America Makes

Driven by… NCDMM NATIONAL CENTER FOR DEFENSE MANUFACTURING AND MACHINING

Additive Manufacturing Technology Roadmap for Casting & Forging

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Executive Summary

Background

Cast and forged components lie at the heart of critical weapons platforms across the Department of Defense (DoD), providing a vital contribution to warfighter readiness for the United States. With a 67% reduction in the number of US foundries since 2000, the US Castings and Forgings (CF) ecosystem supply chain is dwindling. Accounting for offshoring and persisting economic headwinds, the remaining high-quality domestic purveyors of castings and forgings tend to prioritize high-quantity orders and customers. This problem is particularly exacerbated by the nature of legacy platforms, whose designs and processes were largely conceived, defined, and stored on paper. In tandem with the pervasive challenge of workforce availability, the challenges for the DoD to acquire low-volume cast and forged components pose a critical and enduring issue amid geopolitical turmoil.

This report defines a multi-year technology roadmap to develop and deploy Additive Manufacturing (AM) capabilities at scale to augment existing CF operations. The use of advanced technology, particularly that which poses compelling advantages at low production volumes, unlocks a crucial capability for the Defense Industrial Base (DIB) to respond to warfighter needs rapidly and in an economically viable manner. There are many examples of AM's benefit in principle and a few in practice, developed within siloed pockets of expertise over numerous years and at a significant cost. This effort recognizes the timebound need to rapidly scale AM capabilities out of the lab, beyond proof of concept, and onto shop floors nationwide. America Makes is poised to lead the way in delivering these capabilities at scale.

Approach

The roadmap has been intentionally shaped to be broadly applicable yet meaningfully specific. It has been structured for use across two manufacturing industries and all military branches, with products of nearly all risk levels, materials, sizes, and applications having been considered. The complexity of AM has been overlaid with these spaces to identify what sits at the intersection of need and capability, charting a path forward for how it can be achieved. These layers were navigated through a three-phased approach to gather data, construct execution plans, and validate the path forward. Diverse sets of experts across the CF and AM ecosystems representing Government and Industry stakeholders were strategically convened at each phase and across geographical regions. Extensive data collection from these collaborations has been supplemented by and compared against academic literature searches, subject matter expert interviews, production site visits, and DoD order data.

Roadmap

The roadmap comprises a portfolio of 21 projects and their execution plans over a 57-month duration. The underlying strategy is focused on deploying technology at scale. Within its scope, 40 material-process combinations and 52 individual components are assessed alongside 25 demonstrations to transfer key outcomes and five pilots to perform stress tests in production environments.

Executive Summary Continued

To realize the capabilities identified through this process, investment is required in four critical areas:

- **Scale Current State:** This group of projects aims to disseminate established technology beyond siloed pockets of expertise. The capabilities that these projects promote tend to be more mature compared to the Prove Production Capability Swim Lane
- **Prove Production Capability:** This group of projects seeks to mature demonstrated and emerging technology to meet production needs predictably. The capabilities that these projects promote tend to be less mature compared to the Scale Current State Swim Lane
- **Build Digital Foundation:** These projects will help establish an infrastructure for components and simulation models to drive agility and accelerated design cycles. As the name describes, these projects are foundational for the future deployment of advanced manufacturing technologies across the Defense and Organic Industrial Bases (DIB and OIB)
- **Supporting Efforts:** These projects centralize common activities across the projects in other swim lanes to drive the adoption of the developed capabilities. These projects standardize documentation, drive efficient delivery, and strive to build awareness and competency across the DIB and OIB

No Regrets Next Steps

Through the roadmap and the process of crafting it, America Makes has gained valuable insight into how development and funding should be positioned and delivered to impact casting and forging supply chains. With a path forward established, continued, and sustained investment is required to ensure that warfighter readiness is enabled by arming the CF ecosystems with accessible and capable AM solutions. To realize a broad and enduring national capability, continued focus is required to ensure technology development is transferred from demonstration to production, realized through three key next steps:

Lower Adoption Risk
While the benefits and potential of AM are well known, so are many examples of failed printing pilots. Many risks driving these failures are seemingly hidden as they sit adjacent to the printing process. Providing small and medium manufacturers with resources to make informed decisions on when to use AM and to upskill staff without major financial investment will support the broader adoption of AM technologies.

