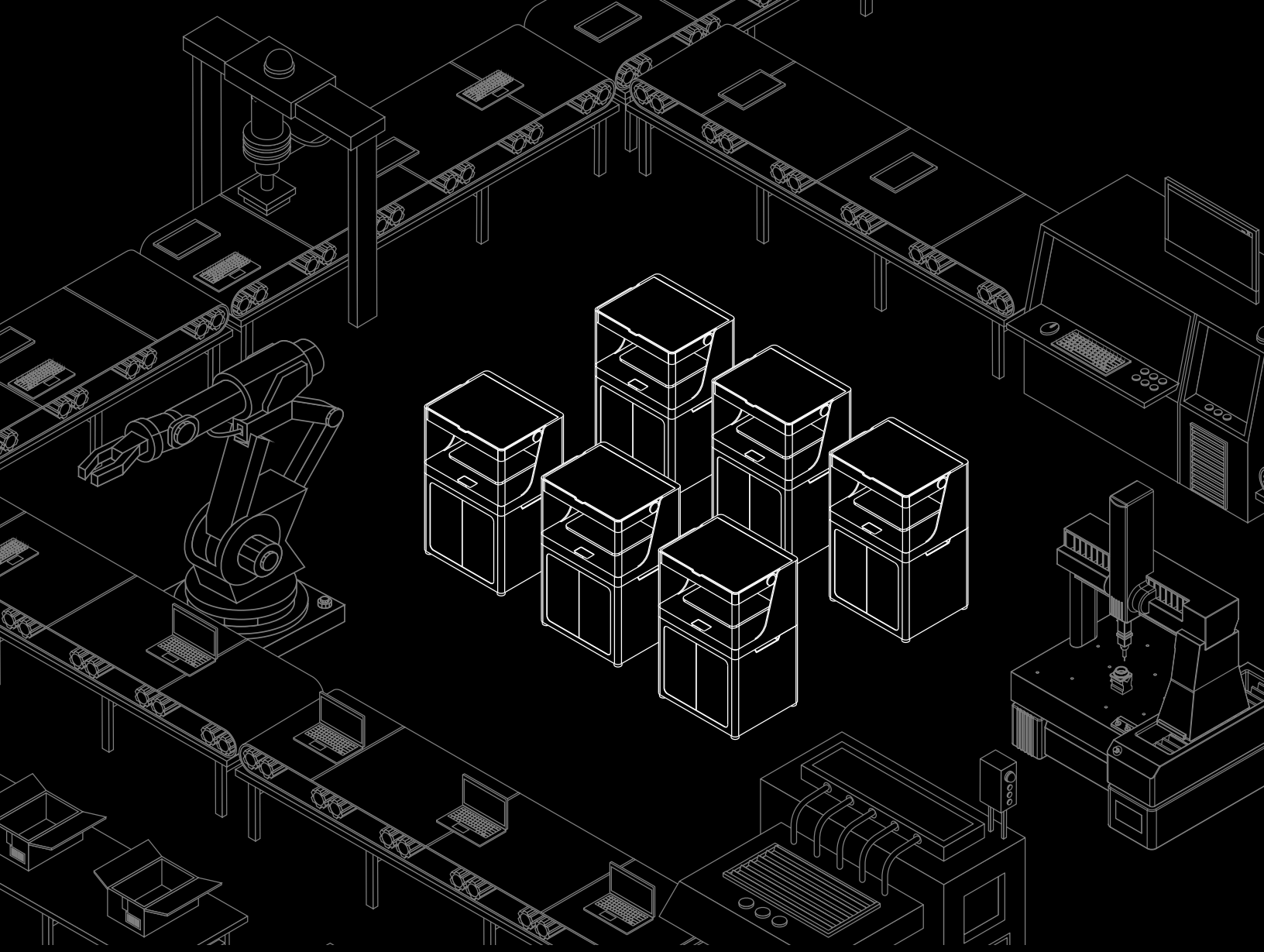


MARKFORGED WHITE PAPER

GUIDE TO 3D PRINTING ON THE PRODUCTION LINE

Many manufacturers have realized significant cost savings and productivity improvements by integrating high strength additive manufacturing (AM) technology into their business, especially in support of their maintenance, repair and operations (MRO) strategy. For many more, identifying where additive will be most impactful to their business can be a daunting task, and increasingly one that corporate leadership has directed plants to investigate. This white paper provides structure and clarity to that task by demonstrating strategies and applications for integrating high strength AM opportunities on the manufacturing floor.

Markforged

MARKFORGED.COM

IDENTIFYING OPPORTUNITIES

Additive manufacturing (AM), or 3D printing, has been hailed as the future of manufacturing for years, but despite a torrent of media anticipation, widespread manufacturing of end-use production parts via AM has not materialized. When compared to high volume manufacturing, the economics for AM are less attractive — relatively slow print times and high unit costs will never beat the massive production capabilities of high speed processes like injection molding. Instead of using it to replace existing processes for end-use production, manufacturers can leverage high strength AM to complement existing technologies in their maintenance, repair, and operations (MRO) efforts, dramatically reducing the cost of factory tooling.

