Divergent Paths: The Materials vs. Products Commercialization Conundrum

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Senior Analyst

April 5, 2017

lux executive summit

Boston · April 4-6, 2017

Magic trick…

Am I a magician?

Diapers are enabled by performance materials

- Converting materials to successful products is critical whether you are developing materials or developing products enabled by those materials

Superabsorbent polymer enabled diapers to be thinner, last longer, and reduce leakage and diaper rash

Adhesives on tabs improved convenience

Elastomers improved performance and fit in legs and waist

Kimberly-Clark

P&G

Procter&Gamble

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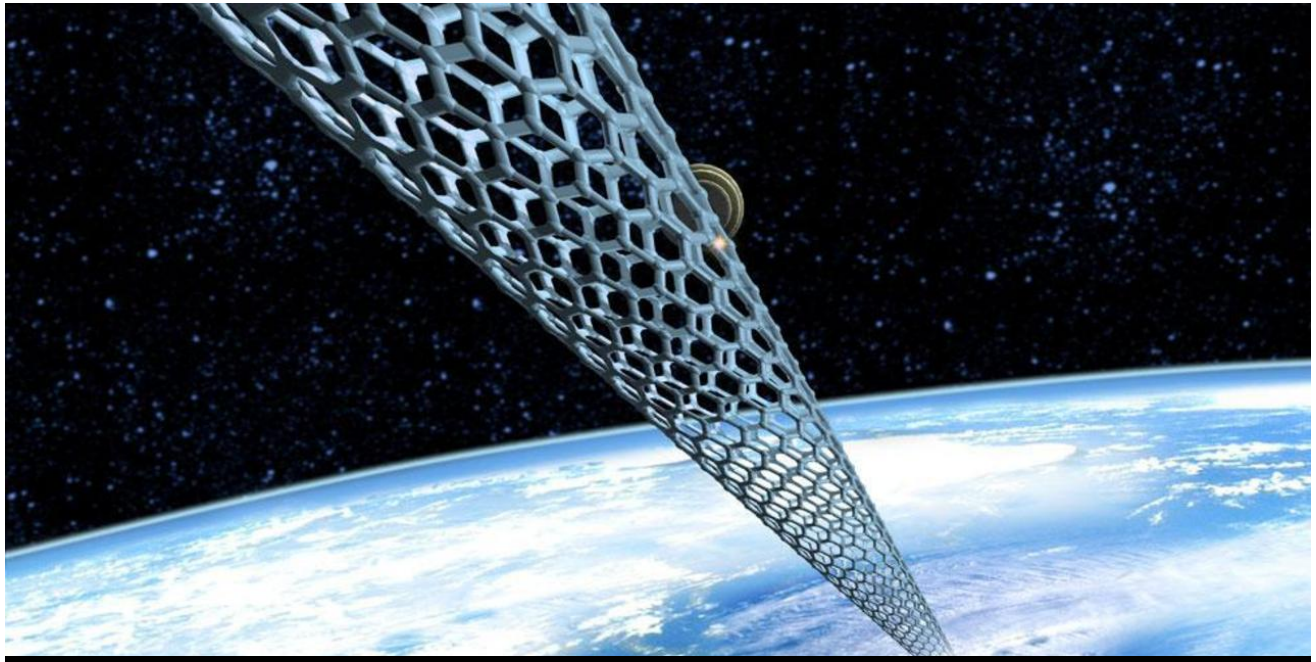
Translating performance and value proposition from material to final part form factor is very difficult and often overlooked