Invest in Technology Deployment
Implementing AM successfully requires much more than a capable printer. Continued focus on transferring key outcomes out of the lab and onto the shop floor is crucial to drive familiarity with AM and create true learning environments for users. Guidance for everyday process control should be established and provided as oversight to onboard new technology.

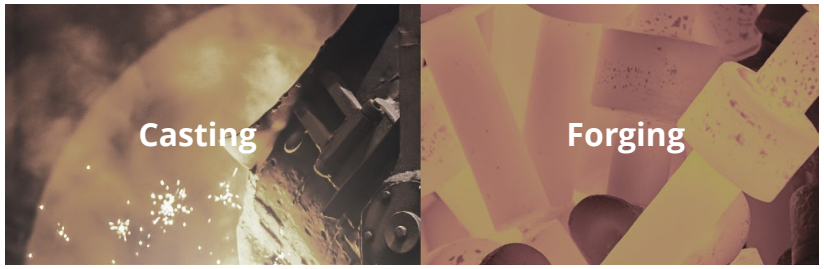
Incentivize Expertise
Early adopters of AM have significantly invested in developing their internal capabilities and intellectual property. These key examples have the potential to be replicated at scale but can only be done so by establishing incentives for knowledge sharing.

These areas are the “No Regrets Next Steps” necessary for the long-term success of an AM-augmented, agile, and resilient supply chain for the DoD.

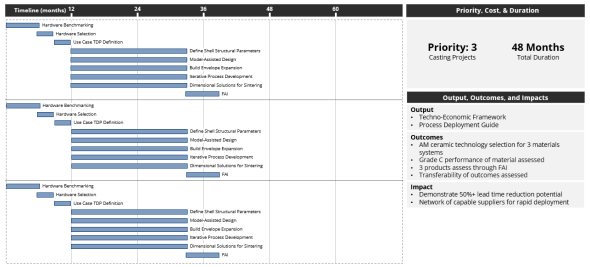
Roadmap Structure & Navigation

The Roadmap Structure

1 Roadmap



21 Projects



4 Swim Lanes

Scale Current State	**Disseminate established technology beyond siloed pockets of expertise**
Prove Production Capability	**Mature demonstrated and emerging technology to predictably meet production needs**
Build Digital Foundation	**Establish infrastructure for component/simulation models to drive agility and accelerated design cycles**
Supporting Efforts	**Centralize shared activities across projects to standardize documentation and drive efficient delivery**

Making the Roadmap Actionable

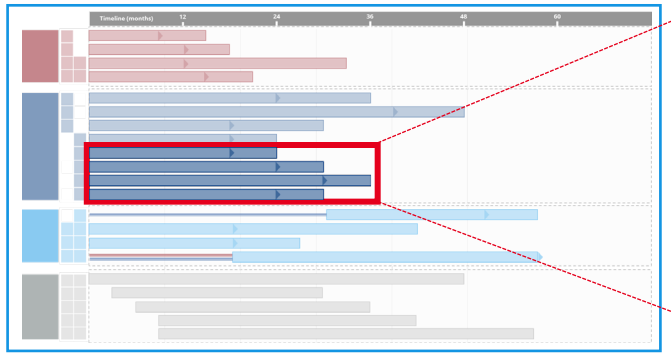
Implementation Activities
Identified over three stages: near-term, mid-term, and long-term

Impact, Output, and Outcomes
Results and products of project delivery

Interdependencies
Connectivity outlined across projects, lines of effort, and sub-tasks

