Developing an Enduring Manufacturing Infrastructure

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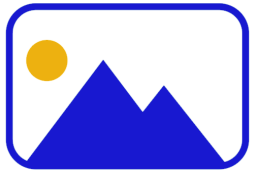


Mountain View Energy

Introduction

- Issue: Most emerging process manufacturing start-ups lack the relevant tools for success.
  - Lack of ideal manufacturing technology.
  - Lack of capability to define and create equipment/processes to support the technology.
  - Reduces chances of success.
- Constraints:
  - Market/technical needs difficult to anticipate over the time period required to develop the technology.
  - High resource cost and short time horizons for start-ups. Cannot tolerate failure.

Concept

- Solution:
  - Create foundational manufacturing technology development program (FMT).
- Goal:
  - Train a workforce that anticipates and develops the tools for manufacturing technologies.
  - Develop expertise in foundational technologies that enable new manufacturing paradigms.
- Concept:
  - Develop a line (small scale) using existing technology to manufacture product as a baseline.
  - Piece-by-piece insert ideal capabilities to test and supplant existing technology.
  - Engage students in all aspects of the program: decision making, design, debugging, analysis.

FMT Advantages

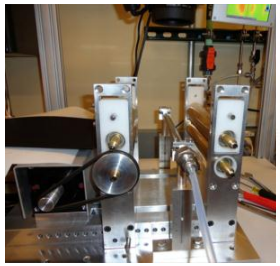
- Build enduring workforce
  - Graduates immediately move into the workforce and contribute to fundamental technical manufacturing problems.
- Trade knowledge and intellectual property
  - Creates accessible intellectual property.
  - Creates a local pool of trade knowledge.
  - Promotes insight and support for local companies.
- Commercial support
  - Permits multiple attempts with small investment.
  - Tolerates uneven rate-of-progress.
  - Provides a robust platform as markets evolve.
  - Resource for industry to solve time-consuming issues.
  - Minimizes the potential for private capital loss.

FMT Program Components

- A pervasive underserved technology issue for manufacturing.
- Educational plan
  - 1.5-2 year student commitment. Overlay cohorts.
  - Project based; goals shift over time and build on prior efforts.
  - Maximize student decision-making and contribution.
  - Pursue multiple solutions in parallel using design competitions.
  - Judgement oversight by executive staff.
- Technical plan (see next slide)
- Resources
  - Facility/space to set up baseline and foundational technology line(s).
  - Access to product analysis/testing (internal or external).
  - Access to equipment fabrication capabilities (internal or external).

FMT Technical Plan

- Plan
  - Specify real and ideal products.
  - Specify a real and ideal process flows.
  - Perform product gap analysis.
  - Perform process flow gap analysis.
  - Build baseline and test.
  - Debug and improve tools for process technologies.
- Considerations
  - Evaluate and decide methodology for make versus buy.
  - Specify and design process tools / technologies.
  - Understand how to integrate tools.
  - Set program milestones based only on technical accomplishments.



Courtesy AMO, DOE, 2015.

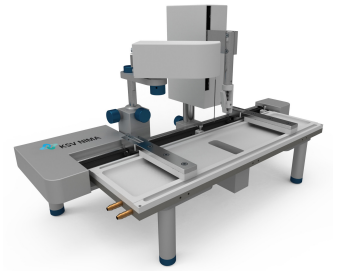
FMT Program Lifecycle

- Lifecycle stages
  - Line creation
  - Baseline process development
  - Foundational technology invention and refinement
  - Technology insertion and testing
  - *(Iterate until ideal line is achieved)*
- Educational plan
  - Teach all components
  - Project types
    - Planning and analysis
    - Technology development and assessment

List of Potential Foundational Manufacturing Technologies

- Separation and purification techniques.
- Controlled atmospheric processing.
- Surface polishing (roughness control).
- Hierarchical self-assembly.
- Customizable fabrication.
- Resource reduction in manufacturing (materials, energy, waste).
- Dissimilar and zero-clearance joining.
- Bio-mimetic structures.

Courtesy GH Group, 2017.



Courtesy Biolin AB, 2017.