Example Diligence report
Heron Scientific, Inc.

Overall Risk-At-Maturity: High

Company's technology development efforts are ahead of their investigations into customer discovery and scaling, and this leads to significant execution and market risks. Company's technology base does seem solid, and they have developed proof of principle devices and are technically capable researchers. However Company does not have enough data to support their proposed development budget and timeline and market projections, and there are significant concerns that they will slip.

Recommend that more effort be placed on investigating barriers to manufacturing and barriers to market before investment.

Background:

Company is developing a low-cost MEMS resonator (*application confidential*). This resonator is intended to be lower performance than existing devices, and the company believes there will be a market for this low cost/low performance technology.

The differentiating aspects of their resonator are:

- **High temperature stability enables advanced MEMS packaging**. Their resonator uses [*confidential*] as the resonating element. These resonators are more thermally stable than competing elements, and this thermal stability enables the use of high temperature wafer level packaging (WLP) methods in the fabrication of the device. These WLP efforts can yield packaged devices at lower cost than competing methods, which require individual sealing of chips. **These cost advantages associated with moving to WLP represent the single biggest advantage of their designs.**
- **Reduced cost silicon**: They have a design that is made using a single-mask silicon-on-insulator (SOI) process using bulk micromachining, which will provide lower cost MEMS devices than conventional processes that use surface micromachining and which require as many as 15 masks. This is a secondary cost advantage of their design.
- **Roadmap for further silicon cost reductions**: Company is considering switching to a lower performance resonator using [*confidential*], which yield wafers at still lower cost then the bulk micromachining technique described above. The design may also yield smaller die to further reduce device costs. This process will also use a WLP process, and a shift to smaller die can have a big price impact once WLP is already implemented.

What is Risk-At-Maturity?

Risk-At-Maturity is a metric that encompasses a company's readiness for investment, relative to the stage of technology development they are in. The ideal company will have a balance of efforts confirming that their technology is differentiated and can be brought to market to eager customers. The level of proof required should reflect the maturity of the company, but in all cases there should be a balance between the technical, production, and market efforts.

Color code

- (Green) Progress is promising and stage-appropriate
- (Yellow) A solution is possible, but concerns exist about achieving it on time/budget
- (Orange) Significant information is needed to validate that this is achievable
- (Red) A roadblock exists, and no investment should be made until this is removed

Technology summary: Company

(Green)
Is the idea technically viable?
Company is entering the market with a low cost, low performance device. Their approach is aligned to this goal, and it seems viable for them to produce a device at lower prices than competitors, if sufficient volume is achieved.

(Orange)
Will it be competitive?
Company did not provide any customer interview data or competitive pricing data to establish their position relative competition in the marketplace. This is concerning.

(Yellow)
Is it scalable?
The technology platform, once developed, uses a scalable CMOS-friendly MEMS process that is suitable for high volume production. However, the MEMS vacuum packaging process they intend to use has only been scaled by a single company, so in practice it will take years for them to scale to high volumes.

(Red)
Are they likely to execute according to their time/cost plan?
Their execution plan is high risk, as it requires their vendor to develop a MEMS vacuum packaging process for the first time. Comparable packaging programs have required higher costs and more time than what Company is budgeting.

(Orange)
Overall score
Company needs to present far more detailed plans from their MEMS packaging vendor to demonstrate that they can deliver their next milestone on time and on budget, and that the vendor will be able to scale it at an acceptable unit price. Company also needs to establish that the technology and price point they have targeted will be valued by customers, and that they will be profitable at these price points.

Suggested diligence actions (prioritized list):

1. Contact Z-Fab, get details on their current process to establish the likely time and budget for full manufacturing release of the MEMS vacuum process
    - Process flow of Z-Fab, with SPC data for each process node
    - Reliability test plan
    - Plan for singulation and mounting of individual devices
    - Estimated timetables for manufacturing release
2. Contact Z-Fab, discuss pricing for the development phase and long term contractual arrangements to ensure that Z-Fab does not capture all of Company's profits
    - What are the milestones on the development program?
    - What are the costs associated with each milestone?
    - Is Z-Fab willing to bid this partnership at a fixed price?
    - Is Z-Fab willing to have contractual incentives for on-time delivery?
    - What will the long term pricing of this process node be, as a function of volume?
    - Can Company port this process to another fab?
    - Will Z-Fab offer an exclusive for use of their vWLP process for the Company's applications?
3. Conduct customer discovery sessions to assess demand for low cost, low performance parts and develop a market requirements document
    - Identify three component-level customers
    - Identify three system-level customers
    - Conduct discovery interviews to clarify who will be purchasing these devices, and for what applications
    - Draft market requirements document, including performance (sensitivity, etc.) and price
    - Draft technical specifications document drawing from these market requirements, and confirm that the current designs can meet these technical specifications

This plan should be revisited after the above actions have been obtained, and the process repeated to generate a revised risk assessment.

Risk analysis methodology:

Below I present the top two risks identified in this initial analysis. More risks exist, and a full process audit and FMEA will be needed to explore them all. Both myself and Prof. X broadly agreed that these are the most significant risks based on our current knowledge.

