Successfully Transferring MEMS Process Flows from University Labs to Commercial Foundries

BSAC Seminar

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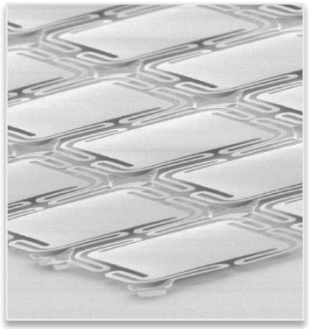
AMFITZGERALD
& ASSOCIATES

Overview

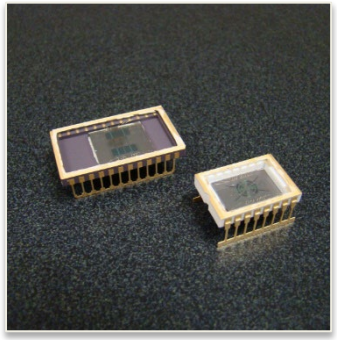
- About AMFitzgerald
- Stages of development
- Development ecosystems
- Are you ready for a foundry?
- Choosing a foundry
- Transfer to a foundry

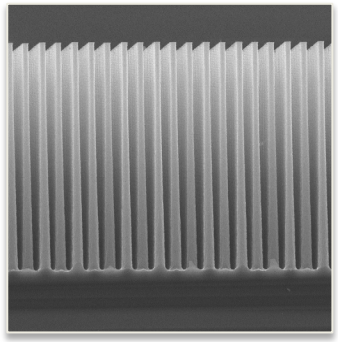
AMFitzgerald: Your partner in specialty MEMS and microtechnology development



AMFitzgerald develops innovative MEMS and sensor solutions for specialty applications

We collaborate with our customers to create high value products enabled by customized microtechnology





With integrity, expertise, and attention to detail, we deliver what has never been done before

Our product development services get clients to production and to market

NASA Technology Readiness Level (TRL)

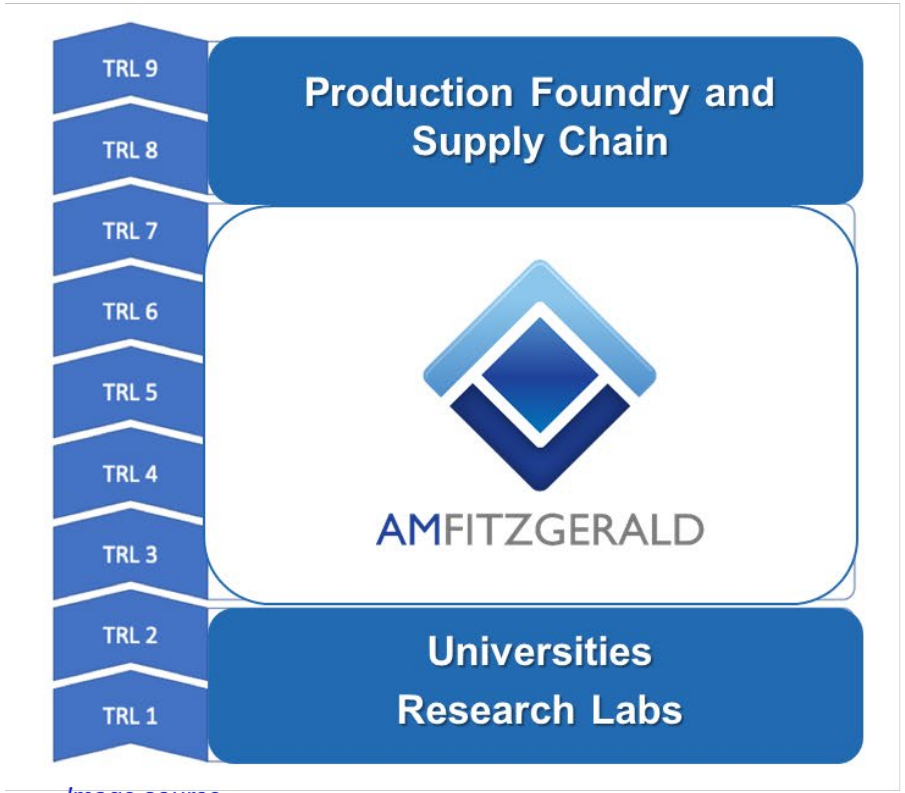
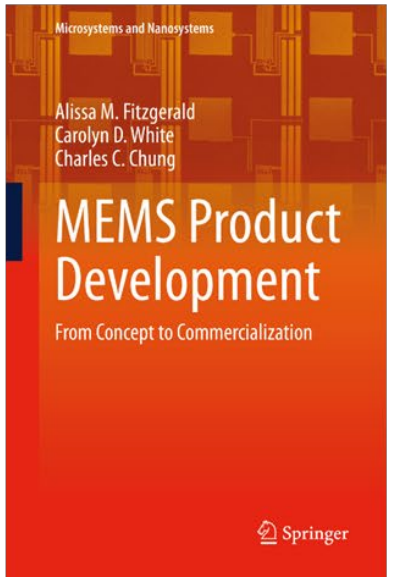