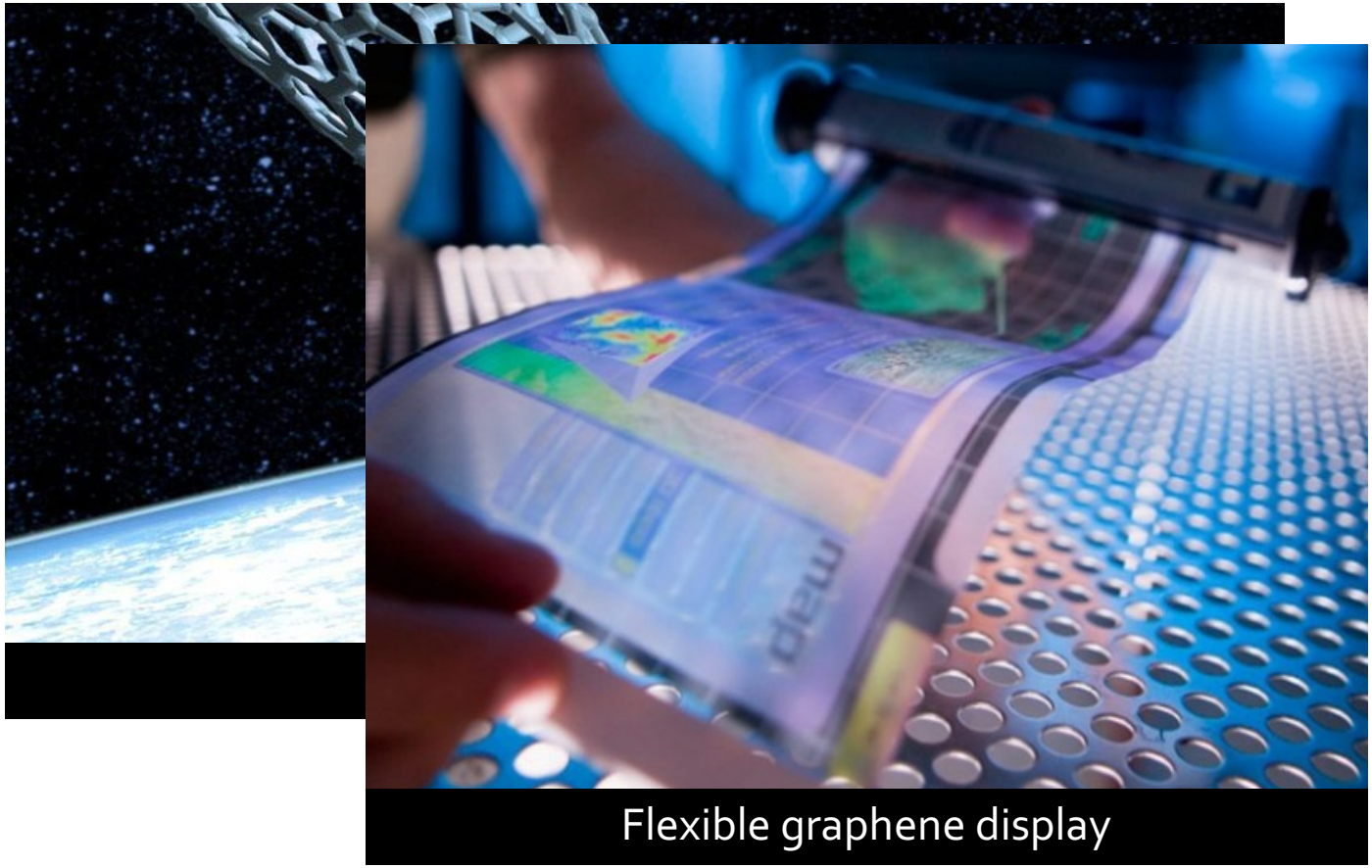
I'm not joking…



CNT space elevator

Image source: BBC.com

I'm not joking…



Flexible graphene display

Image source: nanotechmag.com

I'm not joking…

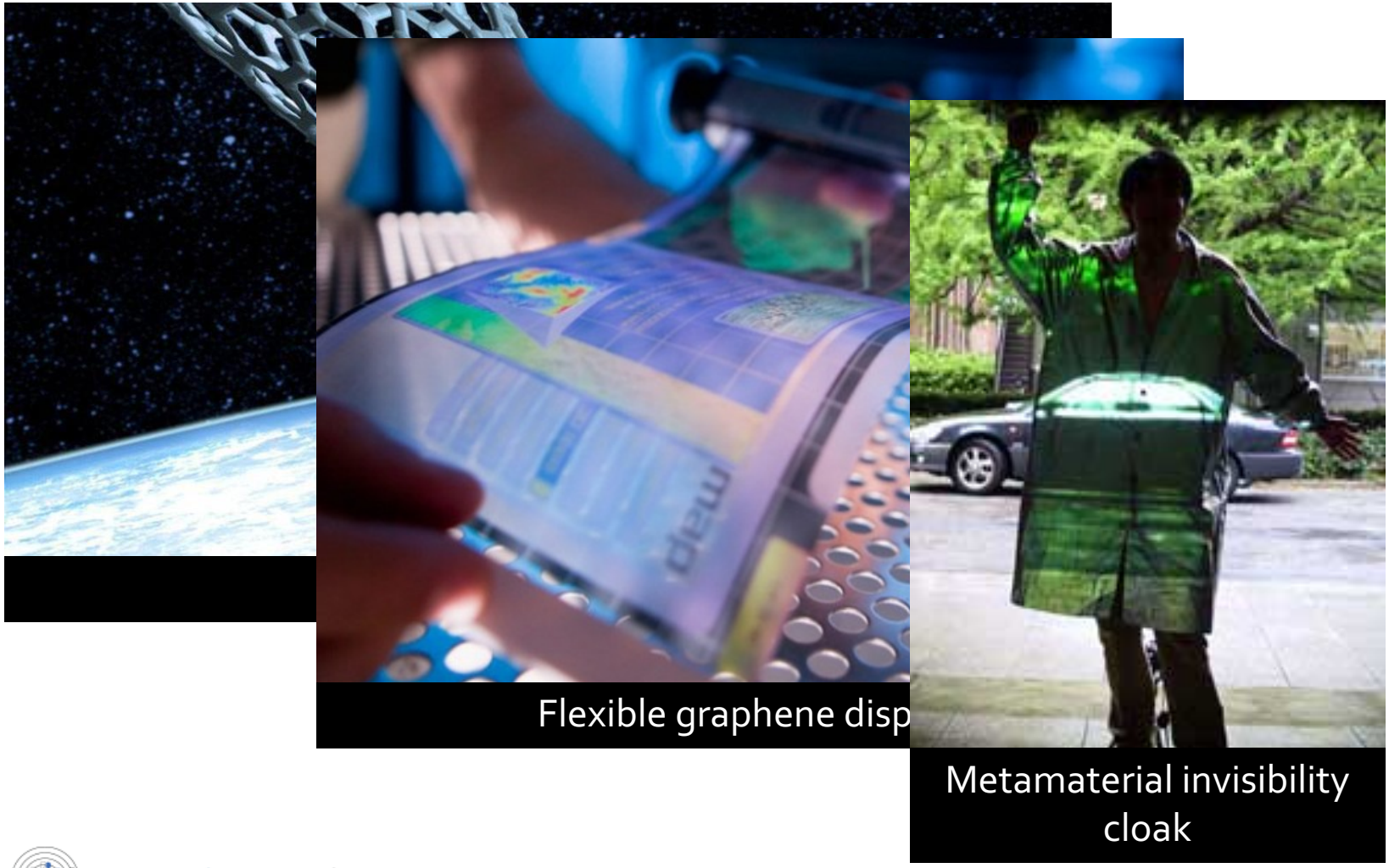
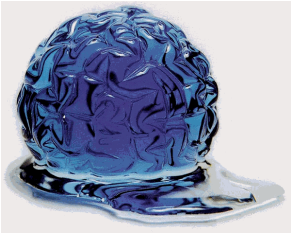


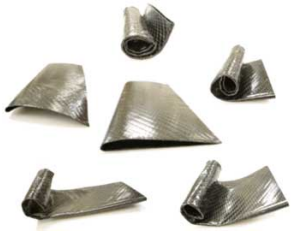
Image source: Tachi Laboratory, The University of Tokyo

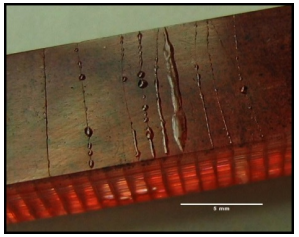
This challenge is only going to get more complex as innovation potential rises

Multifunctional platforms like CNTs, graphene, and NCC epitomize this challenge, but next generations of materials present even greater complexity:

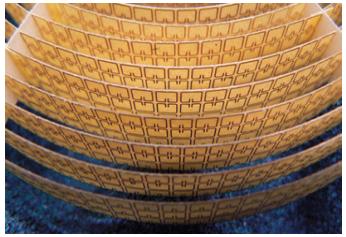
- **Smart materials** change their properties in response to environmental stimuli and provide dynamic rather than static functionality

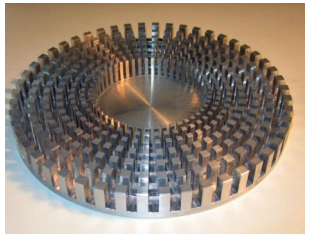






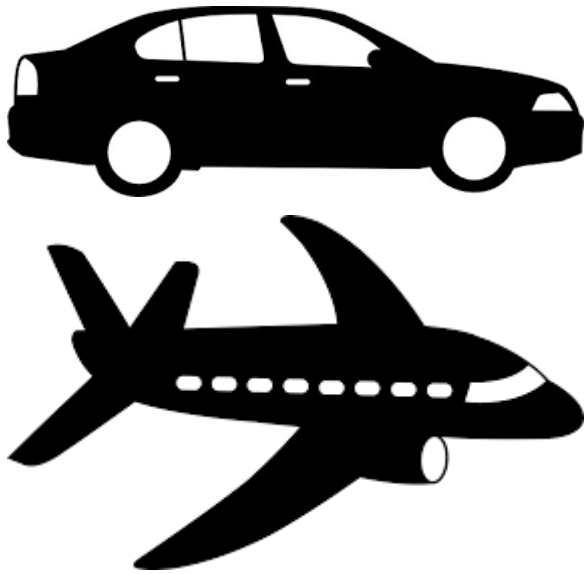
- **Metamaterials** derive unusual mechanical, electromagnetic, or acoustic properties from a carefully controlled microstructure or nanostructure





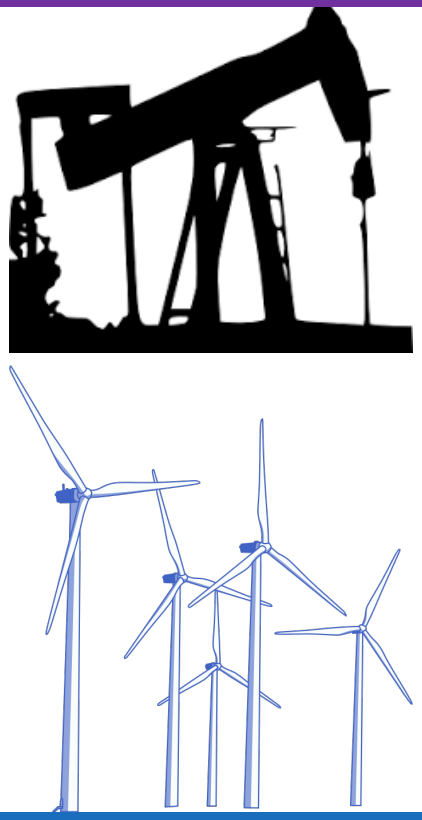
Materials are critical for transformational disruption across industries

Transportation



Lighter weight structures, cleaner catalysts, longer lasting batteries, better sensors, debris-resistant coatings

Energy



Improved corrosion- and wear-resistance, anti-icing coatings, stiffer structural materials

Consumer products

Flexible displays, scratch-resistant surfaces, better barriers, bio-based polymers

Image source: sealpac.de

Agenda

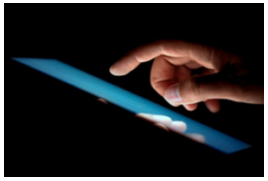
- We have a problem!
- **What are we going to do?**
- How are we going to do it?