I have divided the risks into four categories:

1. ***Performance***: Are there scientific/technical questions about whether the stated process can achieve its state goals? Subquestions in this category include:
    - Has a prototype been built that meets requirements?
    - Can this prototype be built repeatedly at this specification?
    - Will the design be reliable in the field?
2. ***Cost/Schedule***: Is this really going to be done according to the time and budget specified? Subquestions in this category include:
    - How much experimentation is needed to develop this process/technology?
    - How much time is required for each learning cycle, and are there steps that can be taken to shorten this time?
    - If the schedule starts to slip, can we add or re-allocate resources to get it back on track?
3. ***Contingency***: Is success in this process contingent on other processes, or vice-versa? Subquestions in this category include:
    - If this process/technology fails, is there a back-up plan?
    - If another process/technology changes, do we have to re-do this from scratch?
    - If this process/technology changes, do we have to re-do other processes from scratch?
4. ***Business*****:** Do the business goals align to the technical plan? Subquestions in this category include:
    - Are there trade-offs between technical parameters that will impact market acceptance?
    - Does completion of the task impose business limitations such as a sole-source contract or partnership?
    - Are there regulatory implications to the process/technology?

For each identified risk, a mitigation plan is proposed that has the potential to reduce the risk from its stated value. Examples of mitigation include:

- Completion of an FMEA to more comprehensively identify technology concerns.
- Creation of a milestone-based investment plan to eliminate major risks without investing a full round of funding
- Re-organization of the technical plan to focus on improving the rate of learning

Risk #1: Achieving a stable vWLP process
Company requires a commercially scalable vWLP process to make a cost-competitive device. Company previously contracted with the MEMS foundry Y-Fab to produce vacuum packaged parts, but these parts leaked and the investment was lost. Company has expressed readiness to develop a new partnership with the MEMS foundry Z-Fab, who they believe has a superior process to IMT.

Performance: Good
A vWLP process has already been commercialized by Invensens that meets Company's performance and reliability requirements. This is doable.

Budget/Schedule: High Risk
While Company has demonstrated their process in-house, an entirely new process must be developed by their partner Z-Fab for use at Z-Fab. We do not currently understand how mature Z-Fab's process is, and how much investment or time will be required to make a manufacturing-approved process.

Mitigation: Z-Fab needs to share their budget and timeline for delivery of a vWLP process for full production release. They will need to provide process documentation and test plans. It is possible that their process is more mature than I currently understand it to be; we need to ask. The more risk that Z-Fab is willing to take on (in the form of fixed price deliverables rather than engineering investment, and schedule-based pricing), the lower the cost risk will be.

Contingency: High Risk
All of Company's products require vWLP in order to achieve the cost points necessary for market acceptance. The value of the Company MEMS design is contigent on achieving low costs thanks to vWLP; there is no back-up plan to a vWLP failure, and all of Company's assets will lose value if we cannot make vWLP work.

Mitigation: If possible, the vWLP risks should be dealt with before a other large investments are made.

Business: High Risk
vWLP is not a common MEMS process; in fact, it has been commercialized by only one company, Invensense. If Z-Fab does deliver, they would be in a position to charge at a rate that would undercut Company's objective to produce a low-cost, profitable device.

Mitigation: Contractual agreements with Z-Fabs, including long term costs, should be made prior to investments in process development, as each step down the road increases Z-Fab's leverage over Company. Company could try to negotiate to own and transfer the process elsewhere, for example, though Z-Fab is likely to resist. To achieve its long term goals of low cost, Company will have to bring on a second or third source to bid against Z-Fab (and this will take more time and investment as these other fabs bring up their own processes).

Risk #2: Moving to a next generation low cost design
Company has indicated a desire to move from their current resonator to a lower cost, lower sensitivity solution. This lower cost has been demonstrated in the lab, and will be lower sensitivity than their existing approach. It saves cost because it does not use the SOI process that their current device employs, and may be easier to process (this is not clear to me, however).

Performance: Risky
It is not clear whether a desirable cost/performance trade-off can be achieved. The approach seems sensible and it should be functional at some performance level. Their approach should be transferable to an outside fab for production, but we did not cover these risks in detail.

Mitigation: A market requirements document is needed to identify what the necessary performance metrics are.

Budget/Schedule: Moderate
The background technical information provided by Company was for its design. The requirements for their new design do not appear to be difficult

Mitigation: A process flow and FMEA for their new design would highlight the risks.

Contingency: Risky
Changing to a smaller footprint will impact the vWLP process. There will likely be a smaller amount of chip area to bond to, and that could affect yield or reliability.

Mitigation: If we decide that we want to invest in vWLP to de-risk it, we will have to decide whether to invest in the new chip design at the same time. Going forward with vWLP with and old design will de-risk vWLP, but we would have to re-prove the process again with a smaller chip once it is ready, which means greater total costs. However, spending on the new chip design in parallel with vWLP means that this money could be wasted if vWLP fails.

Business: High Risk
We do not yet understand whether the performance of the device will be acceptable to customers, and what the market value is.

Mitigation: More market detail is needed to justify the pivot. Customer interviews should be requested to validate this decision; these documented examples of customer interest will allow for direct customer diligence.