# *Where are the Breakthrough Technologies – How We Go From Test Bench to Utility-Scale Implementation?*

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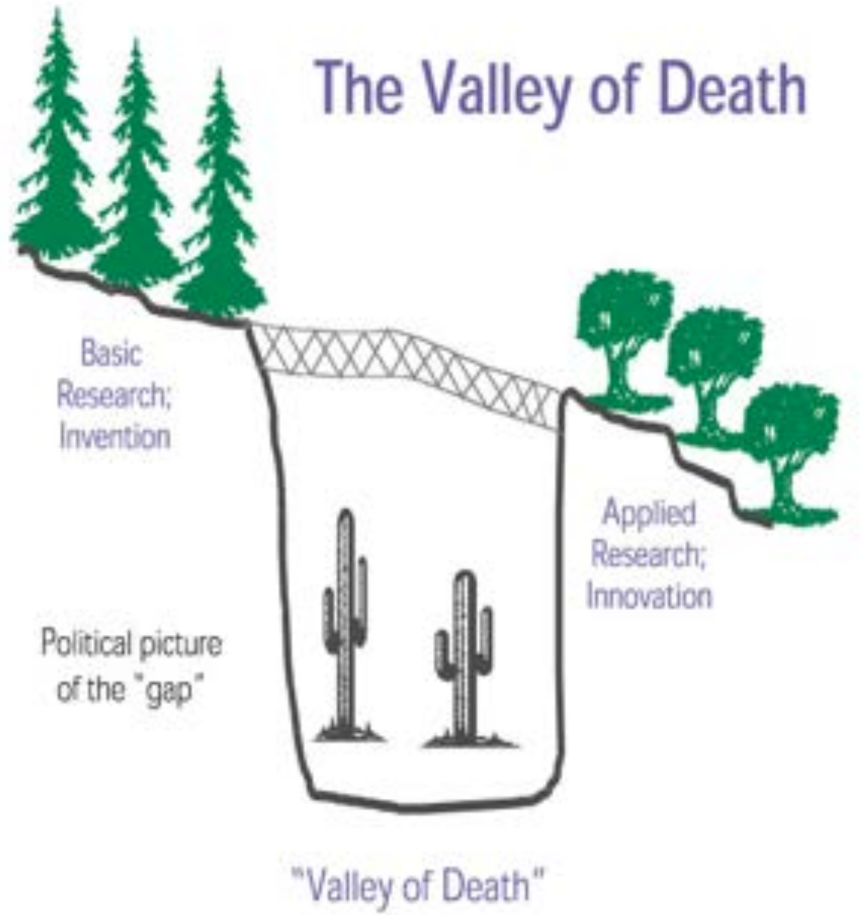
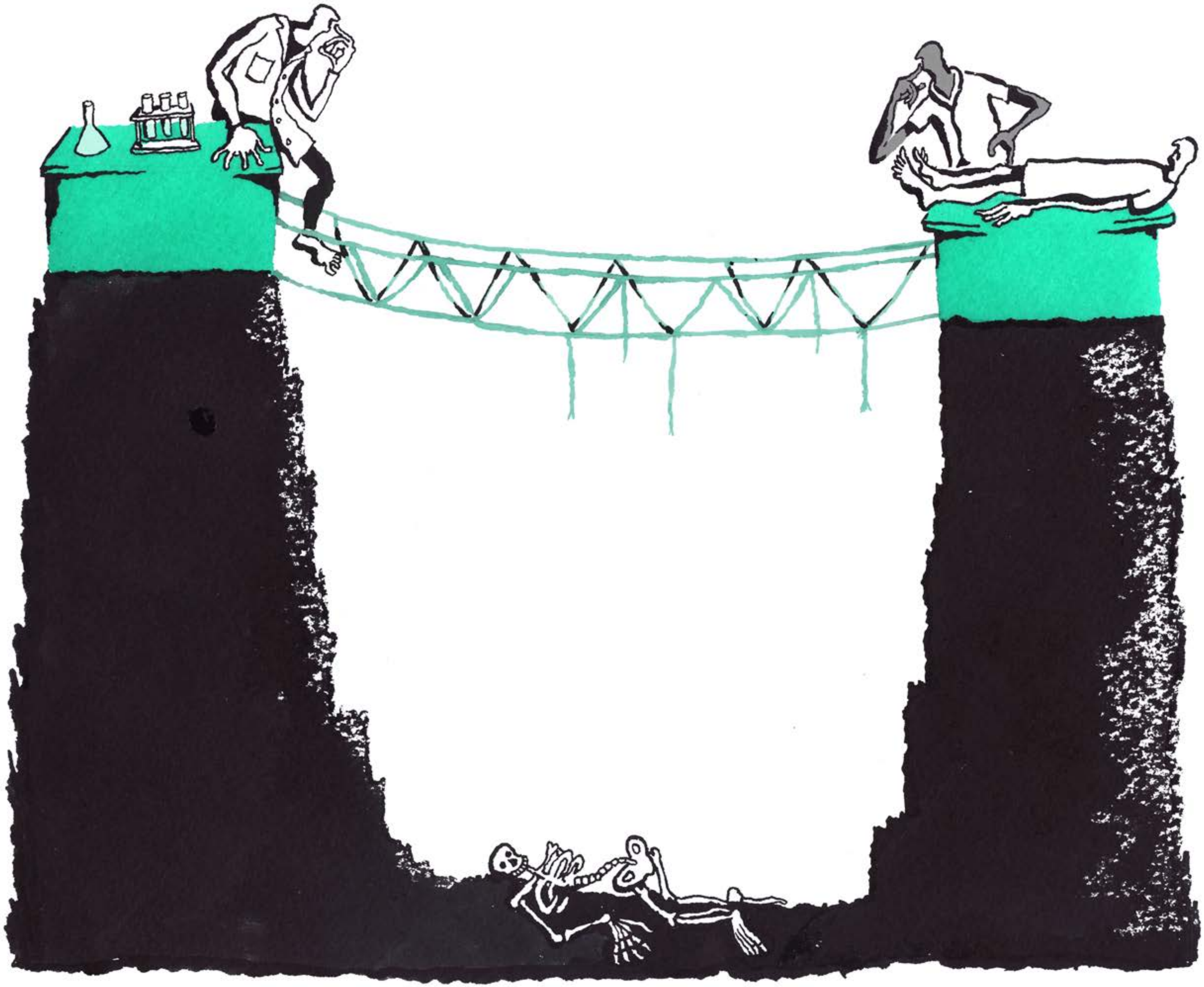
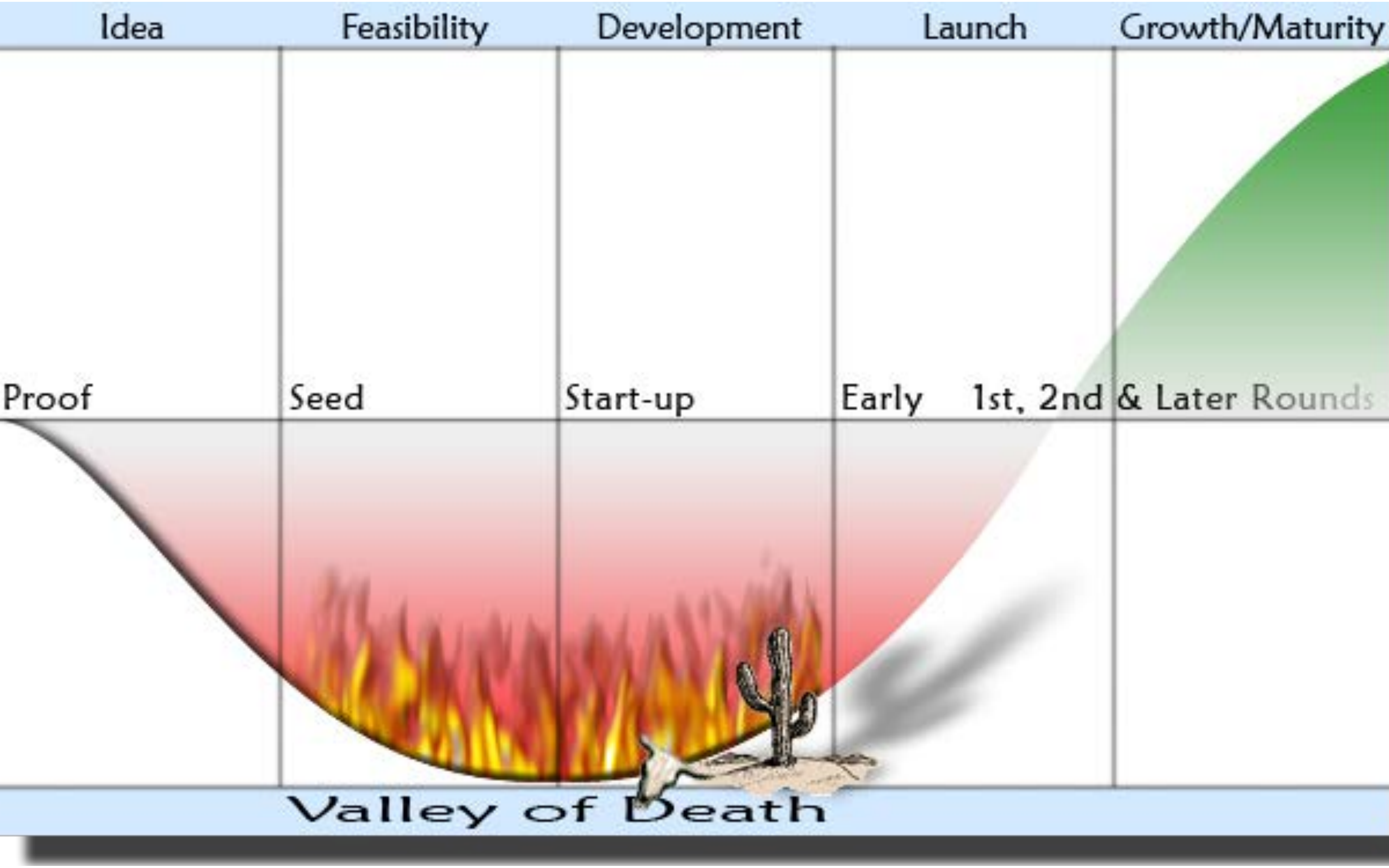
# Innovation’s Valley of Death