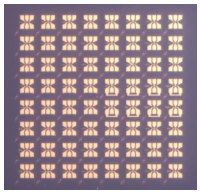
We have long advocated materials developers moving down the value chain

- This has led to some modest initial successes…

Graphene film developers aim to spur revenue growth by pivoting from TCFs to sensor products

- Most hype and attention on graphene application development initially focused on TCF segments like displays and touchscreens
- Commercialization progress has been slow due to high cost and deposition area limitation challenges
- Pivot among leading developers to sensors should reduce product integration complexities and increase revenue potential over pure play materials business model
  - Graphene Frontiers and Bluestone Global Tech developing FETs for sensor applications
  - Graphenea working on sensor applications with Nokia and Infineon





Graphene Frontiers

GRAPHENEA

BGT BLUESTONE GLOBAL TECH

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Graphene film developers aim to spur revenue growth by p

- Most hype and atte development initia displays and touch
- Commercialization high cost and depo
- Pivot among leadir reduce product inte increase revenue p business model
  - Graphene Fro Tech develop
  - Graphenea w with Nokia ar

Graphen Frontie

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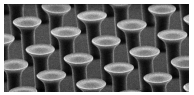
Mechanical metamaterial start-ups position themselves as solution providers

nanoGriptech (GECKO-INSPIRED ADHESIVES)

High-friction adhesives

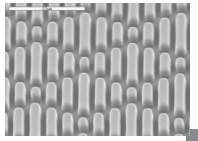
Lux Take:	Employees	Revenue
Positive	7	$1.4M



Sharklet Technologies, Inc.

Antimicrobial patterned films

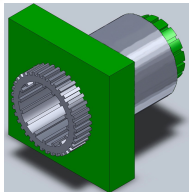
Lux Take:	Employees	Revenue
Wait and See	10	$2M



haowaki

Patterned surfaces for friction reduction

Lux Take:	Employees	Revenue
Positive	6	$2.5M



- Rather than relying on (and pushing) the hype of metamaterials as a material class, these start-ups have achieved initial commercialization successes by developing products that provide solutions

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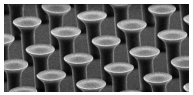
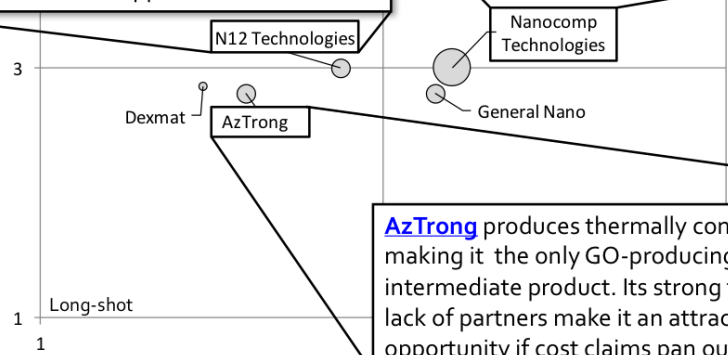


- Rather than relying on these start-ups have ac products that provide s

Sheet, tape, and yarn form factors lead to easier product integration and better chance of success

N12 Technologies, which develops sheets of vertically aligned CNTs, has demonstrated very strong momentum by forming partnerships, fundraising, and scaling up. While costs are still high, N12's ability to decouple CFRP toughness from the resin could be valuable in volume applications.

Nanocomp Technologies is the most mature producer of CNT yarns and sheets, with products successfully deployed. Clients with cost-tolerant wire, electrostatic discharge, and thermal needs should look to Nanocomp first.



AzTrong produces thermally conductive sheets from GO, making it the only GO-producing company with an intermediate product. Its strong thermal performance and lack of partners make it an attractive partnership opportunity if cost claims pan out.

Despite high costs, many of these companies have made substantial inroads deploying materials with partners

We have long advocated product thinking and moving down the value chain

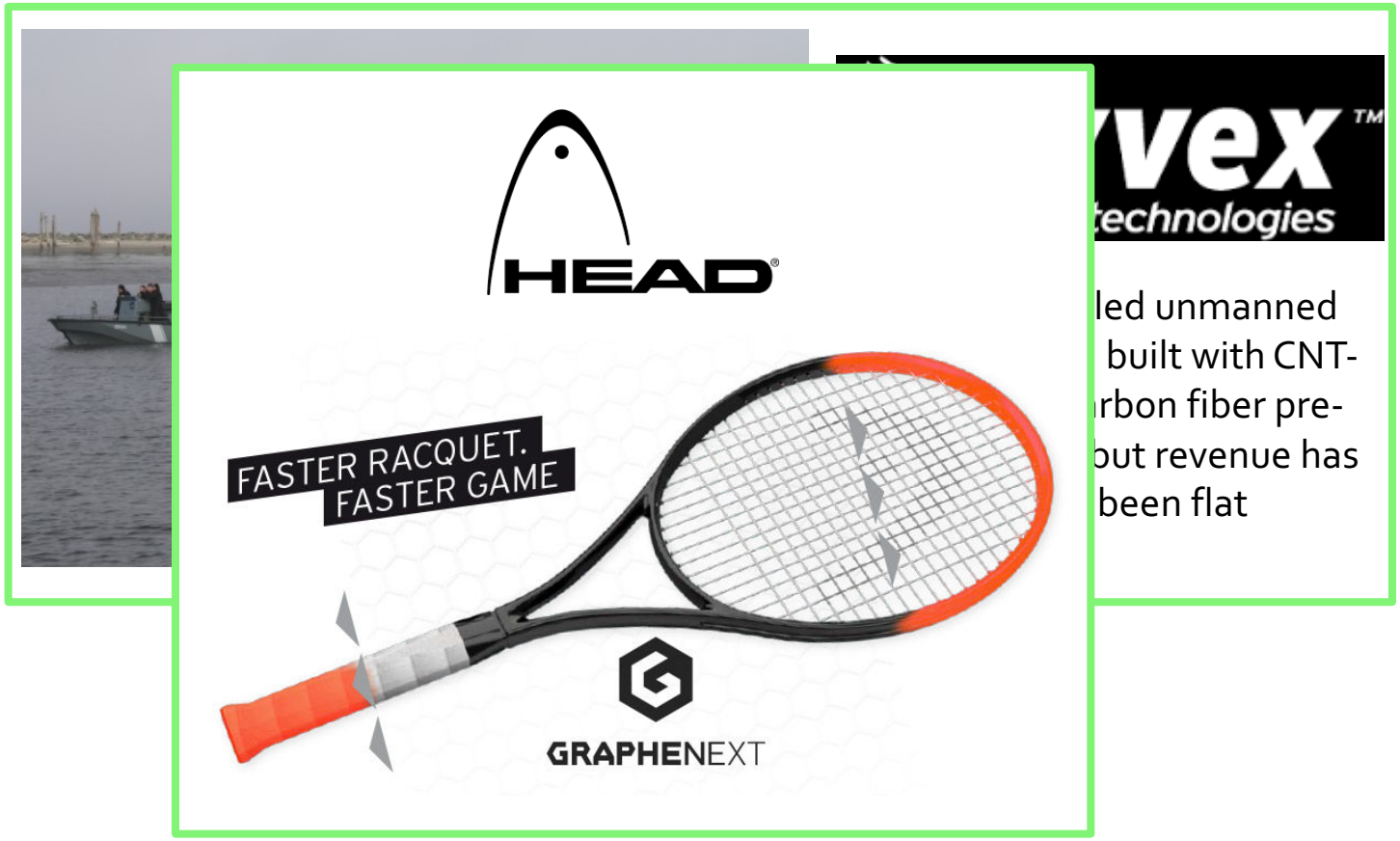
- ...but also some ridiculous and purely marketing-based products

zyvex™ technologies

Zyvex unveiled unmanned surface vessel built with CNT-reinforced carbon fiber pre-preg in 2010, but revenue has largely been flat