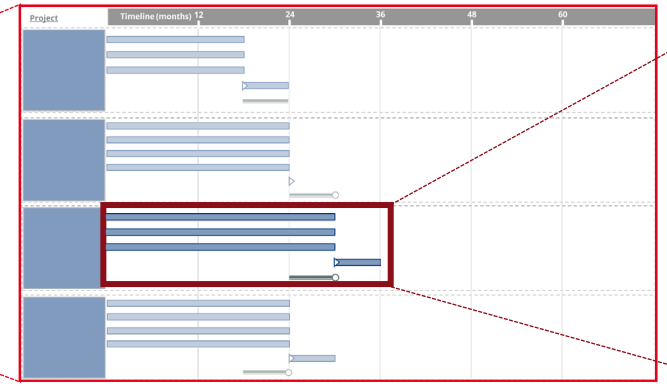
Navigating the Roadmap

ROADMAP LEVEL



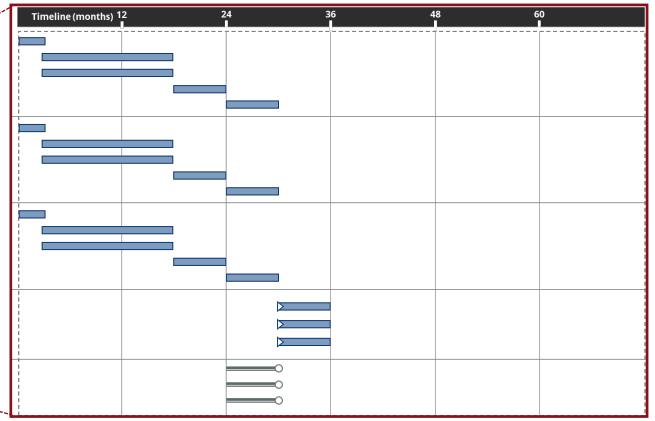
The highest level depicts the multi-year view of all projects, summarizing their attributes and impacts. It provides the framework for down-selecting projects and their activities for funding, organizing the overall projects by applicable ecosystem (casting/forging) and area of focus (swim lane).

SWIM LANE LEVEL



The swim lane level organizes projects that aim to achieve similar outcomes, and are delineated along the lines of technology maturity and the digital-physical nature of AM. This level of the roadmap presents a deeper look into each swim lane and its projects.

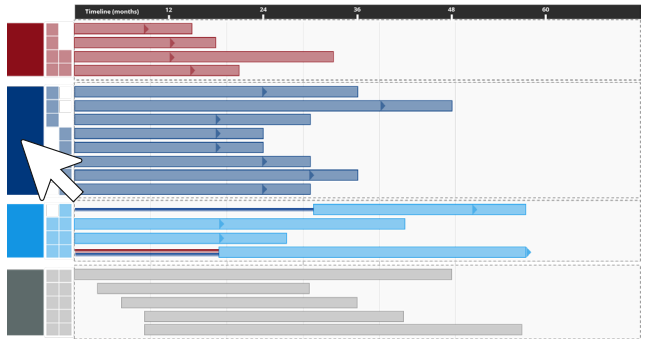
PROJECT LEVEL



The project level details execution plans that drive individual activities to a specific application domain and outcome. They provide a structured and comprehensive breakdown that describes the attributes of priority, schedule, and results (output, outcomes, and impact).

Navigating the Roadmap Continued

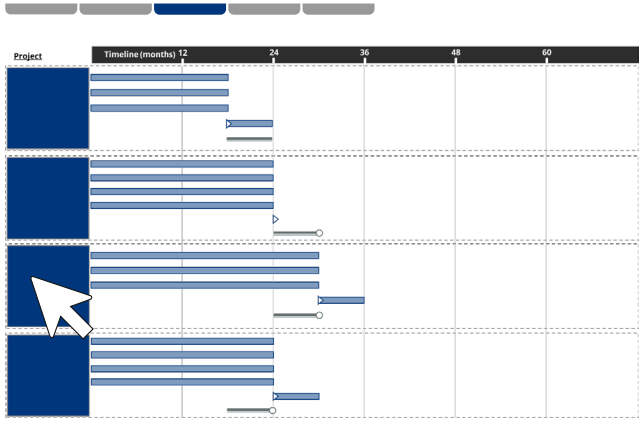
ROADMAP LEVEL



To navigate to a swim lane, click the swim lane title along the left of the slide.

To navigate to a particular project, click the project bar within the roadmap.

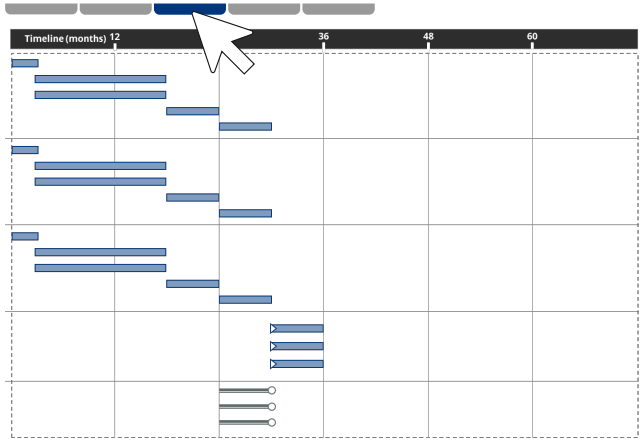
SWIM LANE LEVEL



To navigate back to the roadmap or a different swim lane, click the appropriate button at the top of the slide.