Image source

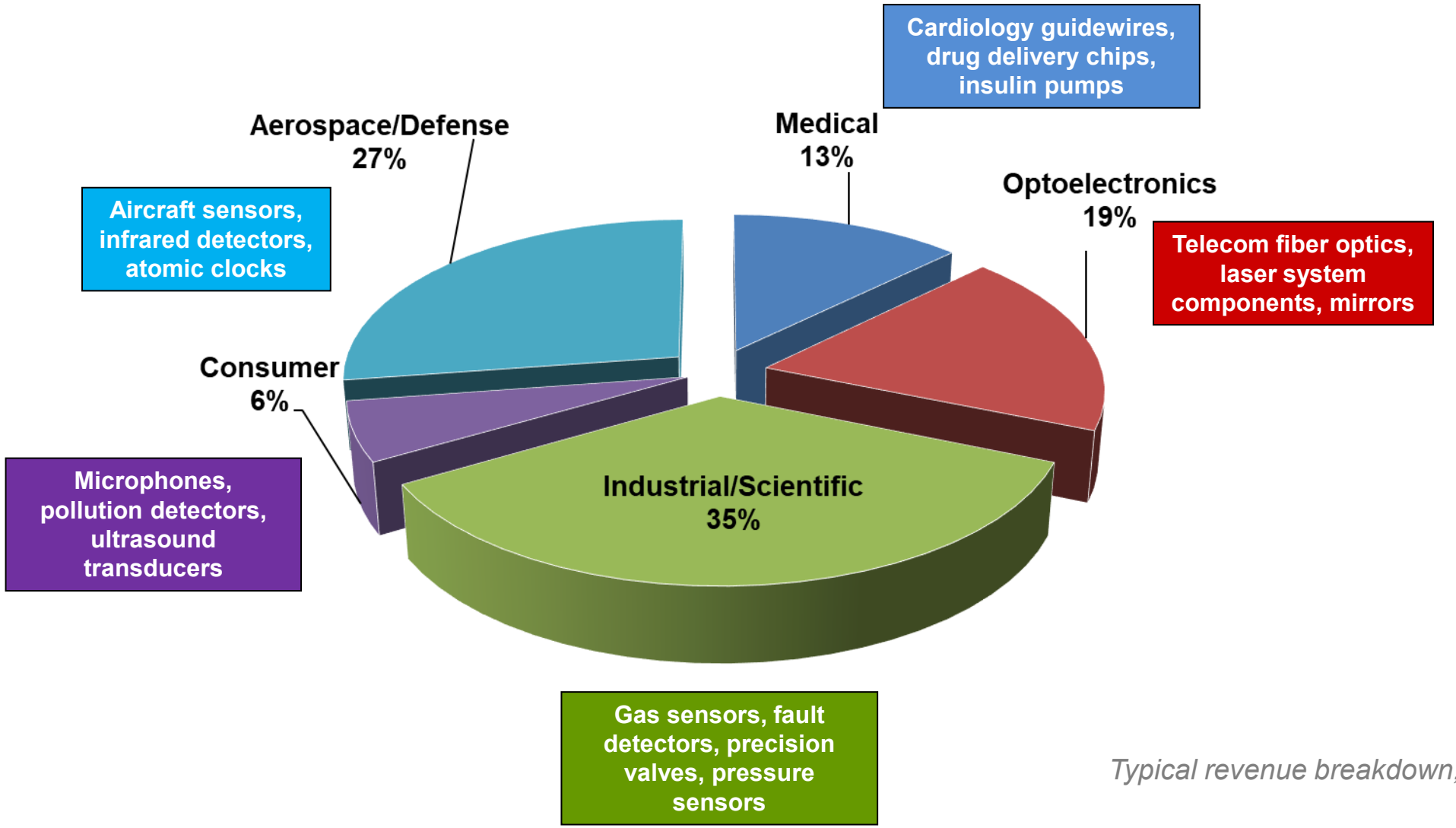
AMFitzgerald bridges the development gap (TRL 3-7)

We have worked with clients all over the world



The topics we are presenting today are covered more extensively in our book.

Our custom MEMS designs enable products in high value markets



Typical revenue breakdown, by market

Stages of development

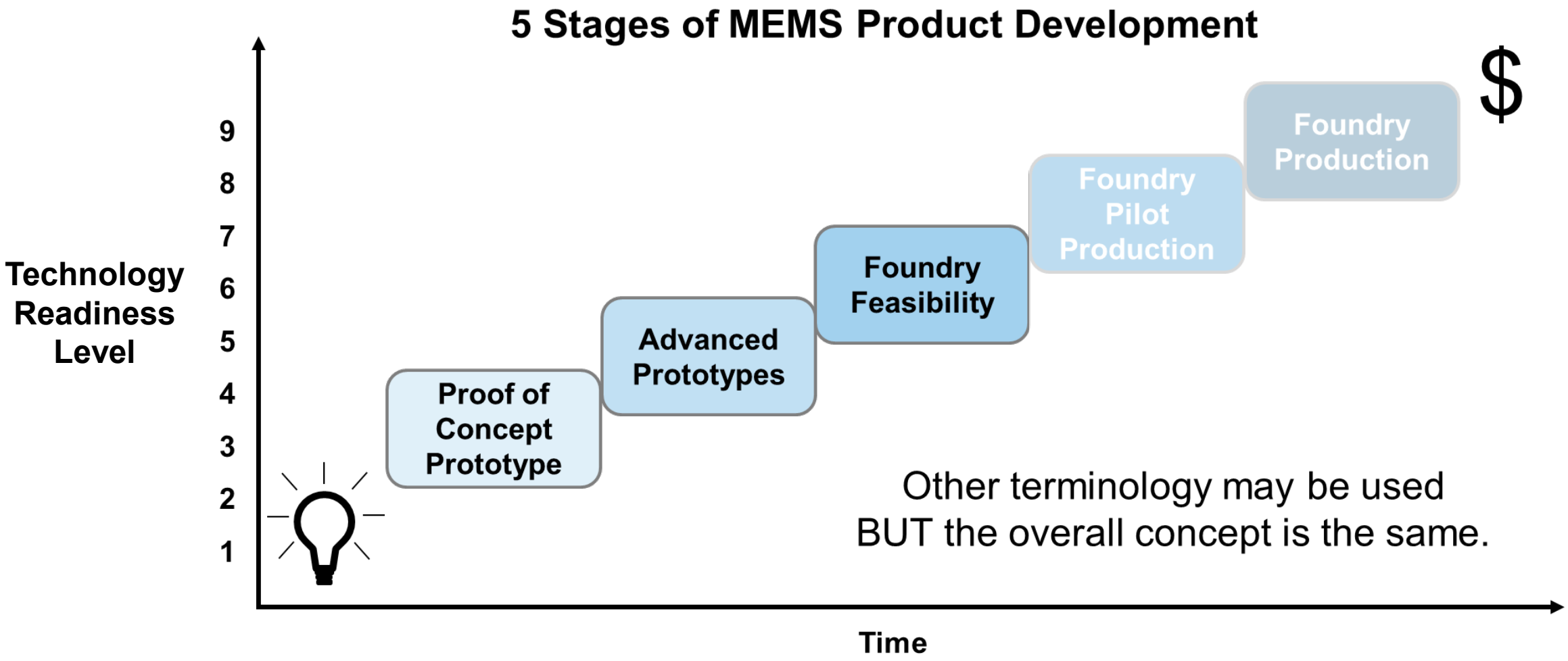


Figure 3.1 *MEMS Product Development*

The #1 reason our startup clients do not advance to volume production is…

They don’t have enough resources (cash) to make the long journey.

The technology usually works!

But it needs <u>a lot</u> of money and time to perfect.