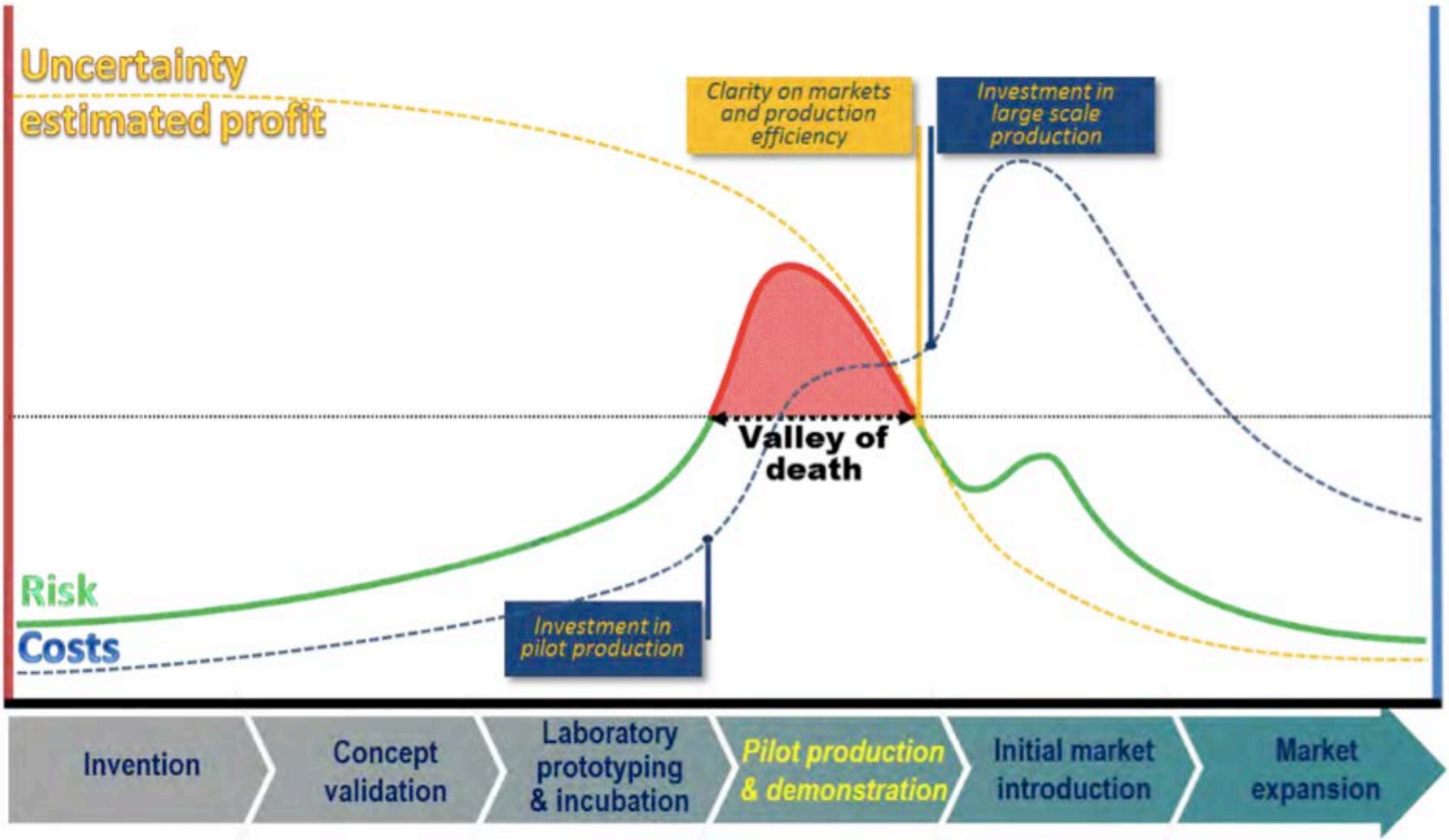
Where good ideas go to die



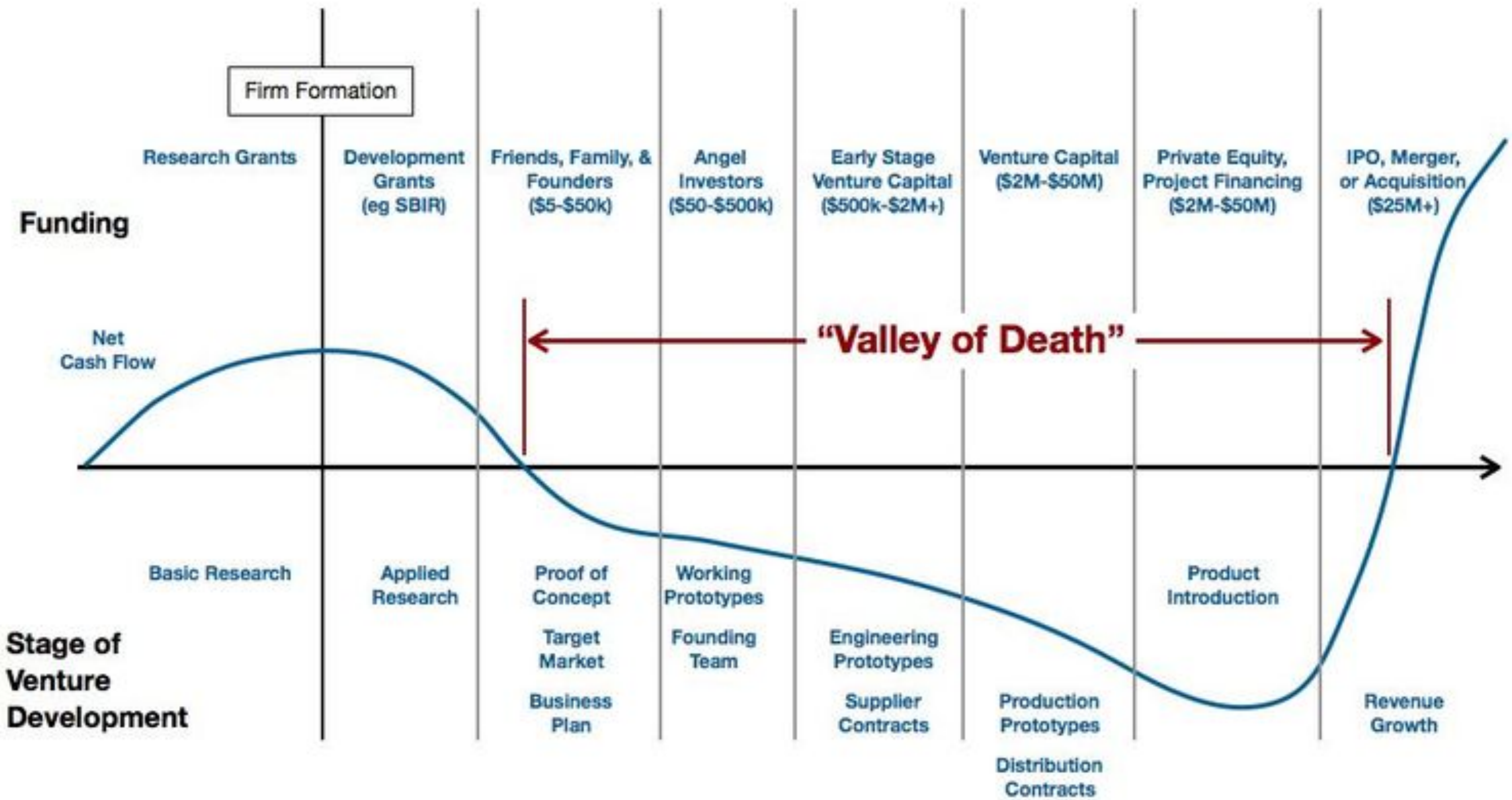

Source: NIST http://www.atp.nist.gov/eao/gcr02-841/fig3.jpg




Idea
Feasibility
Development
Launch
Growth/Maturity
Proof
Seed
Start-up
Early
1st, 2nd & Later Rounds
Valley of Death


Uncertainty
estimated profit
Clarity on markets and production efficiency
Investment in large scale production
Valley of death
Risk
Costs
Investment in pilot production
Invention
Concept validation
Laboratory prototyping & incubation
Pilot production & demonstration
Initial market introduction
Market expansion