To navigate to a particular project, click the project title along the left of the slide.

PROJECT LEVEL



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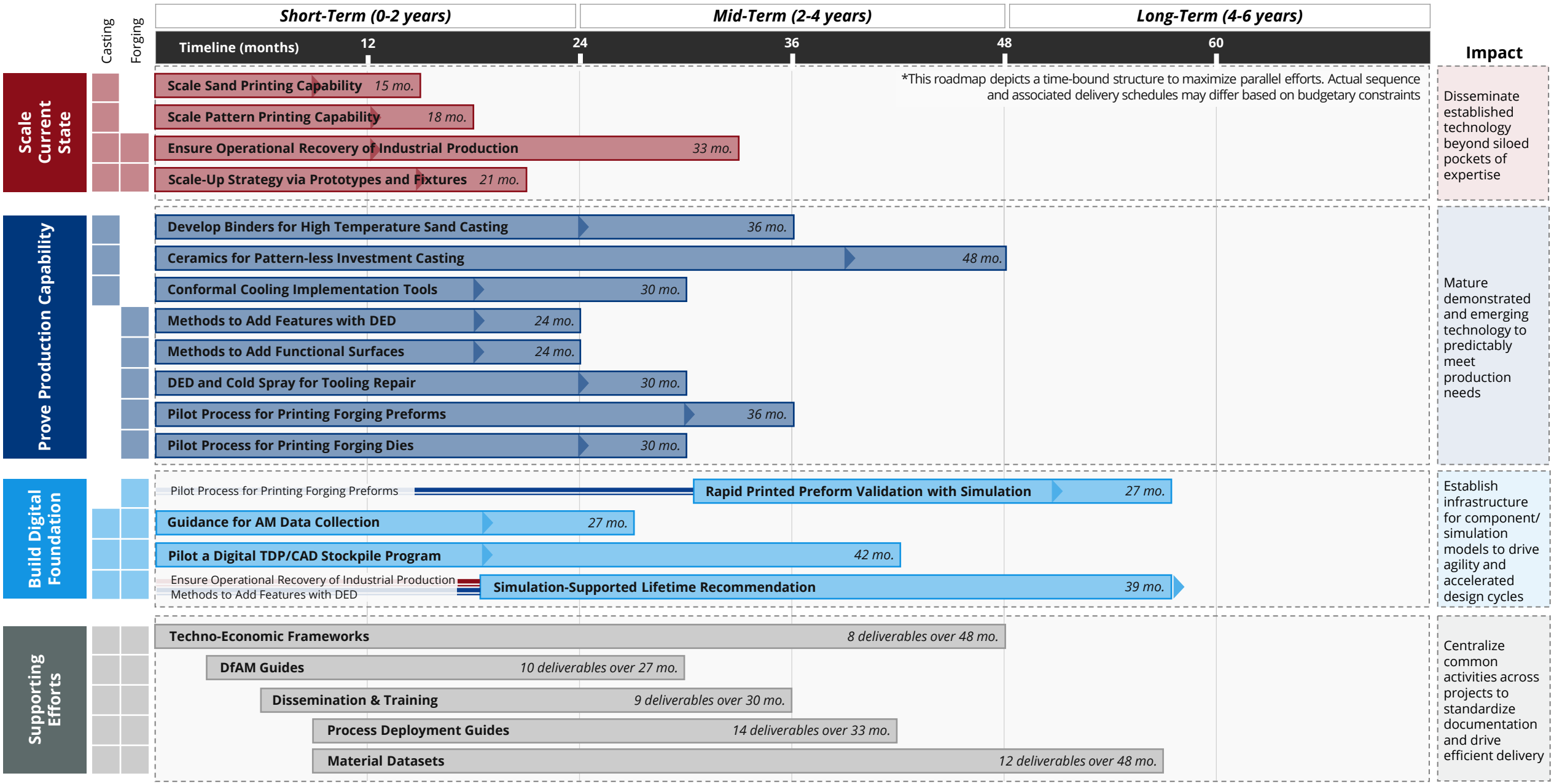
Additive Manufacturing Technology Roadmap