Minimum to reach production of a MEMS-based product

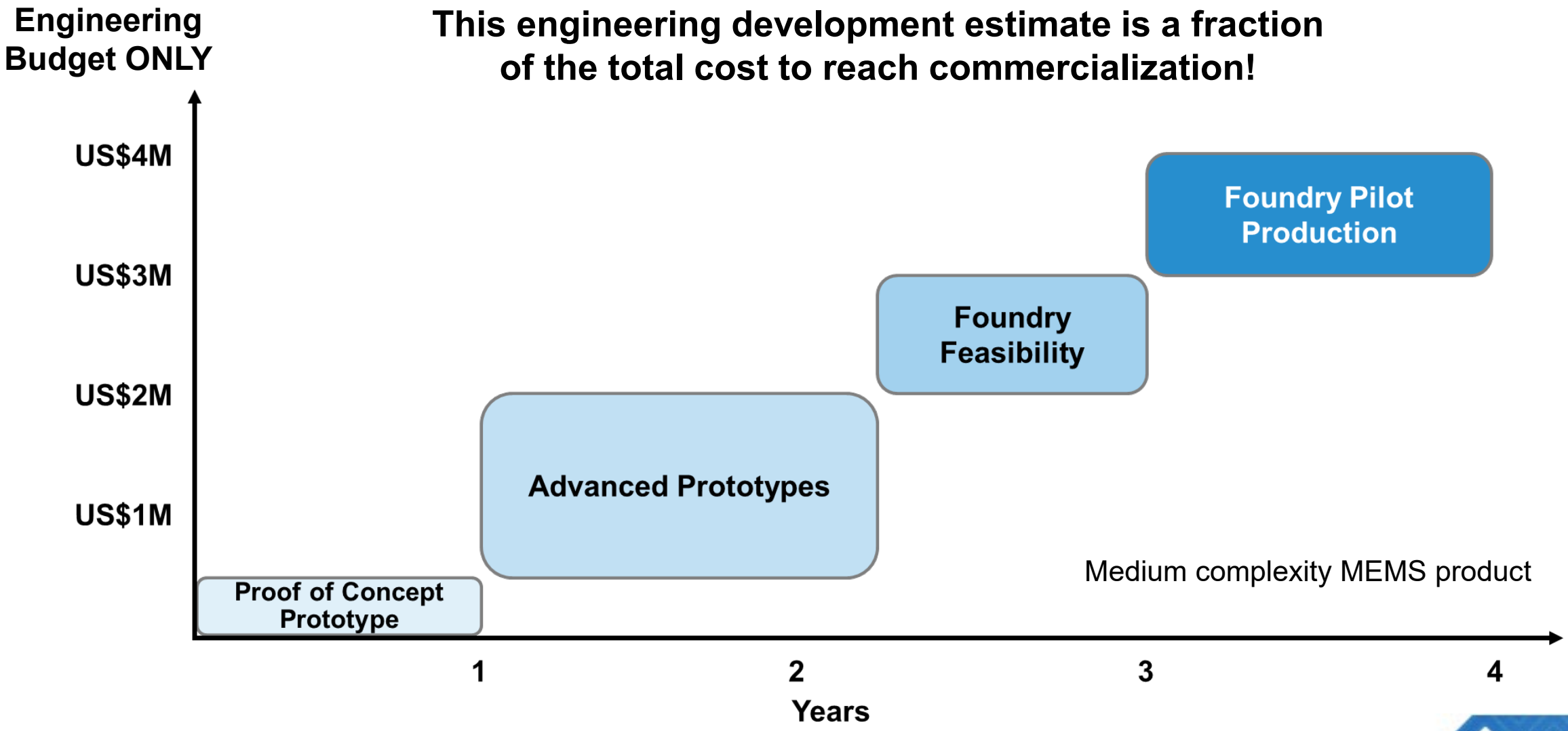


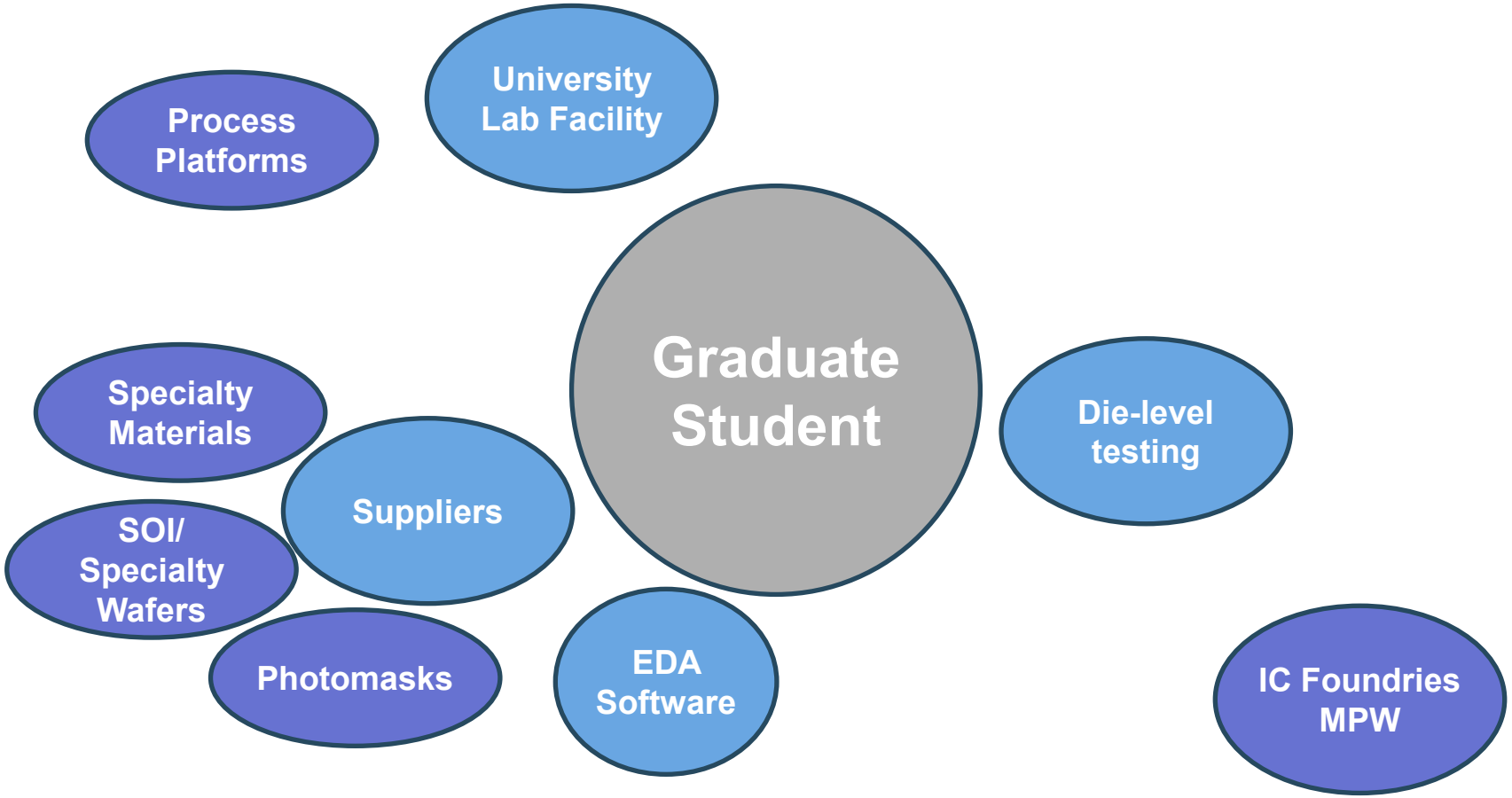
Figure 3.3 *MEMS Product Development*

The #2 reason university startups do not advance to volume production is…

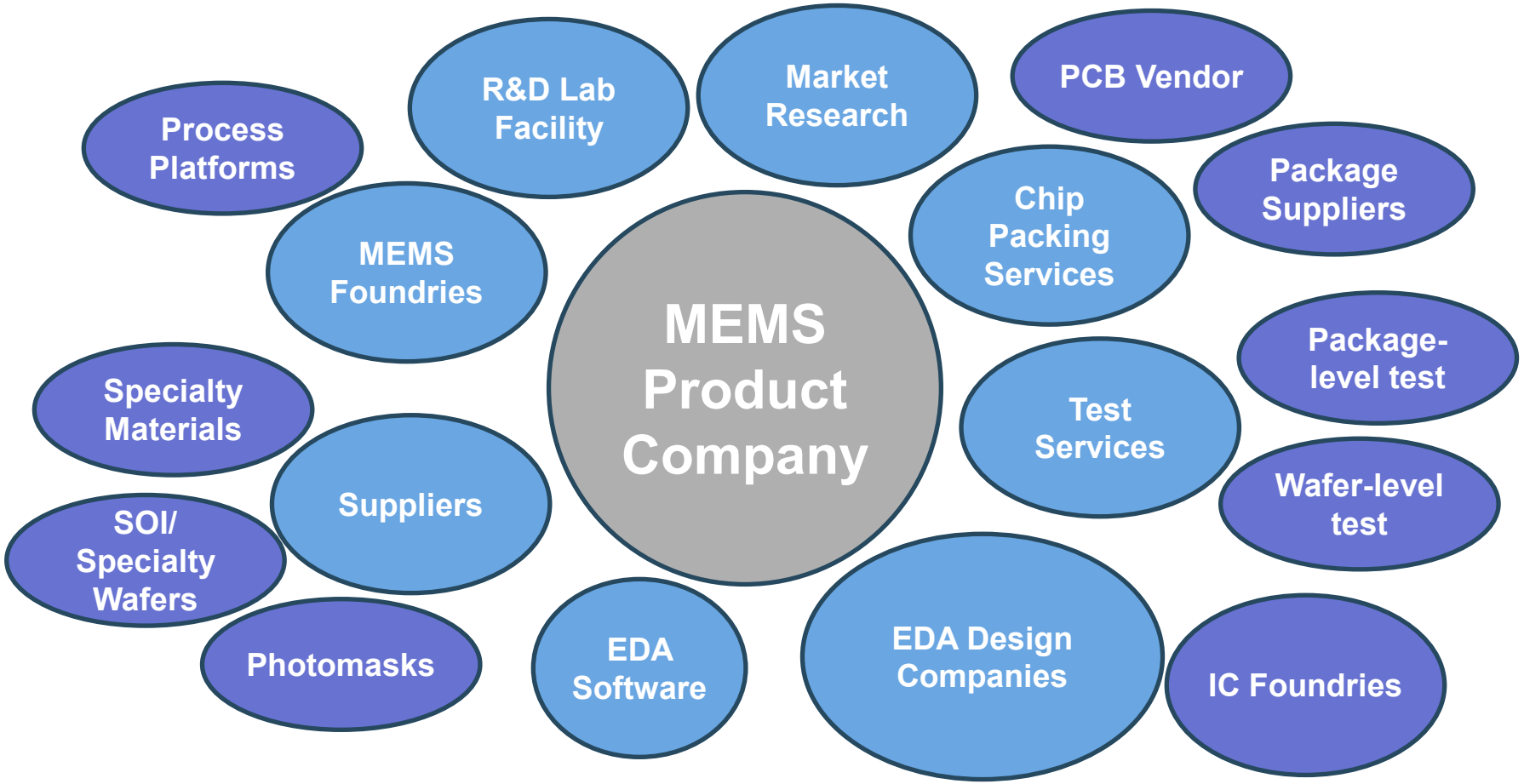
due to mismatch in expectations regarding necessary technical development.

The proof-of-concept fabrication at a university is VERY different than foundry production.

Typical University MEMS ecosystem

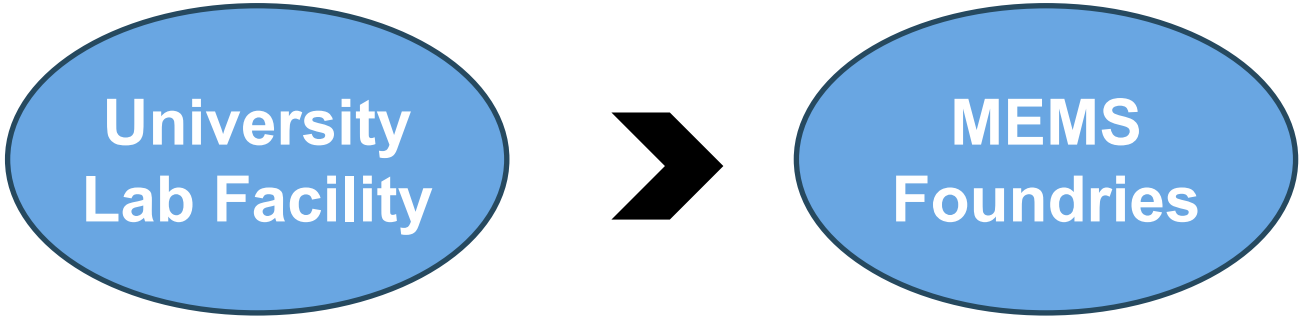


Typical MEMS startup ecosystem



Assembling this ecosystem takes time and resources

Access and communicate prototype design and process decisions



- Did you make any process or design decision based on
  - available toolset,
  - having more time than money,
  - or to publish/generate IP?
- Can your process be repeated by another MEMS process engineer?
- Have you documented *applicable* lessons learned?
- Do you have any yield data?
- Communicate that you have:
  - a working proof-of-concept prototype
  - AND what challenges need to be addressed.

Are you ready to go to foundry?

- **YES, if you have:**
  - **Stable process flow and mask set**
  - **Budget (> $1M/yr.)**
  - **Order schedule for next 1-2 years (i.e. customers)**
  - **Cost targets**

Example: Startup Production Order Schedule

Production	Number of Wafers	Target $/Wafer
Year 1	500	$1500
Year 2	1000	$900
Year 3	1500	$700

- **NO, if you:**
  - **Are still exploring the physics of your devices and trying to improve them significantly**