We have long advocated product thinking and moving down the value chain

- ...but also some ridiculous and purely marketing-based products



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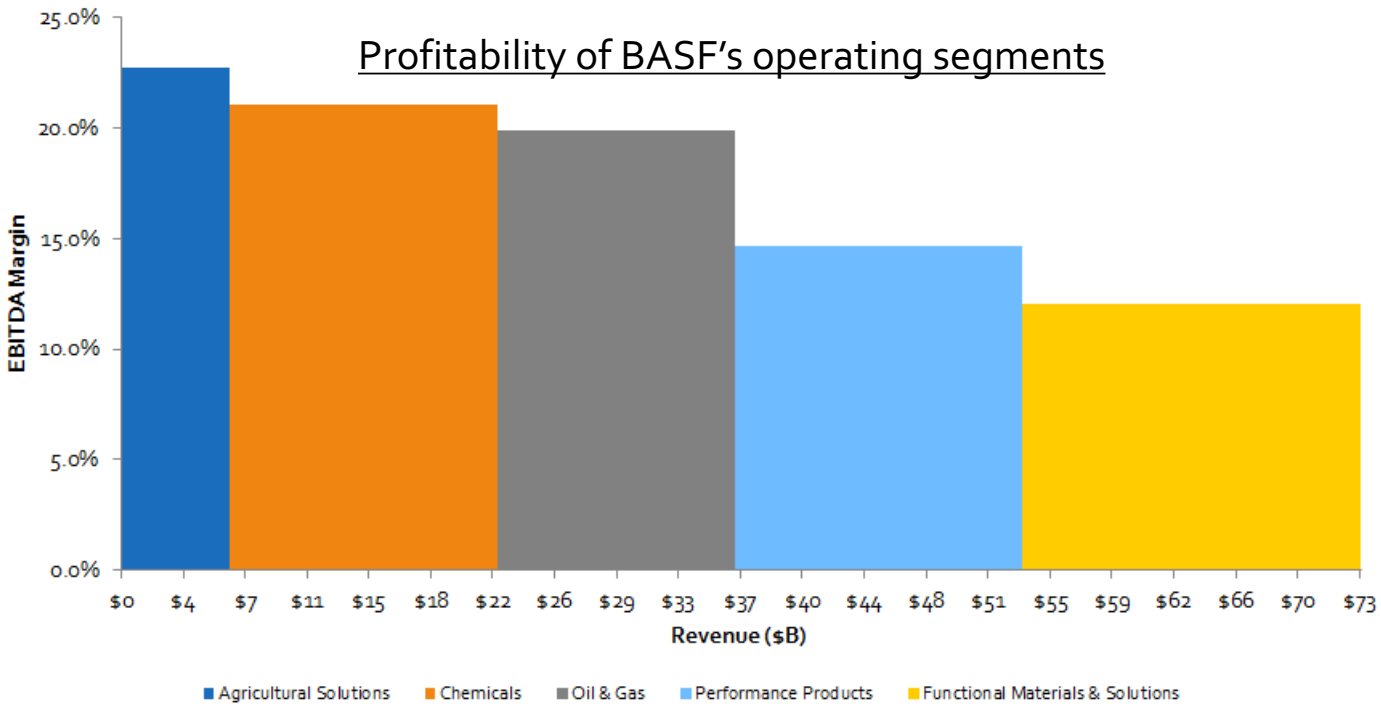
"The company, which has raised some $90 million in venture capital funding, calls the tie the product of more than 200 person-years of research and design." *C&EN*

Large chemical and material companies are also struggling and under significant market pressure

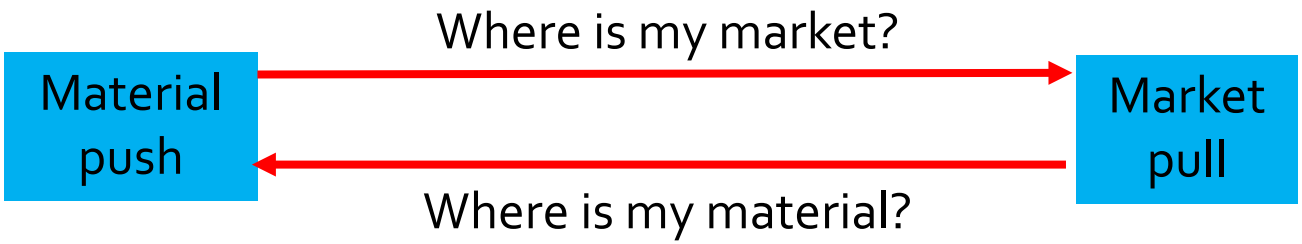
- Big oil is starting to moving downstream, while the traditional move to specialty chemicals has become less attractive
  - BASF's specialty businesses have lower margin than their commodity business



We need to rethink the relationship between materials, products, and markets

Classic material push vs. market pull conundrum

- Allure of platform materials push is many potential applications, but history has repeatedly shown challenges of such a model
  - Great at everything, good at nothing
- But relying solely on market pull also isn't the answer, as avoiding platform technology push altogether would miss out on really big opportunities
  - Incremental success at expense of step-change disruption



Can we have the best of both worlds?

How do we get from material to market?

- Design tools accelerate timeline from lab material to final product

Citrine

Reported up to 2x shorter R&D cycle for material design and selection using materials informatics

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A List of Single–Crystal Elastic Constants for Some Oxides
ABS

HYUNDAI

Alcoa

Panasonic

Design

- **Materials informatics and design software**

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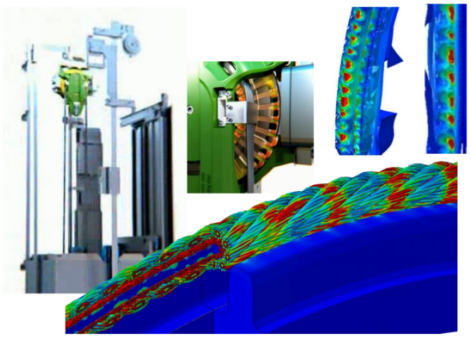
ProperTune®

Multiscale modeling and simulation software used by elevator components manufacturer KONE to select optimal wear resistant materials; claims can shorten time-to-market for new products by 50%



Design →

- Materials informatics and design software
- **Part design software**

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Markforged

3D printers process continuous and chopped fiber composites ; can reduce part cost and development time

Unilever factory floor sensor mounts and fixtures:

	Cost	Time
Replacement part	$51.13	1 week
Markforged part	$23.01	1 Day

Design

- Materials informatics and design software
- Part design software
- **3D printers and scanners**

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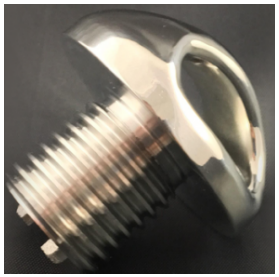
- Manufacturing technologies enable production of advanced products

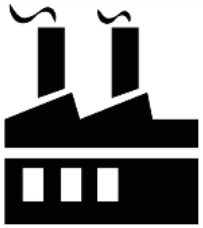
ADDAERO



Scalable metal 3D printing processes; developed custom deck padeye for marine customer; targeting 1,200 aerospace part production runs in 2018

Manufacturing →

- **Additive manufacturing**



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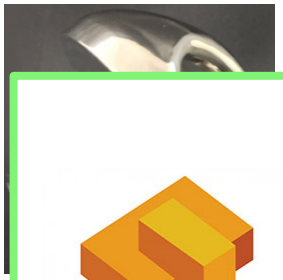

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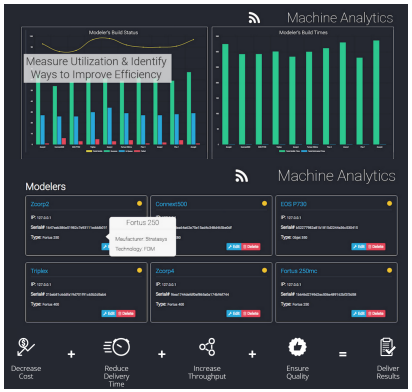
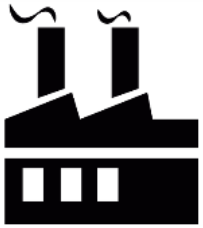


Manufacturing execution system software uses real-time equipment data and machine analytics, to move additive manufacturing operations from lab to production scale by reducing cost, saving time, increasing quality, and improving material utilization