Additive Manufacturing Technology Roadmap for Castings and Forgings



Casting Projects Overview

Scale Sand Printing Capability	Disseminate leading practices and promote adoption of 3D printed sand molds/cores
Scale Pattern Printing Capability	Develop and disseminate leading practices and promote adoption of 3D printed patterns for casting
Develop Binders for High Temperature Sand Casting	Develop enhanced binder materials and strategies to drive processing efficiency of 3D printed sand
Ceramics for Pattern-less Investment Casting	Mature ceramic AM technology to enable rapid pours into integrated shell and cores
Conformal Cooling Implementation Tools	Develop and disseminate performance-enhancing tools for implementing AM conformal cooling

Scale Current State | Prove Production Capability | Build Digital Foundation | Supporting Efforts

Forging Projects Overview

Methods to Add Features with DED	Established, assess, and demonstrate transferable capability to add complex geometric features to forgings
Methods to Add Functional Surfaces	Established, assess, and demonstrate transferable capability to add functional surfaces to forgings
DED and Cold Spray for Tooling Repair	Establish methods for planned and unplanned tooling repair and modification applications
Pilot Process for Printing Forging Preforms	Pilot the industrialization of AM preforms to expedite the forging process for low volume components
Pilot Process for Printing Forging Dies	Pilot the industrialization of AM dies to expedite the forging process for low volume components
Rapid Printed Preform Validation with Simulation	Enable optimized process setups with predictable performance using preforms with heterogenous microstructures

Shared Projects Overview

Ensure Operational Recovery of Industrial Production	Establish scalable sourcing model for AM industrial equipment replacement parts to keep critical production equipment running
Scale-Up Strategy via Prototypes and Fixtures	Define an optimal dissemination strategy for design/deployment guides through prototypes & fixtures
Guidance for AM Data Collection	Establish data infrastructure and application-based guidance to collect store data spanning AM process flows
Pilot a Digital TDP/CAD Stockpile Program	Accelerate the creation of TDPs and CAD models for legacy components by building a program of record for continued conversion
Simulation-Supported Lifetime Recommendation	Develop material and geometric performance software solutions to integrate into DoD process flows

Techno-Economic Frameworks	Drive AM utilization by establishing frameworks that clearly define when, where, and how to print feasibly and economically
Design for Additive Manufacturing Guides	Enable confident and efficient usage of AM by documenting proven design rules across parts, tooling, and accessories
Dissemination & Training	Scale the adoption of technical development with focused and strategic communication to build a pipeline of SMMs ready to leverage AM capabilities
Process Deployment Guides	Build delivery mechanisms for technical development by documenting clear and tested procedures for implementing and controlling AM processes on the shop floor
Material Datasets	Enable cross-functional sharing with standardized management and storage of material data gathered during development activities

Scale Current State | Prove Production Capability | Build Digital Foundation | Supporting Efforts