  - **Need Design of Experiments to characterize your device behavior (i.e. many design variants)**
  - **Don’t yet fully understand what design/process conditions create a “good” device**
  - **Have not yet secured > $1M in funding (just for MEMS fabrication)**

Information needed for foundry search and transfer

- **Process of record (POR) documentation includes (at a minimum):**
  - **Mask layout (GDS)**
  - **Written process flow**
  - **Critical process tolerances**
  - **2D cross-section**
- **Additional information can include:**
  - **Images (optical or SEM) of each process step**
  - **Design and process flow history with lessons learned**
  - **Options for processing with different toolsets**
  - **3D renderings**
  - **Sample die**
  - **Test requirements**
- **Business information includes:**
  - **Wafer volume requirements (provided to foundry)**
    - **Steady state production estimate and ramp schedule in the next 1 to 3 years**
  - **Unit cost requirements (used to assess foundry quotes)**
    - **Depends on wafer size, device size, process yield, assembly yield, performance yield**
  - **Conditions that could limit foundries options, e.g. location, possible competitor, etc.**

Choosing your foundry

- **The foundry is your partner in a long-term relationship**
- **Switching foundries = starting over ($$$ and time)**
- **Take time and care to make a good decision!**
- **You may need to educate investors – bigger and well known is not always the best fit**

"I think this is the beginning of a beautiful friendship."

