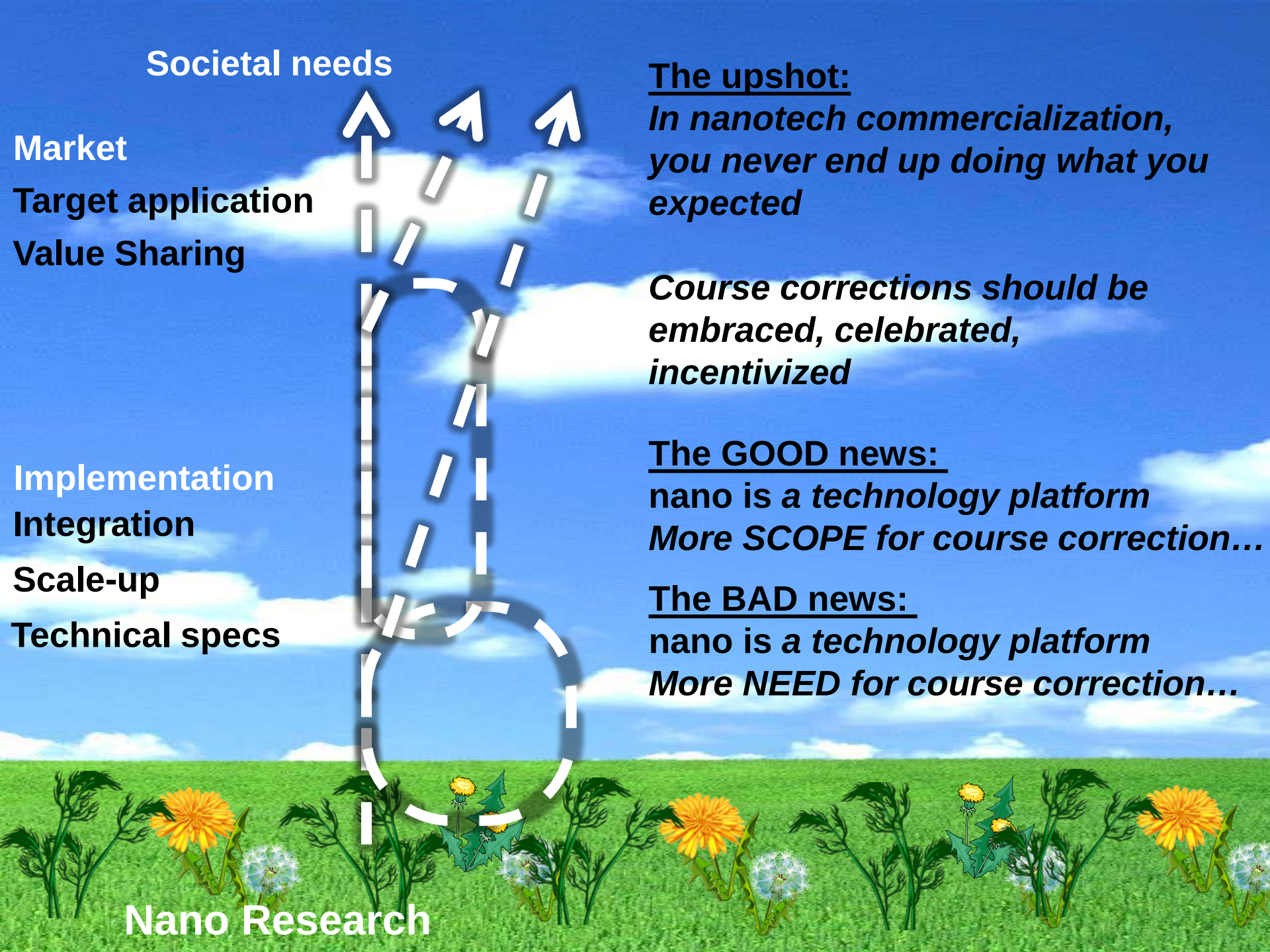
Opportunity:
Strained silicon has much higher electron mobility…

A chance to reduce gate length and preserve Moore's Law
Ca. 2000



Implementation evolution:
Biaxial
Local strain
Overcoating

Tech pathway:
Bell labs
MIT
AmberWave
Intel



The upshot:
In nanotech commercialization, you never end up doing what you expected

Course corrections should be embraced, celebrated, incentivized

The GOOD news:
nano is *a technology platform*
More SCOPE for course correction…

The BAD news:
nano is *a technology platform*
More NEED for course correction…