Scale Current State

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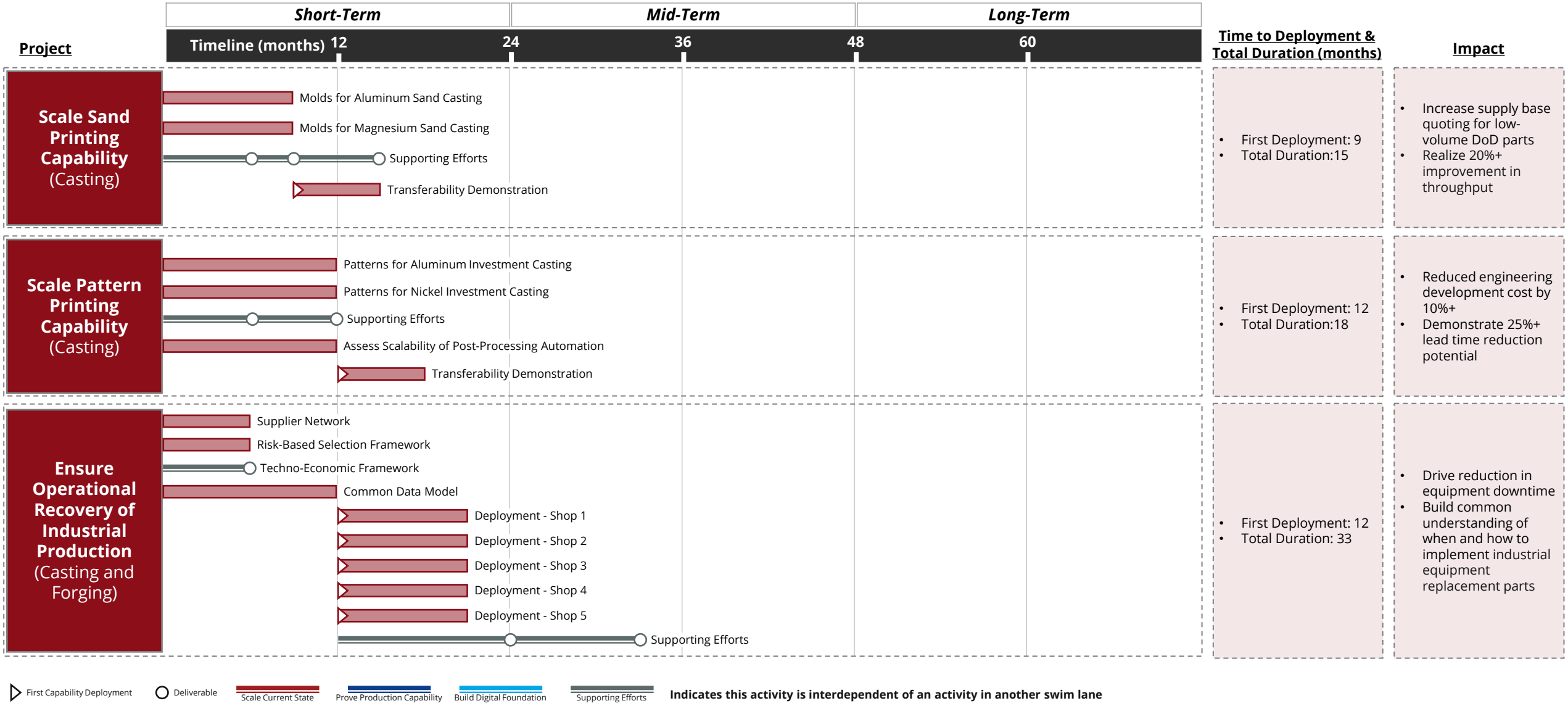
Scale Current State



First Capability Deployment | Deliverable | Scale Current State | Prove Production Capability | Build Digital Foundation | Supporting Efforts

Indicates this activity is interdependent of an activity in another swim lane

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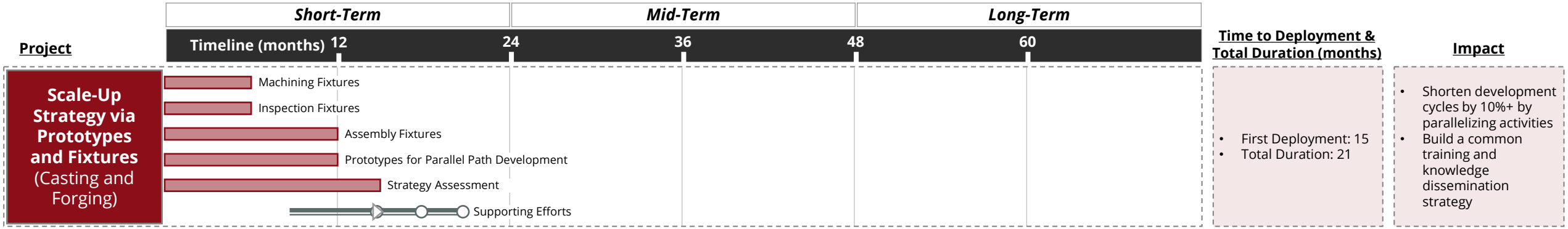
Scale Current State



First Capability Deployment | Deliverable | Scale Current State | Prove Production Capability | Build Digital Foundation | Supporting Efforts