Manufacturing →

- Additive manufacturing
- **Software control systems**



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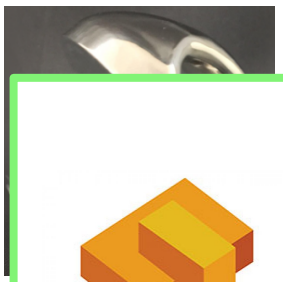
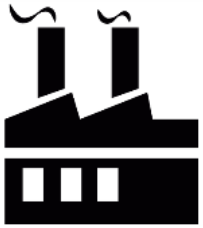


WINSUN 盈创

Uses robotic arm to 3D print prefabricated concrete wall components and then assembles them onsite; 3D printed components claimed to have comparable strength as traditional concrete; automation improves efficiency and saves on labor

Manufacturing →

- Additive manufacturing
- Software control systems
- **Automated equipment and robotics**



New design and manufacturing technologies integrate value chain into continuous feedback loop

- Platform tools (rather than platform materials) enable technology push disruptive potential with market-pull commercialization benefits
  - New software tools allow setting of previously unattainable material and part design goals that software will help solve
  - New hardware tools enable novel composition, geometry, and production economics
  - Swifter commercialization timelines because end goal inherent in all development and production phases

Design

- Materials informatics and design software
- Part design software
- 3D printers and scanners

Manufacturing

- Additive manufacturing
- Software control systems
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This will reshape the path to market for new materials and products across industries

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Manufacturing

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- Software control systems
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Agenda

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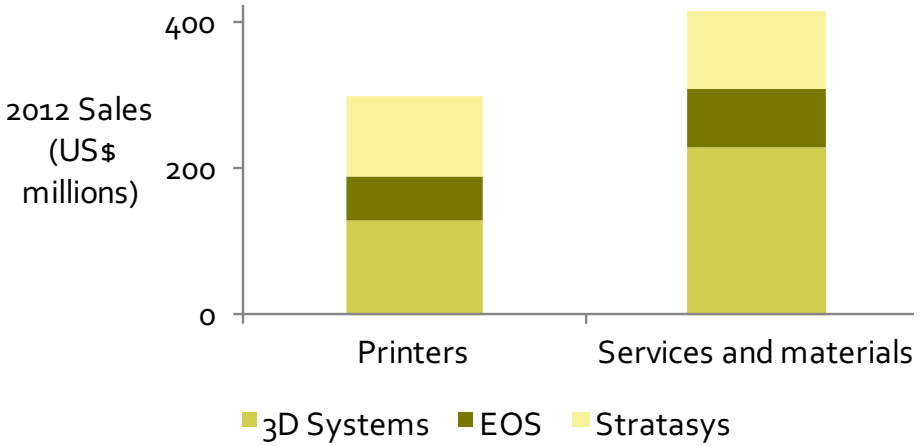
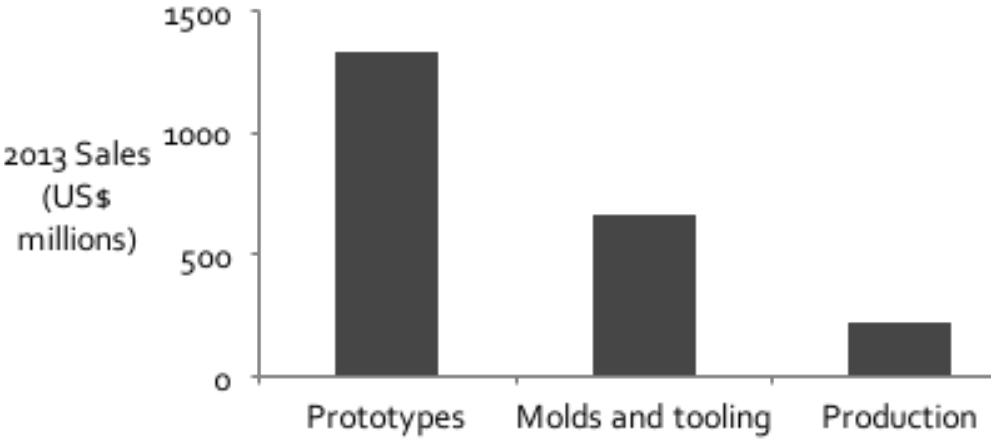
- What are we going to do?
- **How are we going to do it?**

3D printing was held back by bad business models



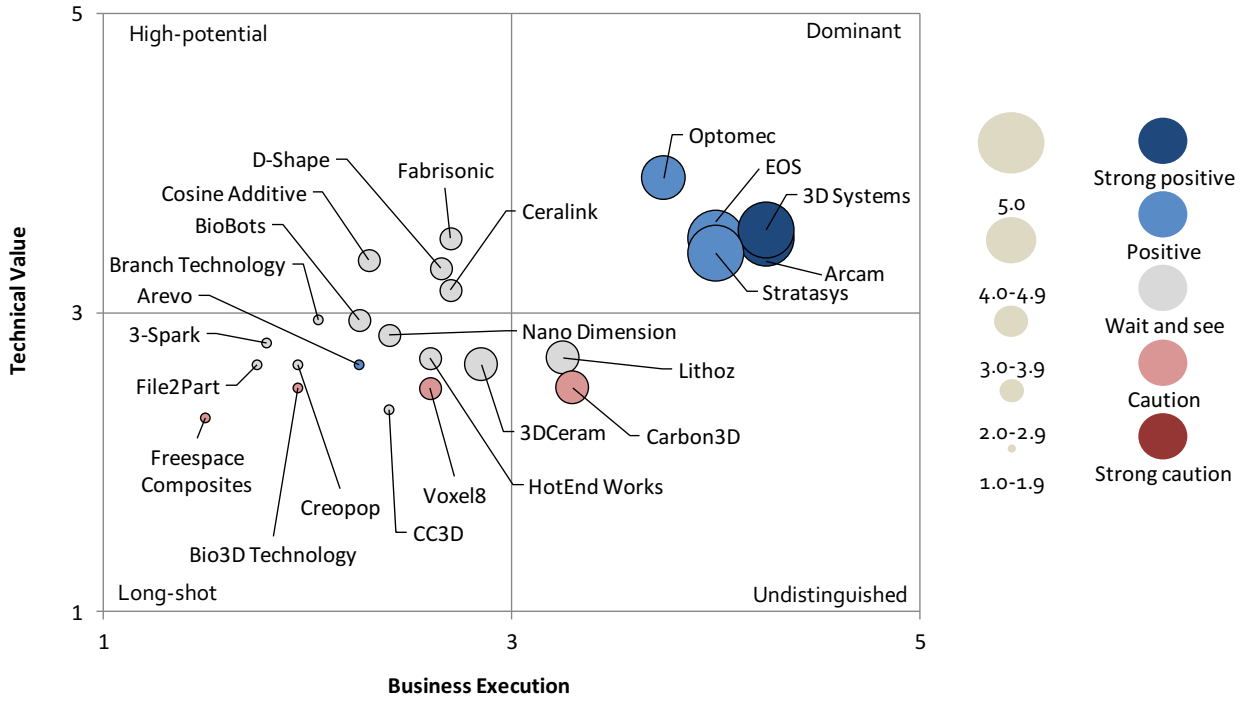


- Printer/cartridge business model deployed by 3D printing incumbents sought to maximize short-term revenue from a prototyping-dominated market
- This strategy was ultimately shortsighted as it hindered materials development and manufacturing-related innovations

Data source: Google Finance

Influx of developers throughout the value chain with open business models got 3D printing over the hump

Established printer players under attack from start-ups with novel approaches and open platforms



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Influx of developers throughout the value chain with open business models got 3D printing over the hump