# Lifecycle of a venture

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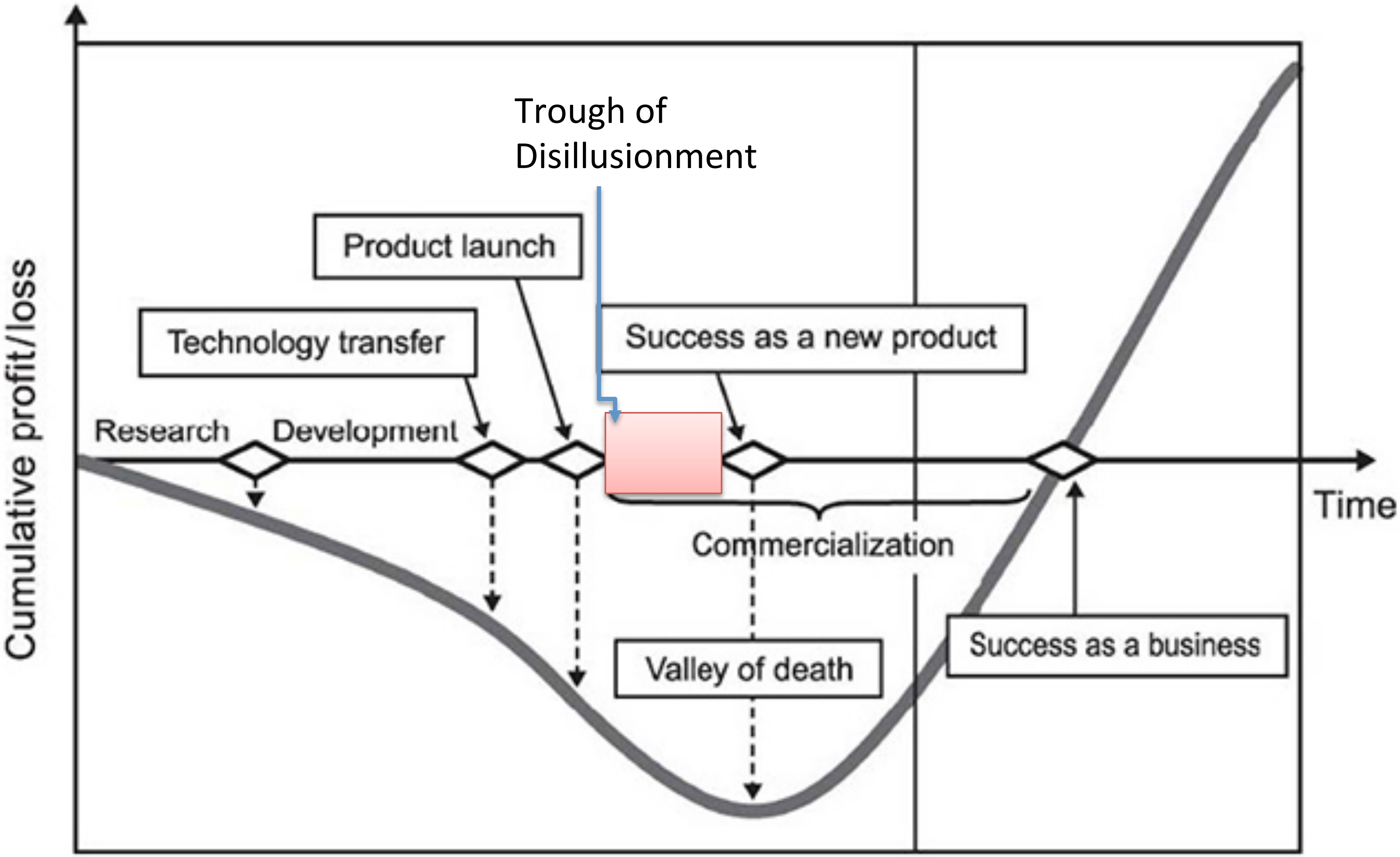
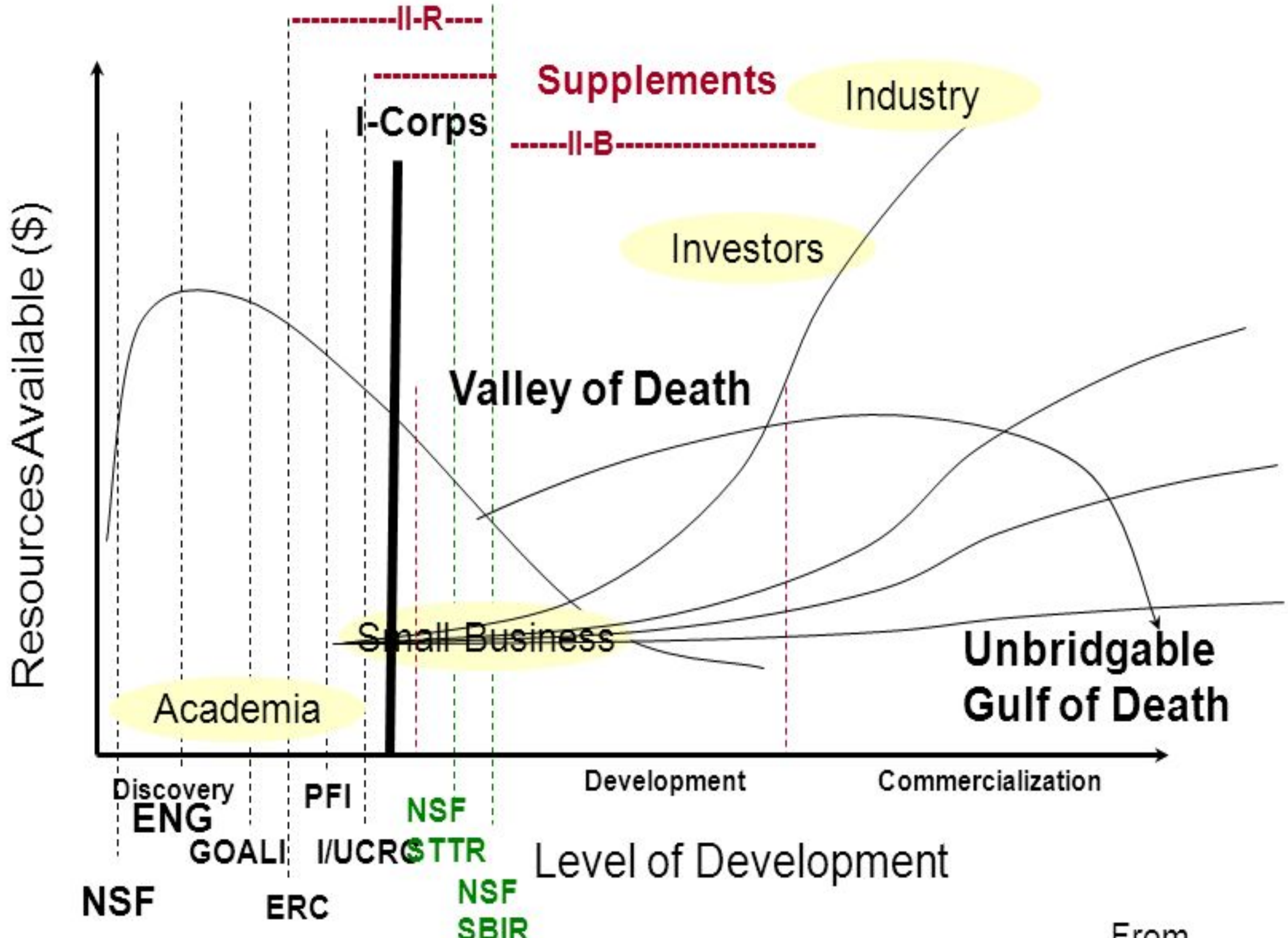