AMFitzgerald's foundry selection process

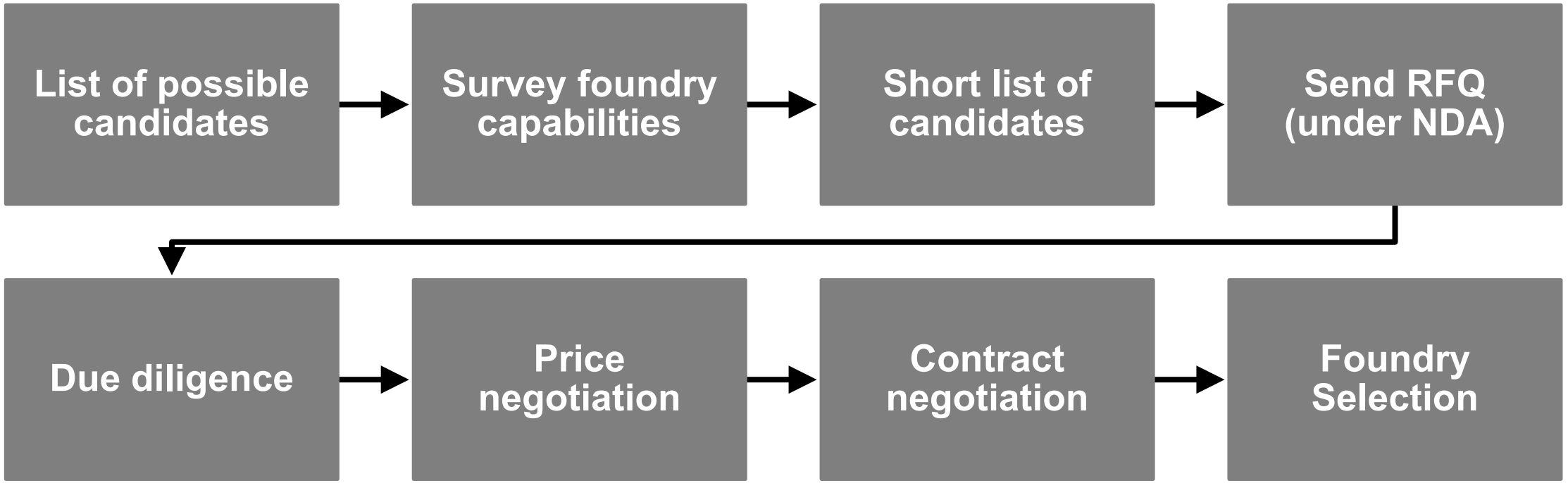
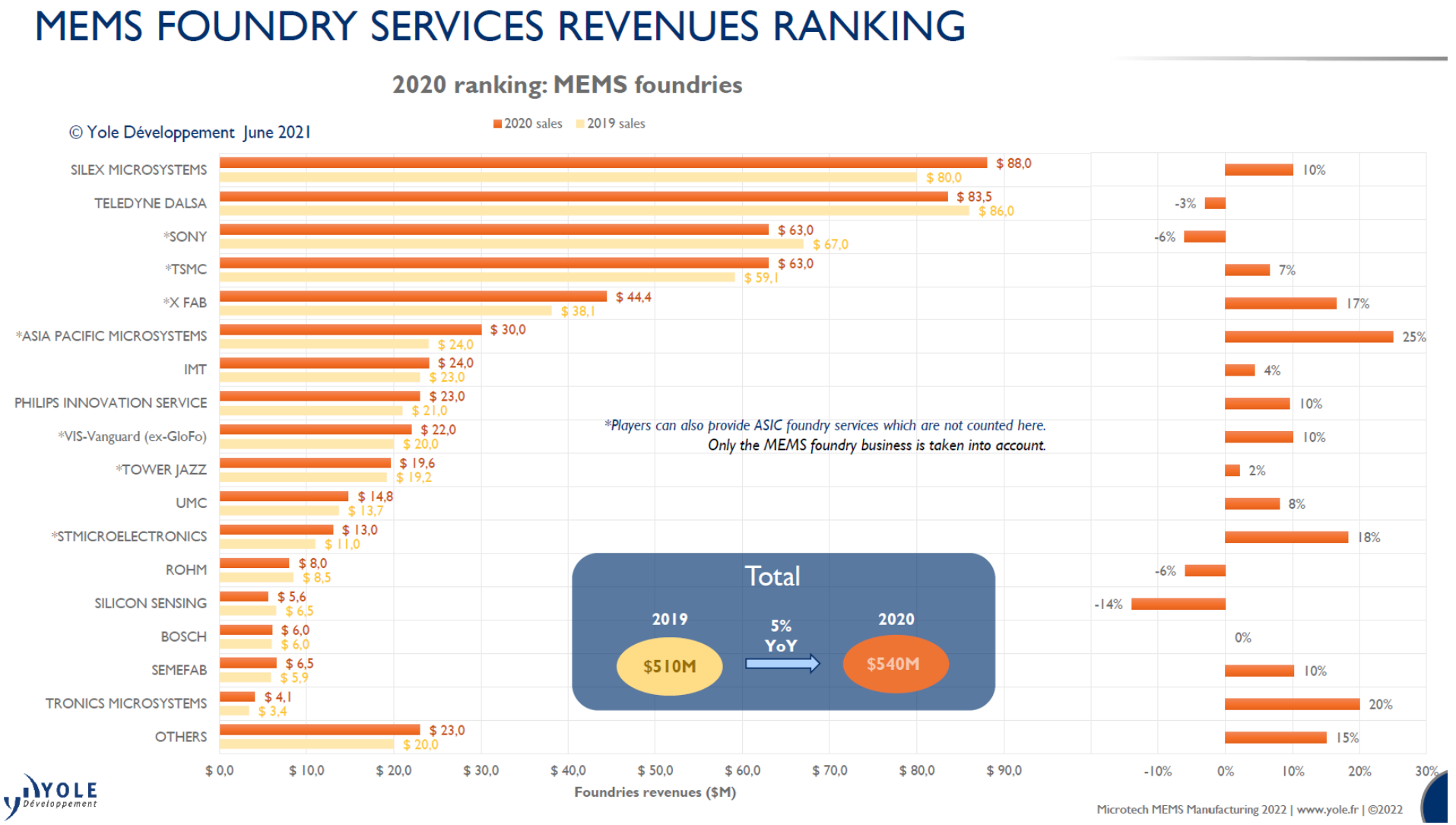