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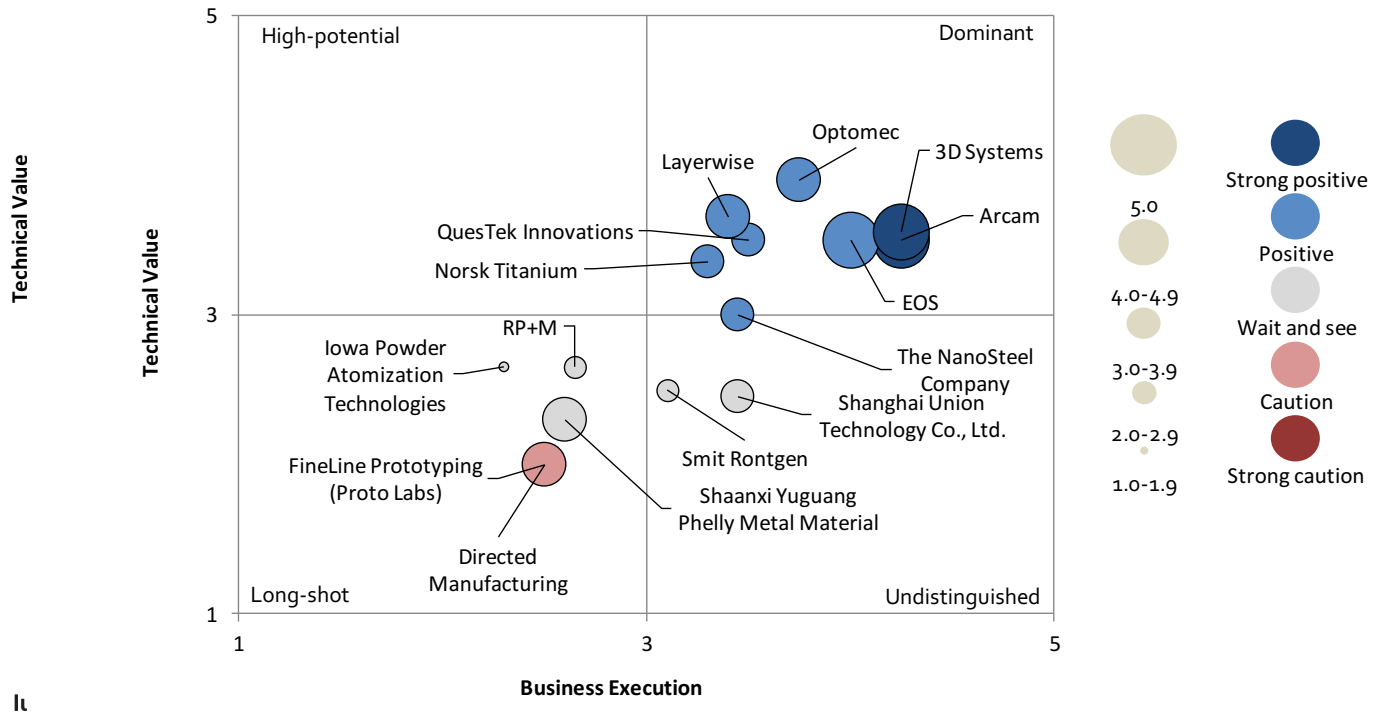
up

QuesTek, Norsk Titanium, and The NanoSteel Company threaten established metal players



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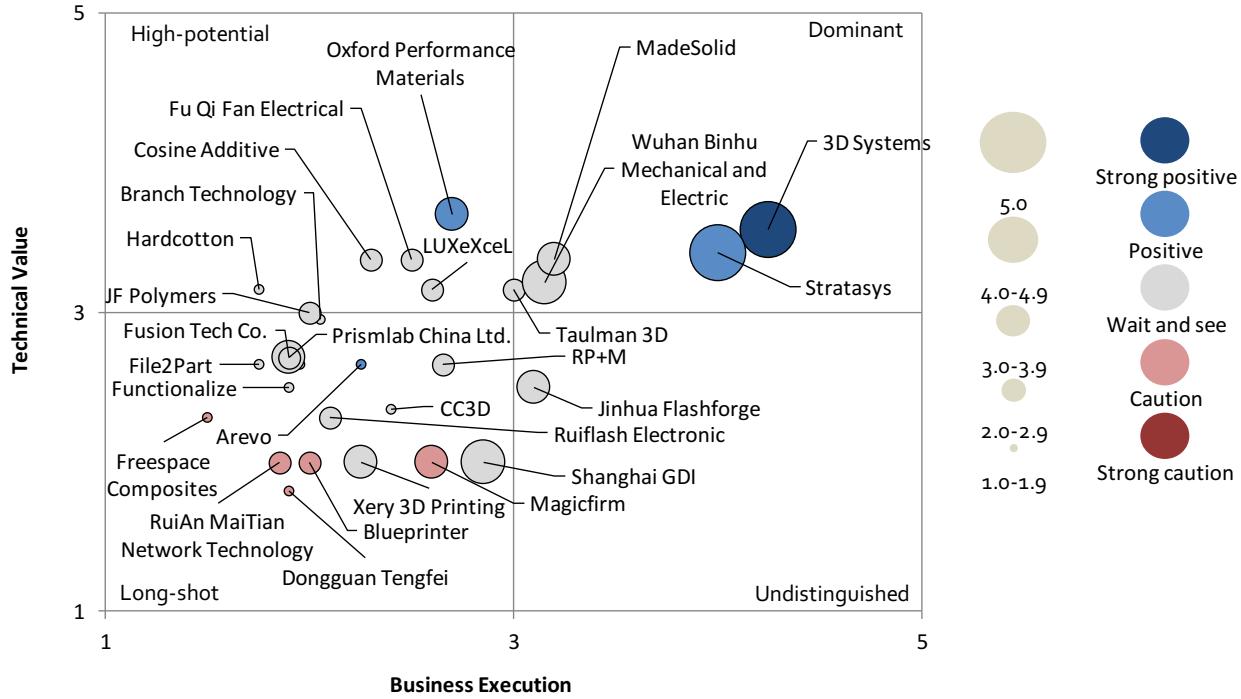
Influx of developers throughout the value chain with open business models got 3D printing over the hump

Polymers space flooded with long-shot developers of materials and systems



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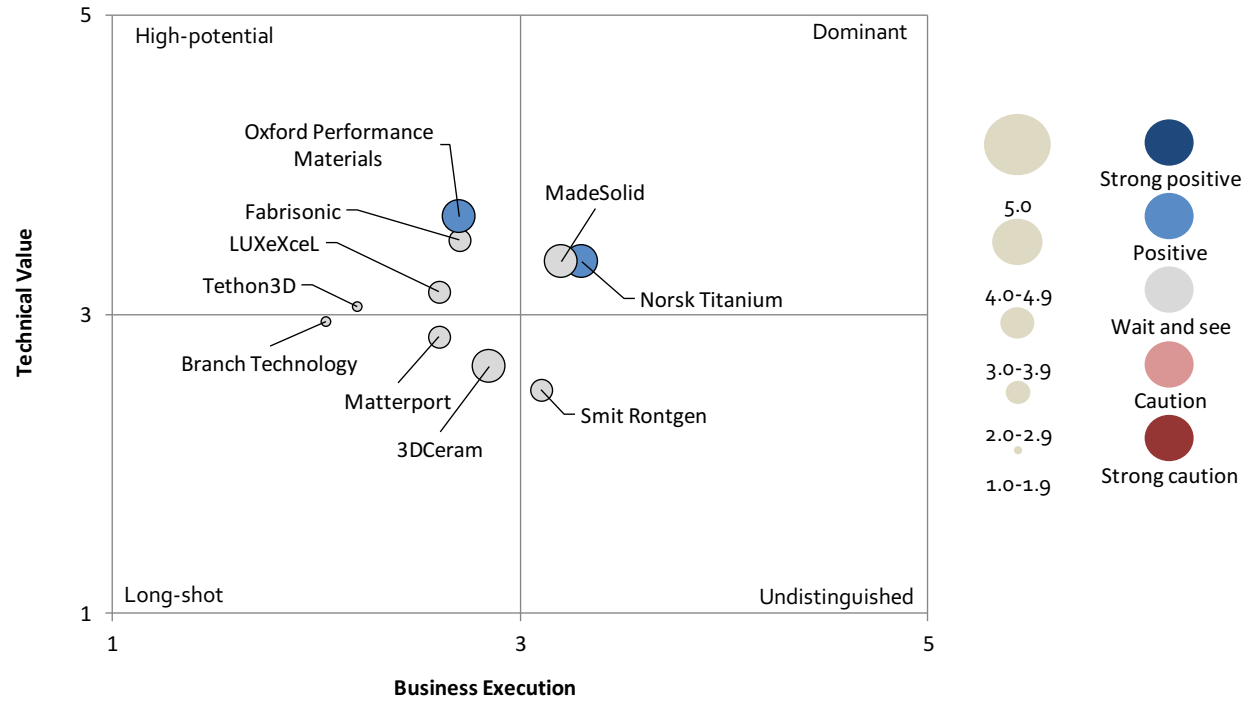
Service providers differentiate with application-specific products and materials