Trough of Disillusionment
Product launch
Technology transfer
Success as a new product
Research
Development
Cumulative profit/loss
Time
Commercialization
Valley of death
Success as a business

# Technology Innovation Spectrum




From
Angus Kingon

# The real reason why most projects don't make it through the valley of death?

- They deserve to die

- Beard et al. (2009) *Research Evaluation*
  - ✓ "Rather, the Valley of Death occurs only in the presence of 'non-economic' investments (such as government expenditures on basic research) that are made in very early stage research without sufficient attention to the likely investment decisions at later stages of the innovation process."

# A Case in Point

- **Two competing environmental remediation technologies**
- **Supercritical $CO_2$ extraction of soils**
  - ✓ Excellent extraction solvent
  - ✓ Advantage of direct separation of organic and mineral components
  - ✓ Supported many faculty and graduate students
  - ✓ Little or no application to soil cleanups
- **Soil Vacuum Extraction**
  - ✓ Application of vacuum to pull air through soil to remove volatile contaminants
  - ✓ Cleaned up many contaminated sites
- **Attributes of soil vacuum extraction**
  - ✓ Low cost
  - ✓ Simple
  - ✓ Effective

# Challenges to development of technologies

- **Attracting investment in good ideas is a real challenge**
  - ✓ The Valley of Death is real!

- **Other challenges…….**

- **Public utilities are notoriously conservative**

- **Regulatory change is notoriously difficult**

- **Where is the incentive for the adopter to adopt?**

# Contaminated Sediments

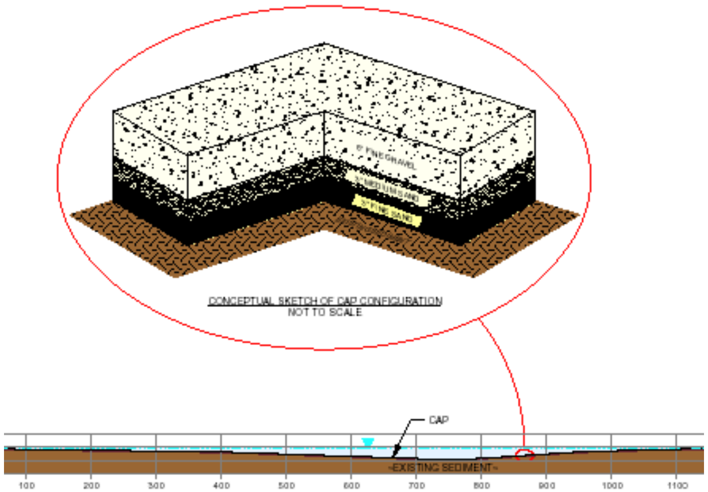
- **Industrial and municipal effluents generally managed effectively**
  - ✓ At least for historical sediment contaminants (metals and hydrophobic organics)
  - ✓ Concerns about perfluorinated compounds, pharmaceuticals, pesticides/herbicides
  - ✓ Current contaminant concerns often not sediment contaminants
- **Stormwater increasingly managed effectively**
  - ✓ Remains a source of sediment recontamination in some areas
  - ✓ Slowing or reversing remedial efforts
- **Legacy of strongly solid-associated refractory contaminants in sediments now pose substantial risk to bodies of water**
  - ✓ Polyaromatic hydrocarbons (PAHs)
  - ✓ Polychlorinated biphenyls and dioxins (PCBs)
  - ✓ Metals