Table 18.1 *MEMS Product Development*

Largest MEMS foundries

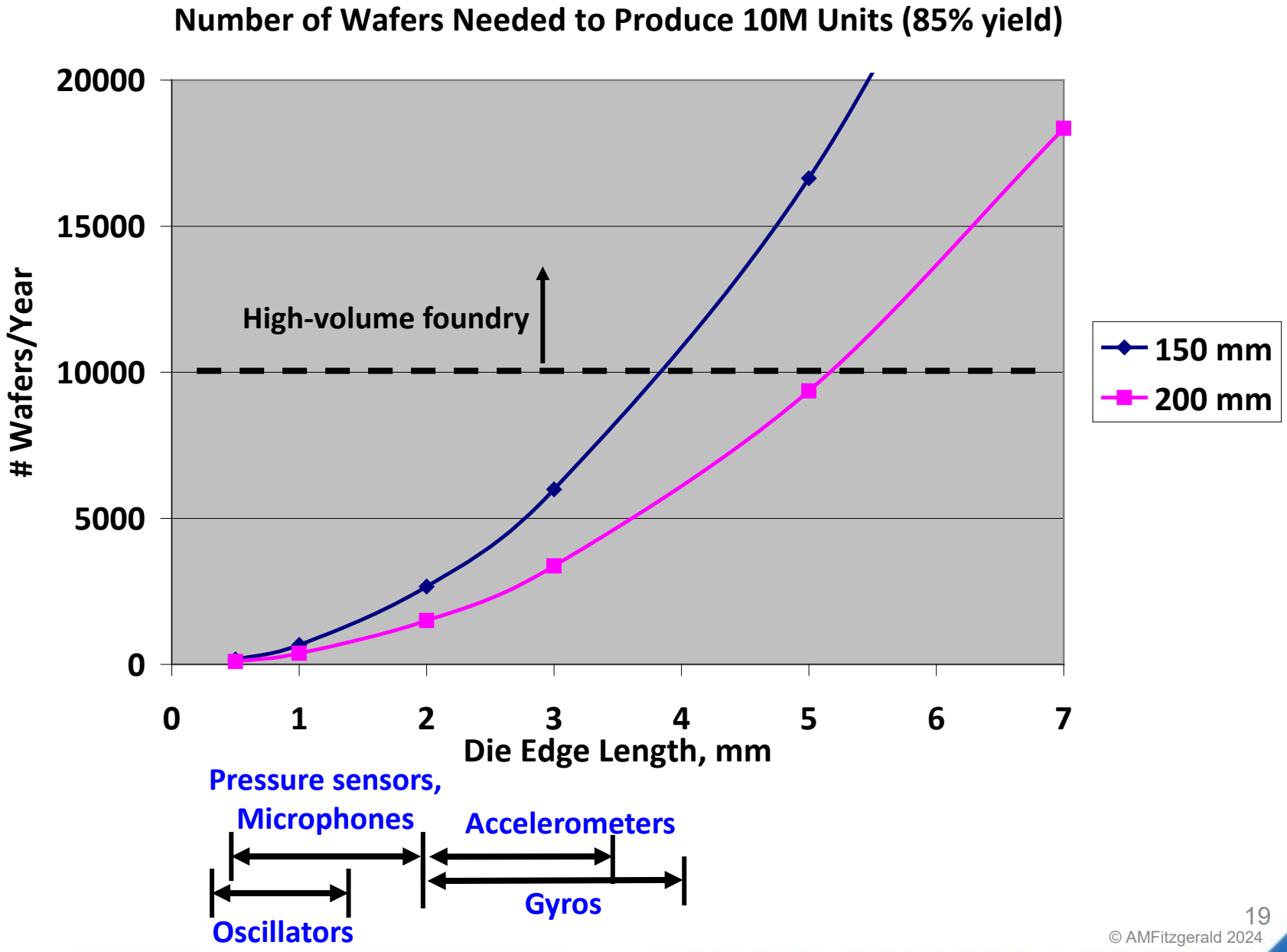


Example foundries for smaller wafer orders (< 100 wafers/year)

- INEX (UK)
- LioniX (NL)
- Micronit (NL)
- Microfab (DE)
- MEMS Core (JP)
- Rogue Valley Microdevices (US)
- Science (f.k.a. MEMSCAP) (US)
- Teledyne Scientific (US) – 4 inch

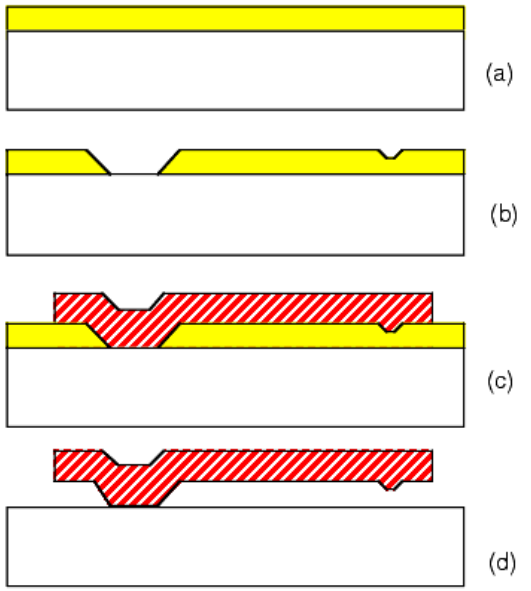
- Larger foundries may charge a premium for small orders

Not all MEMS will need 200mm wafers



First steps after creating short list of candidate foundries

- **Sign Non-Disclosure Agreement**
- **Write RFQ "Request for Quote" document**
  - **Device drawings, process flow, test requirements**
  - **Order quantities, cost targets**
  - **Business case**
- **Send RFQ to multiple foundries**
- **Engineering review with each foundry**
  - **Their feedback can save you $ and time!**
- **Discuss quote with each foundry's sales team**