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Autodesk plays the long game with open source strategy

AUTODESK

EMBER™

- Ember stereolithography 3D printer launched in 2015 is completely open source, including hardware, electronics, firmware, and photopolymer resin formulation
- Enabled use of third-party resins, printing of unique parts, better control over resin curing, and 24x increase in print speed
- This open approach will ultimately boost future software sales, Autodesk's core offering

Integrated ecosystem requires systems mindset and open innovation strategy

- Material development, product design, and final part production are no longer separate functions (and never will be again!)
- Focusing on core expertise and securing ecosystem partners that perform complementary tasks better than you is critical for long-term success
- Those clinging to outdated closed models will get left behind

Design

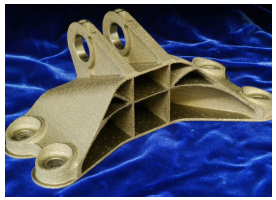
- Materials informatics and design software
- Part design software
- 3D printers and scanners

Manufacturing

- Additive manufacturing
- Software control systems
- Automated equipment and robotics

GE Aviation used open innovation to race ahead of aerospace competitors

- Acquired several leading metal 3D printing companies: Morris Technologies and Rapid Quality Manufacturing (2012); Arcam and Concept Laser (2016)



- In 2013 held an open competition to redesign an engine bracket to reduce weight

- In Oct 2016, GE and Local Motors launched the Fuse platform to crowdsource solutions to innovation challenges; GE claims this can reduce product development time by 50%

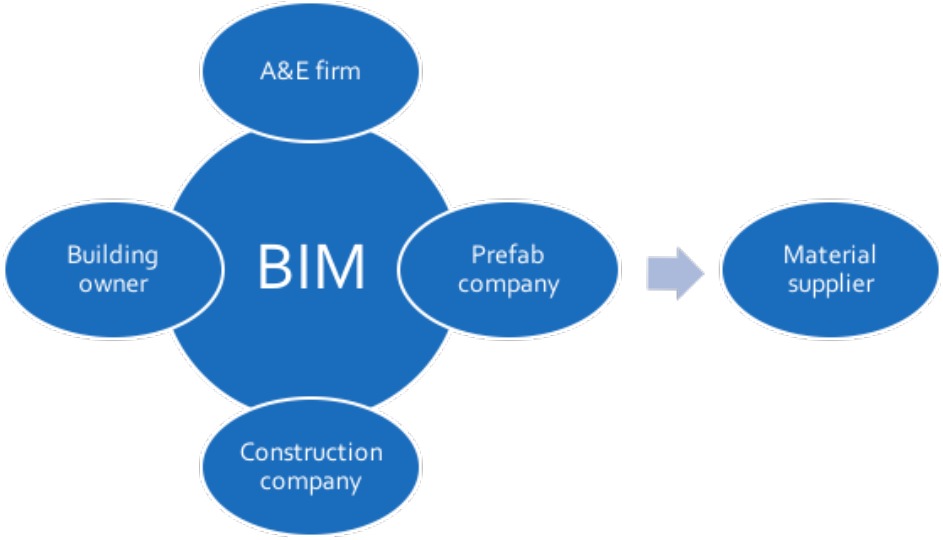
- Launched 3D printed production parts include FAA certified sensor housing for GE90 engines and fuel nozzle for new LEAP jet engine

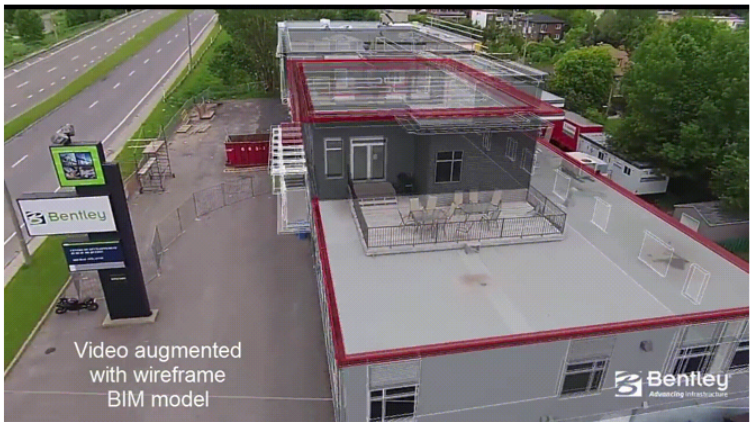
Building information modeling (BIM) core to integration of novel construction technologies

- BIM integrates databases of all information pertaining to a building, including materials, design, performance analysis, and project planning data

- Materials developers need to list their materials in BIM for architects to simulate building performance and cost

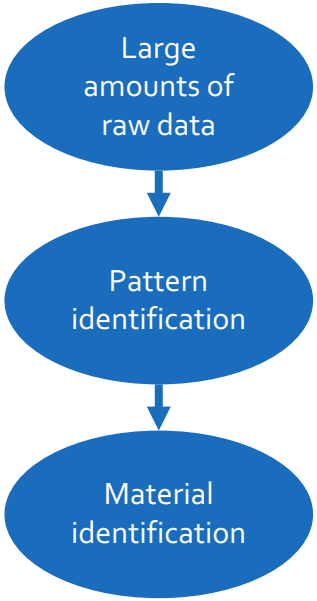
- Allows direct feedback on material choice to guide future R&D; ultimately enables integration analysis with construction tooling

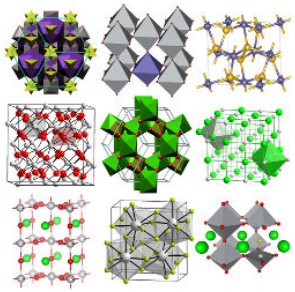




Materials informatics has disruptive potential, but is only as good as the data used to train the models

- Materials informatics can accelerate materials R&D by:
  - Selecting ideal materials from available options
  - Predicting new candidate materials
- Data matters!
  - Quality and quantity of data has major impact on capability for materials informatics to help you
- Chemical and material companies have great potential to benefit because of wealth of already generated data (e.g. material composition/processing/property relationships)
  - Consider providing such data to leading developers, many of which have service-based business models





Citrine

VTT

IBM

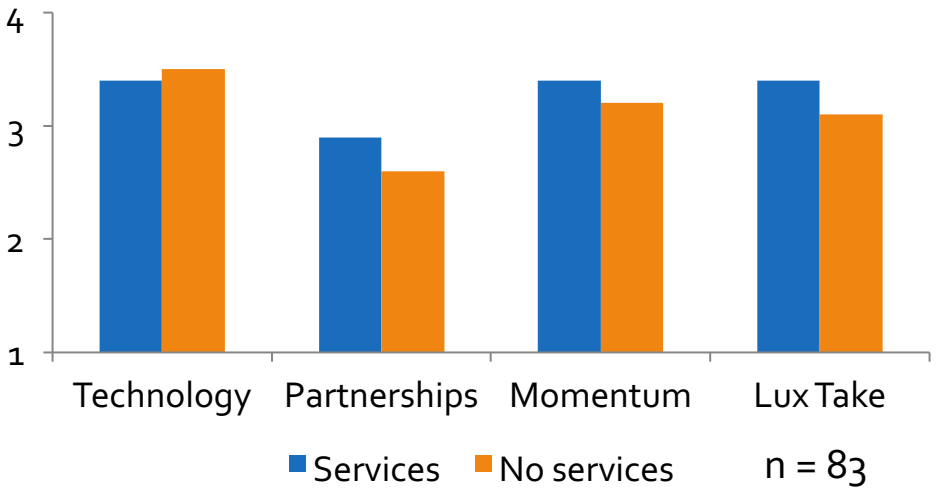
lumiant

nutonian

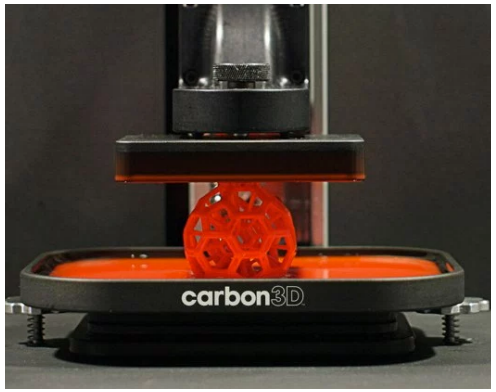
Image source: Tilde Materials Informatics