# Managing Risks
# What are the options?

- **Monitored Natural Recovery**
  - ✓ Depends upon effective monitoring
- **Dredging**
  - ✓ Potentially effective but subject to resuspension/residuals
  - ✓ Current targets are mass and volume oriented- needs refocusing on risk reduction
- **Capping and In-Situ Treatment**
  - ✓ Effective/Efficient/Sustainable
  - ✓ Bulk solid measures not directly applicable
  - ✓ Depends upon effective monitoring and effective long-term stability

# In-Situ Management Approaches to Reduce Mobility and Availability

- **Amendment addition directly to sediments**
  - ✓ Sorbing or reactive amendments
- **Conventional (sand/sediment) capping**
- **Thin layer capping**
  - ✓ Sand or other inert material
  - ✓ Amended thin layer
- **Amended isolation capping**
  - ✓ Sorbing amendments
  - ✓ Active management approaches (e.g. redox control systems)



# Indicators of Exposure and Risk


- **Bulk Sediment Concentration**
  - ✓ Relatively easy to measure
  - ✓ Good indicator of contaminant mass
  - ✓ Confusing indicator of risk
  - ✓ Largely irrelevant to capping and insitu treatment
- **Interstitial Water Concentration (Porewater)**
  - ✓ Indicator of mobility and availability
  - ✓ Indicator of performance of *in situ* treatment technologies

# So How to Measure Porewater?

- **Challenge**
  - ✓ Concentration very low for hydrophobic contaminants (O(1ng/L) or less)
- **Approach**
  - ✓ Expose sorbents to porewater and analyze sorbent
- **Inorganic Species - Diffusion gradient thin film (DGT)**
  - ✓ *nonequilibrium* devices
  - ✓ Chelating resin (infinite sink) uptake controlled by thin diffusion gel uptake
- **Organic Species - Polymer sorbent (PDMS,PE, POM)**
  - ✓ *equilibrium* devices
  - ✓ Partitioning proportional to porewater concentration
  - ✓ Low detection limit = Long equilibrium times

# Challenges

- Lack of standardized analysis and quality assurance procedures
- Difficulty of interpreting porewater concentration
  - ✓ Inorganics?
    - Unclear what is being measured
    - Model based uptake and concentration estimate
    - Does uptake relate to biological relevance?
  - ✓ Organics?
    - Model based partitioning and estimates of deviation from equilibrium
    - Partitioning samplers do not measure total porewater burden
    - Does porewater adequately characterize exposure to deposit feeders?
- Lack of regulatory standards and acceptance

# How is this overcome?

- **Standardize analysis and quality assurance procedures**
  - ✓ Develop ASTM or EPA standard method
  - ✓ Integrate quality assurance procedures
- **Difficulty of interpreting porewater concentration**
  - ✓ Develop standardized procedures for processing and interpring measurements
- **Demonstrate, demonstrate, demonstrate……**
  - ✓ Field trials
  - ✓ Field measurements
  - ✓ Field assessment of effects
- **Integrate into existing standards to gain acceptance**

# Advice for the technology developer

- Understand that everyone is from Missouri
- Recognize that changing regulatory or practice paradigms is frustratingly slow
- Are you acknowledging the overall or full life-cycle advantages and disadvantages?
  - ✓ Do you have blinders on?
- Ask why someone should invest in or adopt your technology
  - ✓ "Wow, that's neat" is not going to do it
  - ✓ Is it simpler, cheaper, better?
  - ✓ What are their incentives and barriers?

# What are some new technologies/ directions? (A very selective perspective!)

- **Technologies that address serious problems and concerns**

- ***In situ* remedial technologies and monitoring tools for sediment remediation**
  - ✓ Organophilic clays to control oily phase contaminants
  - ✓ Activated carbon as an in situ treatment or cap amendment to control mobile and available contaminants
  - ✓ Passive sampling to monitor performance
    - ***Sorbents to concentrate mobile phase contaminant to allow measurement***
    - ***Standardization of methods and interpretation***
    - ***Regulatory acceptance of porewater as an alternative to bulk solid standards***

# What are some new technologies/ directions?

- **Greater use of produced water from oil and gas activities**
  - ✓ 10-30 barrels of water produced per barrel of oil in Permian area of west Texas
  - ✓ Quality >100,000 mg/L total dissolved solids
  - ✓ Treatment to drinking or agriculture waters of *this* water unlikely and probably inappropriate

- **Trends in hydraulic fracturing are toward simpler fracturing fluids that can use this water with minimal treatment**
  - ✓ Eliminates consumptive use of freshwater that could be used elsewhere
  - ✓ Eliminates seismic effects of deep well injection of waste produced water

- **But…substantial regulatory and logistical barriers to use of produced water!**

# What are some new technologies/ directions?

- **Increasing recognition of "fit for use"**
  - ✓ Use water appropriate for a particular application
  - ✓ Adapt the use to the water, don't treat the water to apply it to the use

- **Expanded use of scalable, robust technologies**
  - ✓ Technologies that are not sensitive to changes in input quality
  - ✓ Technologies that minimize maintenance requirements
  - ✓ Technologies that can exploit the marginal quality water resources
  - ✓ Technologies that couple effectively with renewable energy sources
  - ✓ Example – Capacitive deionization
    - **No membranes, no pretreatment requirements**
    - **Electricity cost may limit large volume use**
    - **May be ideal for polishing of drinking waters**