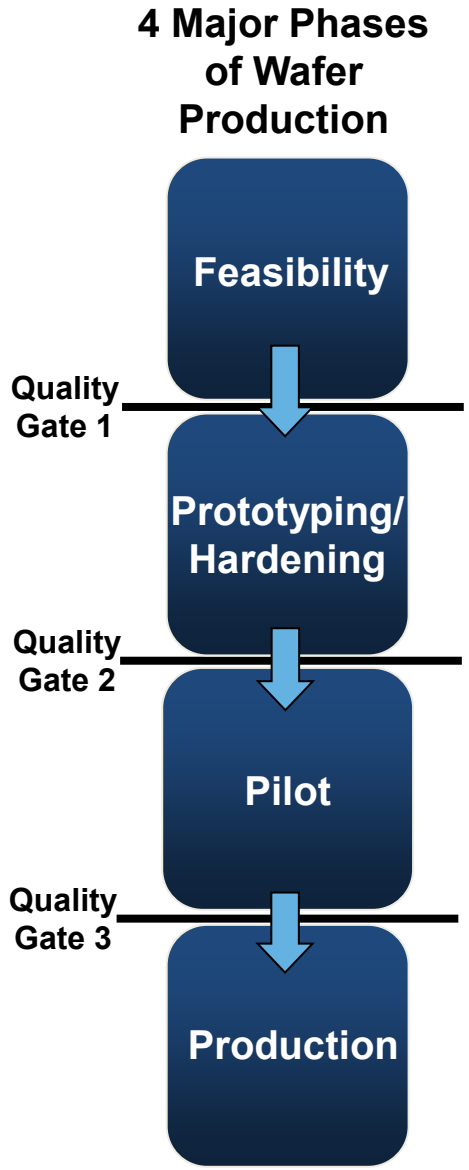


Process Flow Description

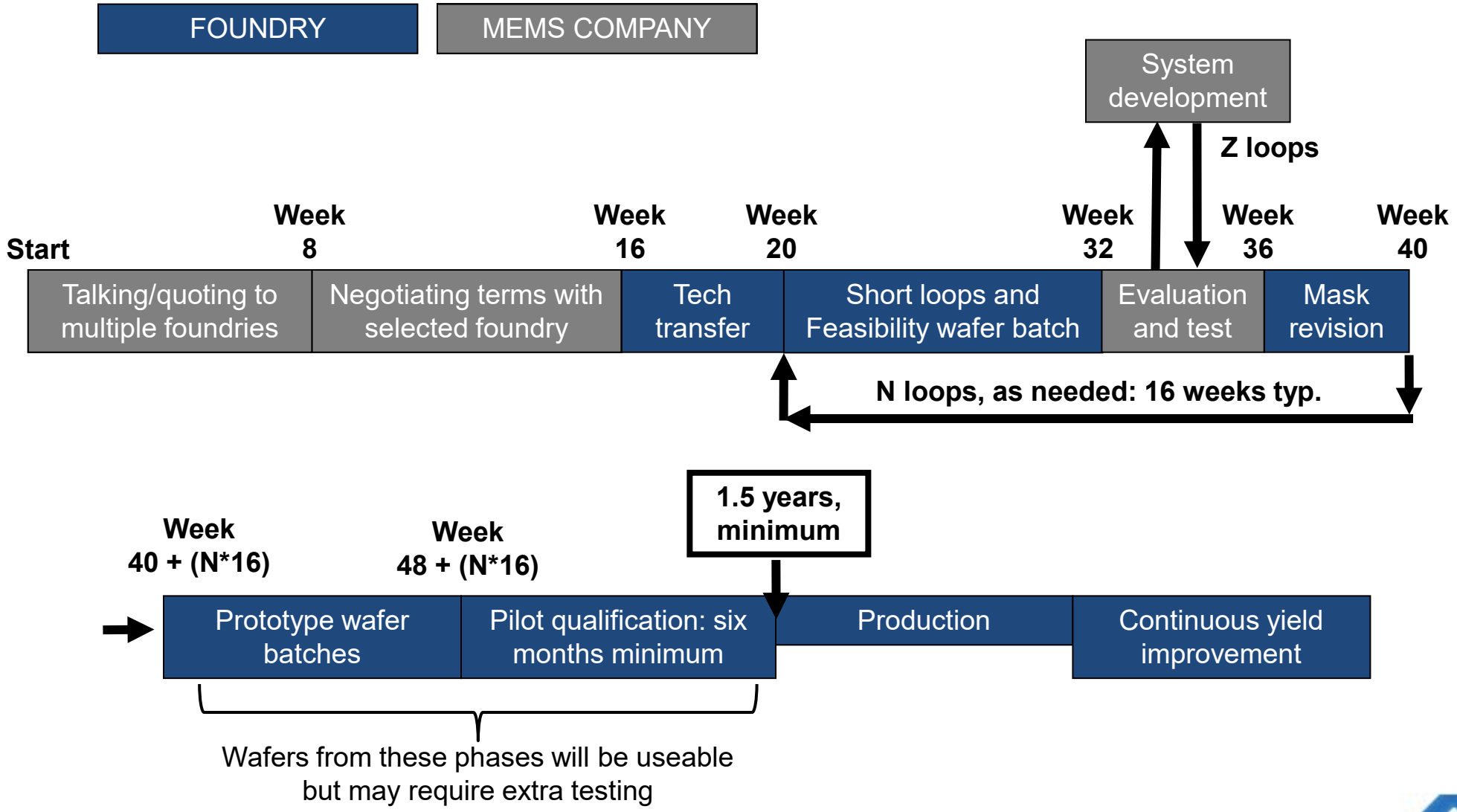
The foundry quote

- **Quote will be for Feasibility phase only, with estimates for Prototype, Pilot phases**
  - **NRE: masks, setup, shortloops**
  - **Wafers**
  - **Batch size minimum 10 wafers started**
  - **Priced per wafer or batch**
  - **No yield guarantees (“best efforts”)**

- **Typically – multiple Feasibility batches required before moving to Prototyping/Hardening phase**



Ramp to production timeline (with an existing prototype)



How to get the best prices

- **Low technical risk keeps NRE low:**
  - **Frozen design/process**
  - **Repeatable process**
- **Confirmed order quantities keep wafer prices low:**
  - **The more you order, the cheaper it gets**
- **Show a path to volume**
  - **Foundries want to crank out wafers, not do engineering projects**

Making a decision

- **Evaluate foundry's process capability and experience with your type of product**
- **Make sure you have compatible:**
  - **Business models**
  - **Timelines**
  - **Expectations**
  - **Quality standards**
  - **Product volumes – ideally, don't want to be smallest or largest customer**
- **Visit prospective foundries to meet their teams and see the facilities in person**
- **Select for best fit, not lowest price**

The foundry will be evaluating you, too!

- Are you a stable company?
- Are you well-funded?
- Do you have established customers?
- Do you know what you are doing?
- What are your growth prospects?

- Present your business well, don't make them dig for information

Closing the deal

- **Initial deal:**
  - **Price**
  - **Contract terms**
  - **Purchase order**
  - **Down payment**

- **Longer term:**
  - **Supply agreement**
  - **Acceptance terms**
  - **End of product life purchase**

Successful technology transfer and ramp up

- **Provide process documentation foundry:**
  - **Die layout in .GDS**
  - **Runsheet, process data**
  - **Lessons learned**

- **Dedicate an engineer to be foundry liaison**
  - **Transfer tech info to foundry**
  - **Monitor wafers in progress**
  - **Troubleshooting**
  - **Visit foundry**

- **Timeline and budget management**

- **To get the best results, be a teammate to your foundry**

Rookie mistakes

- Only quoting one foundry
- Expecting to go to production in less than a year
- Not presenting a good RFQ or business case
- Not discussing your process tolerances with the foundry
- Not understanding the differences between development and production fabrication mindsets
- Twiddling design/process midstream
- Being underfunded
- Lack of communication with foundry

Development to production mindset shift for experienced process engineers

Development	Production
• You are the person processing the wafers and therefore have access to all the process information	• You are 2-3+ people removed from the person processing the wafers and will not have access to all process information (by design!)
• Process timelines are subject to your personal capacity	• Development process timelines are subject to production capacity
• Design variants are for performance characterization	• Design variants are for process hardening/tolerances
• Test wafers and/or broken wafers are kept in case additional testing is needed later in the process	• Test wafers and/or broken wafers are not kept for backup purposes after a process module is collected