There are three key identification paths to discovering the cost savings of high strength AM in your MRO toolkit. Viewing your operations through these lenses can help identify the high value opportunities in your process, which can form a strong foundation when building a return on investment (ROI) analysis of your AM strategy.

PAIN POINTS & COST DRIVERS

Pinpoint root causes for process inefficiencies, equipment failures, and line-down scenarios.

FACTORY APPLICATIONS

Identify key components of factory workflow that could benefit from shorter lead times and lower cost.

MATERIALS IN MRO EQUIPMENT

Determine materials in MRO equipment that could be easily matched by high strength 3D printing.

Start with Your Workforce

The most powerful resource in discovering opportunities is your people. Heads of engineering or manufacturing supervisors are likely familiar with cost drivers and operational efficiency. Technicians close to the manufacturing line have an intimate knowledge of the repair and maintenance requirements. Designing for additive comes with a learning curve, but identifying opportunities to reduce tooling costs with AM in your factory is straightforward.

PAIN POINTS & COST DRIVERS

Unplanned line shutdowns due to equipment failures are some of the most costly aspects of a manufacturing process. Identify applications for additive technology on your factory floor by going to the source of the challenges that keep you up at night — manufacturing steps that frequently stop or slow production, or are expensive to fix. High strength AM can be used to quickly produce replacement parts or custom alignment jigs, making these challenges excellent starting points for building your AM strategy. Once you've identified areas of focus, building an ROI projection for your AM strategy is simple, as you'll have already calculated the cost of production failures. Identify key drivers in the following categories:

STEADY-STATE PROCESS INEFFICIENCY

Throughput rate differences between processes and other standard operating inefficiencies cause bottlenecks even when a line is running normally. Guides, assembly fixtures, and transfer tooling are simple tools that can vastly improve line throughput with additive manufacturing.

LINE CHANGEOVER & STARTUP INEFFICIENCY

Line changeovers, calibrations, or configuration changes can cause productivity inefficiencies due to lost uptime when initializing a line. Printed tools like calibration jigs and mounting fixtures for machine setup can expedite the time it takes to get your production lines running smoothly.

PRODUCT BREAKAGE & WASTE

Line failures that cause the products they are manufacturing to fail or break can result in waste and unplanned downtime of entire manufacturing lines. Custom line add-ons can reduce these failures and improve machine efficiency.

UNPLANNED DOWNTIME SCENARIOS

Unplanned downtime occurs due to breakage or miscalibration of equipment fundamental to the process, resulting in low or zero production rates. Print replacement parts and maintenance tools to keep downtime at an absolute minimum.

PROCESS INEFFICIENCIES

Cardboard Engineering

A recurring source of line inefficiencies is what many manufacturers call 'cardboard engineering': solutions to configuration challenges that utilize cheap and temporary materials like duct tape, zip-ties, and plastic sheet. These are cheap solutions to line roadblocks, but the line configurations they help calibrate is lost between changeovers. This leads to time-consuming startup calibrations that hinder plant productivity. Compare this with AM solutions, which can produce unique parts with integrated alignment features for quick and simple positioning during line changeovers.

OPPORTUNITY IDENTIFICATION

FACTORY APPLICATIONS

Many manufacturers have found success driving down tooling costs in their factories by leveraging high strength AM. Use the application categories they have uncovered as a guide to similar applications in your operations:

MACHINE SETUP

Calibration jigs as well as machine repair and maintenance tools improve line startup efficiency when getting production up to speed.

FIXTURING & POSITIONING

Inspection fixtures, soft jaws, assembly jigs, and other workholding devices require alignment features that can be hard to machine.

LINE OPTIMIZATION

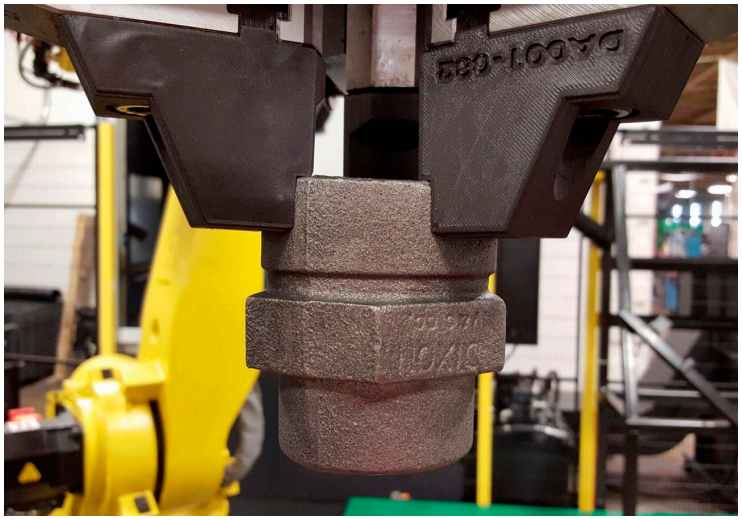
Custom end effectors, line add-ons and upgrades, and even ergonomic and operator equipment can improve line efficiency and operator safety.