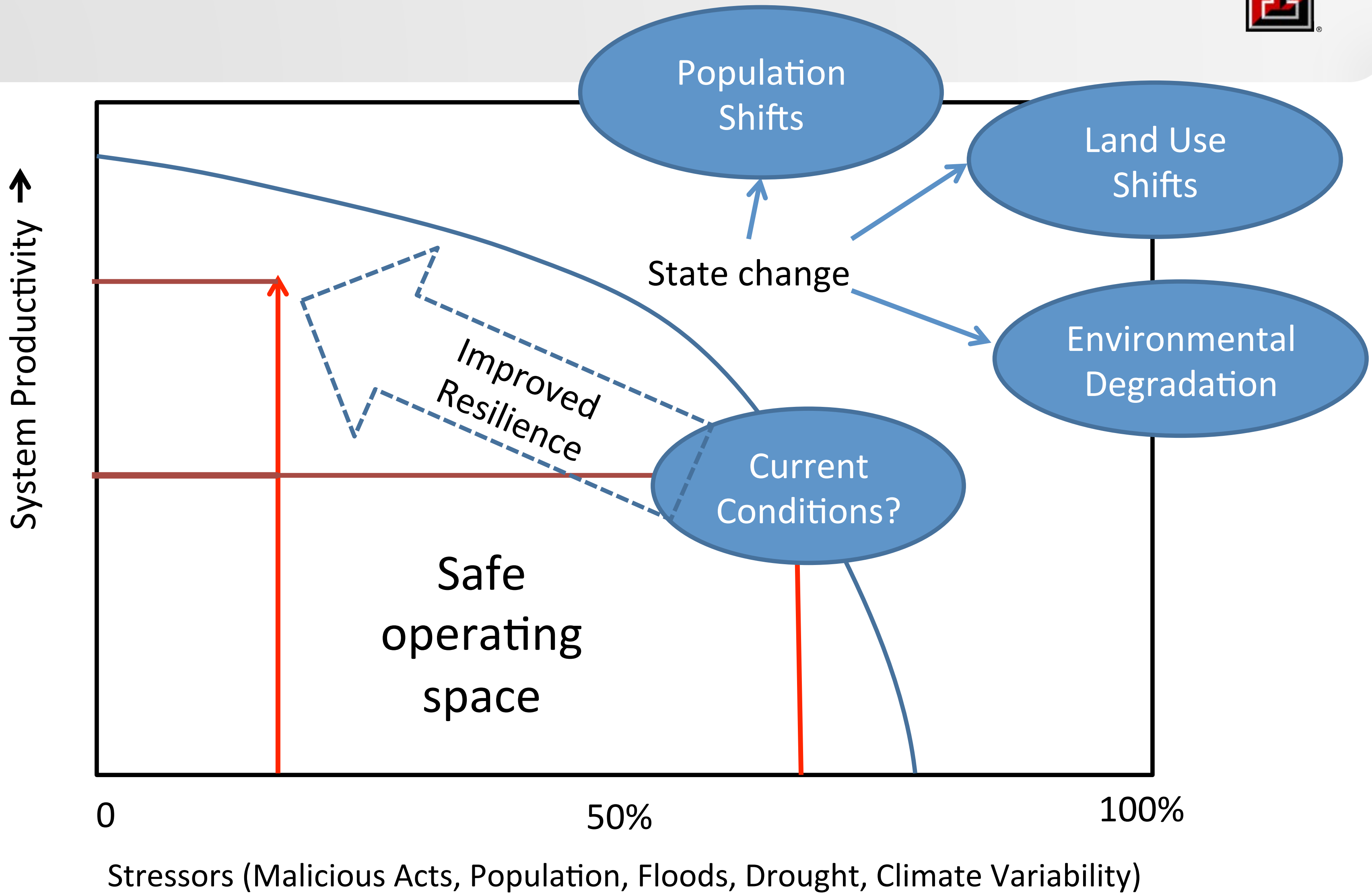
# An Alternative Vision for Water Delivery

- **Current practice**
  - ✓ Deliver high quality water for all uses
  - ✓ Attempt to move toward segregation of grey water and expand reuse
- **A model more consistent with "fit for use"**
  - ✓ Deliver marginal quality/nonpotable water
  - ✓ Employ simple scalable technologies to treat water for human consumption
    - **Need simple, low maintenance technologies**
    - **Energy requirements not a significant concern due to low volumes required**
  - ✓ Implementation
    - **New community/development structured as demonstration**

# A growing challenge

- **Technologies and practices to produce more resilient water systems**
- **Large urban areas have financial, technical and human resources to manage water problems**
  - ✓ Any deficiencies are largely the result of poor planning not lack of capacity
- **Small rural and agricultural communities do not have resilient water supplies and do not have the human, technical and financial resources to resolve these problems**

# Safe Operating Space




Modified from Scheffer et al. 2015