Materials design and manufacturing disruption creates opportunities

1. Service-based business models thrive



Data from ttm Lux Research Materials Design & Manufacturing profiles



>$200M funding

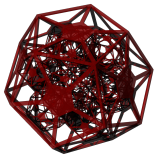
Carbon

M1 printer technology fails to impress, but leasing business model will drive near-term sales by removing upfront cost barriers

Materials design and manufacturing disruption creates opportunities

1. Service-based business models thrive

2. Material selection, form factor, and recycling innovations



Adaptive3D™

3D printable thermosets for production scale parts

VADER

Wire feedstock metal 3D printers

pollen

Pellet feedstock thermoplastic 3D printers

topolog

Metal 3D printers powders from waste material

3devo

Thermoplastic filament shredding and extrusion equipment

ReDeTec

Thermoplastic recycler with integrated shredding and extrusion capabilities

Materials design and manufacturing disruption creates opportunities

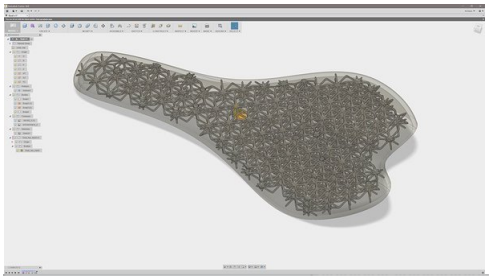
1. Service-based business models thrive

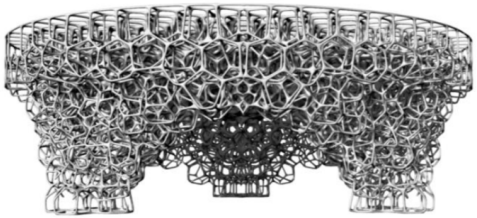
2. Material selection, form factor, and recycling innovations

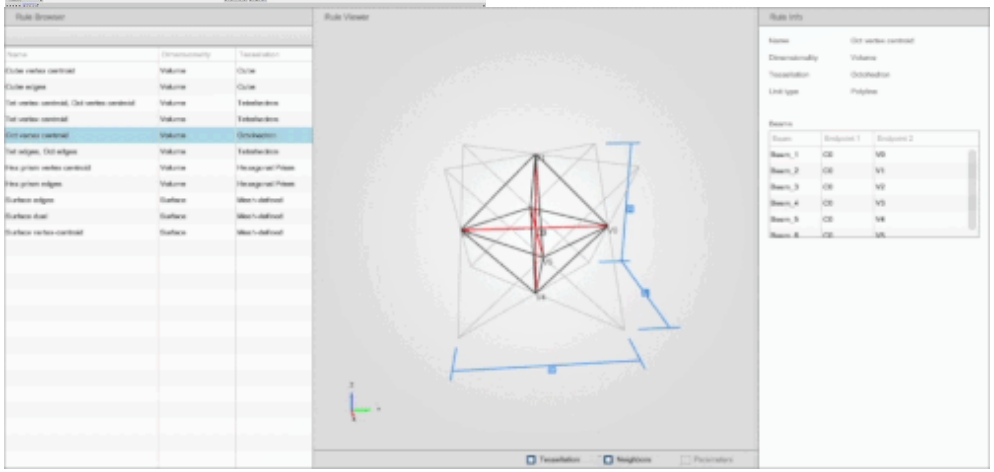
3. Designing parts for additive manufacturing is truly disruptive

nTopology

Additive manufacturing design software enables property gradients to be engineered into parts



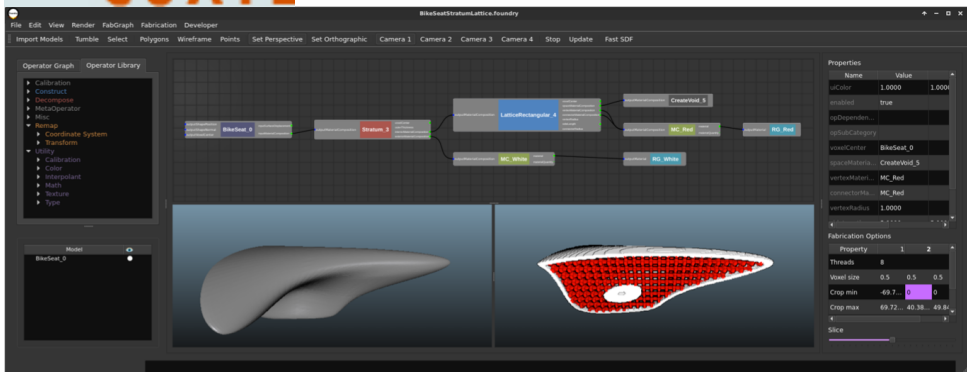




Materials design and manufacturing disruption creates opportunities

1. Service-based business models thrive
2. Material selection, form factor, and recycling innovations
3. Designing parts for additive manufacturing is truly disruptive
4. Democratization of software maximizes open design benefits

MIT's Foundry is a software tool for designing 3D printable parts with complex multimaterial structures; intuitive interface makes user-friendly for non-experts (*"the Photoshop of 3D printing"*)



Materials design and manufacturing disruption creates opportunities

1. Service-based business models thrive
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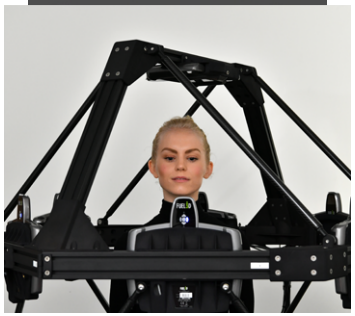
4. Democratization of software maximizes open design benefits
5. Leveraging 3D scanning:

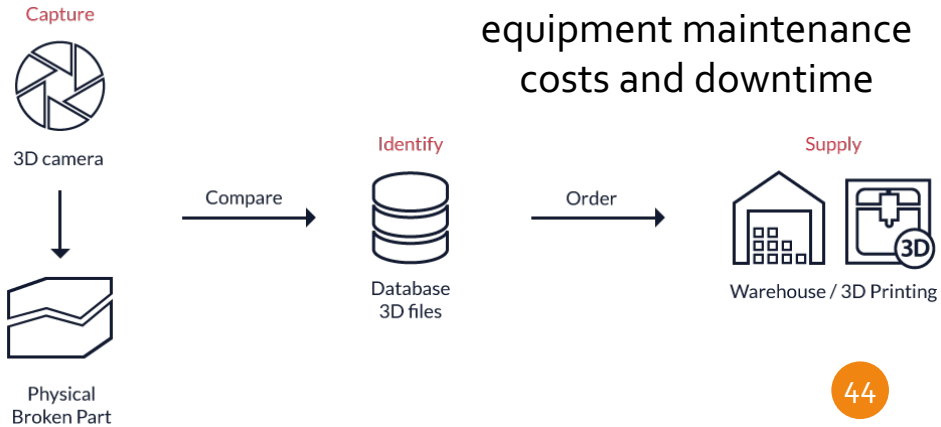
FUEL3D



3D scanning hardware platforms and modeling software creates dimensionally accurate 3D models of subjects with fine geometric detail and color; uses cases include custom fit eyewear, pre-surgery MRI scans, and custom orthotic insoles

pzartech

3D cameras and software tools ID and match parts to CAD files to reduce industrial equipment maintenance costs and downtime



Conclusions

- Materials ≠ products
- Design and manufacturing tools raise disruptive potential of materials technologies AND enable accelerated commercialization timelines
- Success in this integrated ecosystem requires open innovation strategy
- Act now!

Thank you

luxresearch

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