Many of the largest cost saving AM opportunities in manufacturing are produced in low volumes when compared to the number of parts they are used to produce. This is the foundation of saving with AM, as small batch tooling is a leading driver of cost and inefficiency across many manufacturing fields.

CUSTOMER SPOTLIGHT

Dixon Valve Robotic End Effectors

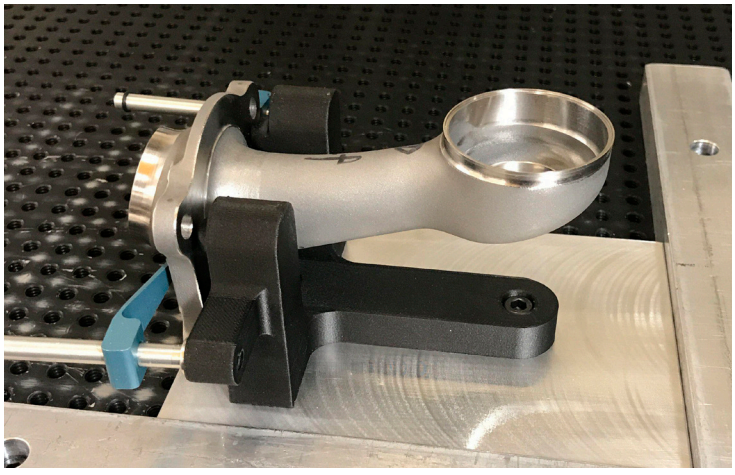
Hose and pipe fitting manufacturer Dixon Valve & Coupling sees massive cost savings by integrating Markforged printers in their factory. After a push to implement automation solutions across their production line, engineers from Dixon Valve's Advanced Manufacturing Engineering Team produced additively manufactured custom transfer tooling for robotic arms in their manufacturing cells, saving the company an average of more than $36,000 per project to date.



CUSTOMER SPOTLIGHT

Duke Manufacturing CMM Fixtures

Duke Manufacturing employs AM to build coordinate measuring machine (CMM) and laser marking fixturing for inspection and serialization of highly contoured parts. Traditional manufacturing can't keep pace with Duke's highly complex fixturing, but integrating printers from Markforged enable Duke Manufacturing to respond quickly to customers' demands while remaining cost-competitive to the industries they service.



OPPORTUNITY IDENTIFICATION

MRO EQUIPMENT MATERIALS

One of the broadest ways to discover potential cost reductions with 3D printing in your plant is to search for a few key plastics and metals that are common in MRO parts or manufacturing tooling. These standard materials have properties that are readily matched or exceeded by modern high strength AM materials, sometimes in combination with commonly available commercial off-the-shelf (COTS) components. In particular, you should focus specifically on critical parts and equipment with frequent use of the following materials:

COMMON ENGINEERING PLASTICS

Delrin® (acetal resin), Ultra High Molecular Weight (UHMW) Polyethylene, and nylon are a few engineering plastics standard in manufacturing for their wear resistance and toughness.

COMMON METALS IN MRO

Aluminum, stainless steel, and tool steel are some of the core metals used in MRO equipment used for their high mechanical strength and stiffness, but they can be costly to manufacture.

Once you've identified MRO equipment using these materials, you can start considering what properties they need for their applications and how AM can help. The strength, toughness, and wear resistance properties that make these materials ideal for the factory floor can be replicated or exceeded by those of Markforged printed composites, often in conjunction with inexpensive COTS parts. Fixtures, guides, custom mounting hardware, and other low volume applications in these materials can be produced with AM at low unit cost, without any of the required workholding setups that make complex machining operations slow and costly.

MATERIALS IN EQUIPMENT

UHMW Manufacturing Cradles

Parts like this UHMW cradle for manufacturing industrial vehicle frames can be slow and costly to produce for many manufacturing departments. These types of tools and materials are excellent opportunities for additive manufacturing on production lines. A high strength 3D printer, like one from Markforged's Industrial Series line, can make quick work of such a part, with mechanical strength and toughness far exceeding UHMW.

MARKFORGED WHITE PAPER

INDUSTRIAL 3D PRINTING

Modern manufacturing requires new tools and new perspectives to maintain a competitive edge. Additive manufacturing can dramatically lower the cost of tooling and parts used in maintenance, repair and operations. Many manufacturers have seen huge improvements to the competitiveness of their operations by leveraging high strength AM solutions like Markforged's Industrial Series printers. These fully instrumented machines enable rapid manufacturing of tooling and MRO equipment tough enough for the rigors of plant floors, all while driving down tooling cost and lead time by an order of magnitude. Advanced printing materials, including continuous strand carbon fiber filament, reinforce parts to achieve strengths exceeding aluminum 6061-T6, and enable geometric complexities beyond the capabilities of 6-axis machining centers — all controlled by a powerfully simple printer management software that requires no CAM or NC programming. The Markforged Industrial Series is a critical tool for cost reductions and capability improvements in your manufacturing strategy.

DISCOVER YOUR COST SAVINGS

See how Markforged can impact your business with our return on investment calculator.

markforged.com/roi-calculator/