Development to production mindset shift for experienced process engineers

Development

- Available process risk mitigation strategies include:
  - Split lots
  - Staging wafers
  - Parallel processing
  - Look ahead wafers
- Process flow changes can be made on the fly – within a process step, process module, process flow…
- You are focusing on device performance first, increasing yield second
- OK to have breaks between process runs

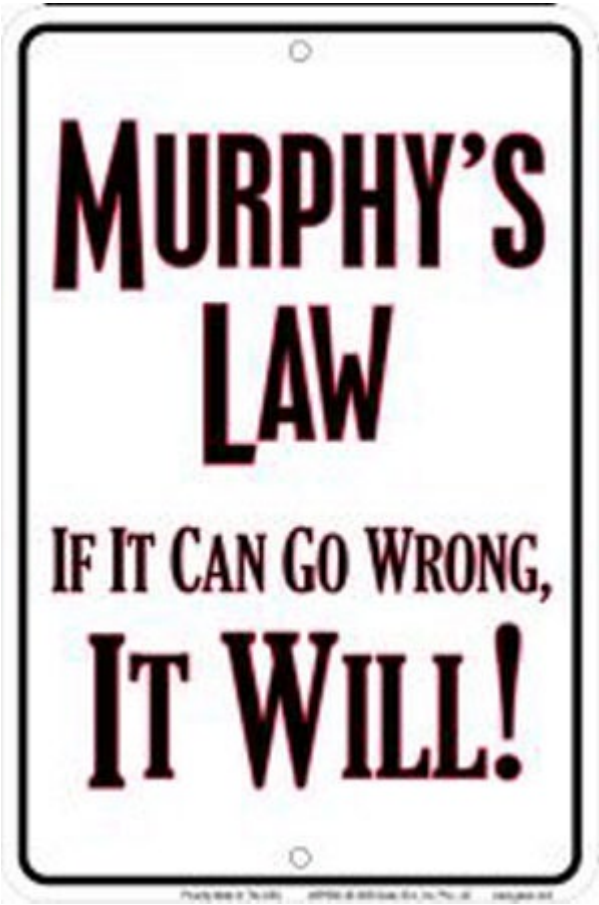
Production

- Available process risk mitigation strategies include:
  - Staging wafers (feasibility)
  - Parallel processing (feasibility/prototyping)
  - Look ahead wafers (within process module)
  - Note: Most foundry wafer tracking systems are not set up for split lots
- Process flow changes are usually done between lots and can require documentation and approvals
- The foundry is focused on process dependent device and wafer yield – based on mutually agree upon specifications
- Expect processing to continue to production without major pauses

Fabless challenges

- **“Golden Wafer” fixation**
  - **Just because you made one great wafer in the past, doesn’t mean it can be easily duplicated**
  - **You don’t have a device technology dialed until you have identified all the knobs and their settings**

- **Murphy lives in the fab**
  - **Bad, weird stuff will happen, guaranteed**
  - **Will you partner with your foundry to solve it, or play the blame game?**

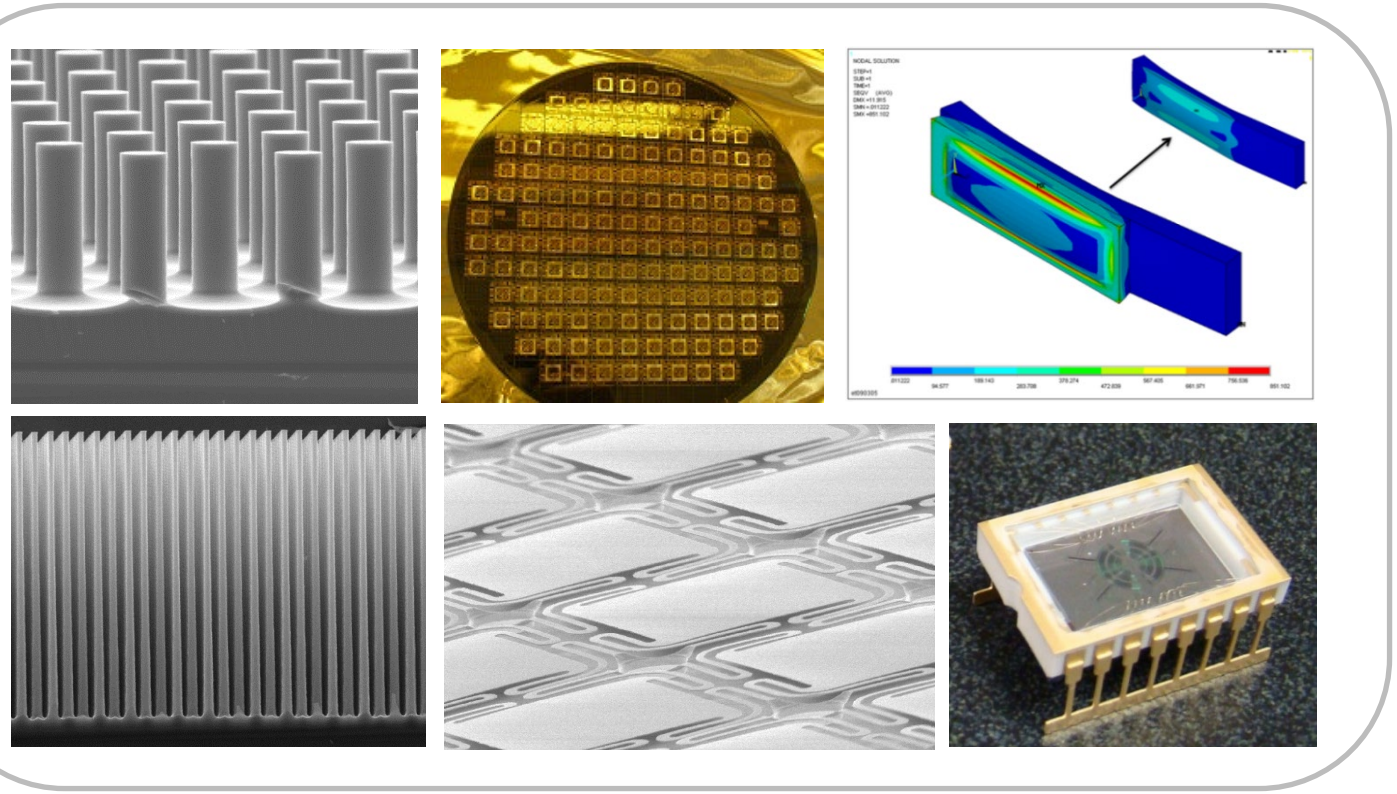


Summary

- **Selecting a foundry is an extremely important business AND technical decision**
- **Don’t underestimate time and money involved**
- **Carefully assess the necessary development to move from a university environment to a production process**
- **Document your process for transfer**
- **Get quotes from and visit multiple foundries**
- **Pick the foundry for the best fit, not the lowest cost**
- **Work with the foundry and expect modifications for production purposes**

Questions?

MEMS Product Development **available now in hardcover or e-book from Amazon (USA) or Springer (Int'l)**



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