Indicates this activity is interdependent of an activity in another swim lane

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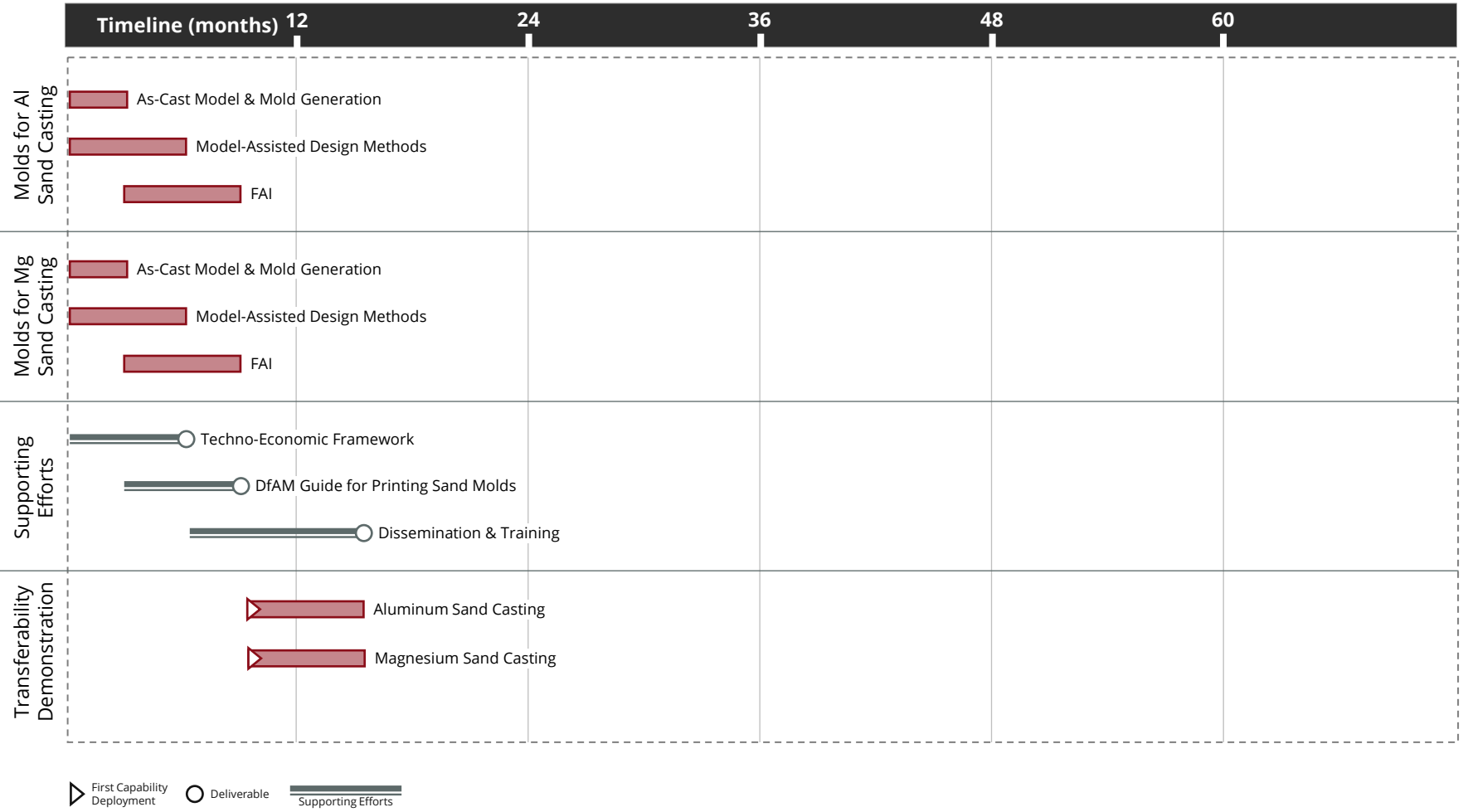
Scale Sand Printing Capability

Disseminate leading practices and promote adoption of 3D printed sand molds/cores

Casting Forging



Priority, Cost, & Duration

Priority: 1
Casting Projects

15 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Techno-Economic Framework
- DfAM Guide for Printing Sand Molds

Outcomes
- 2 material systems characterized: Aluminum and Magnesium
- 2 tailored products designed, manufactured, and validated

Impact
- Increase supply base quoting for low volume DoD parts
- Realize 20%+ improvement in throughput

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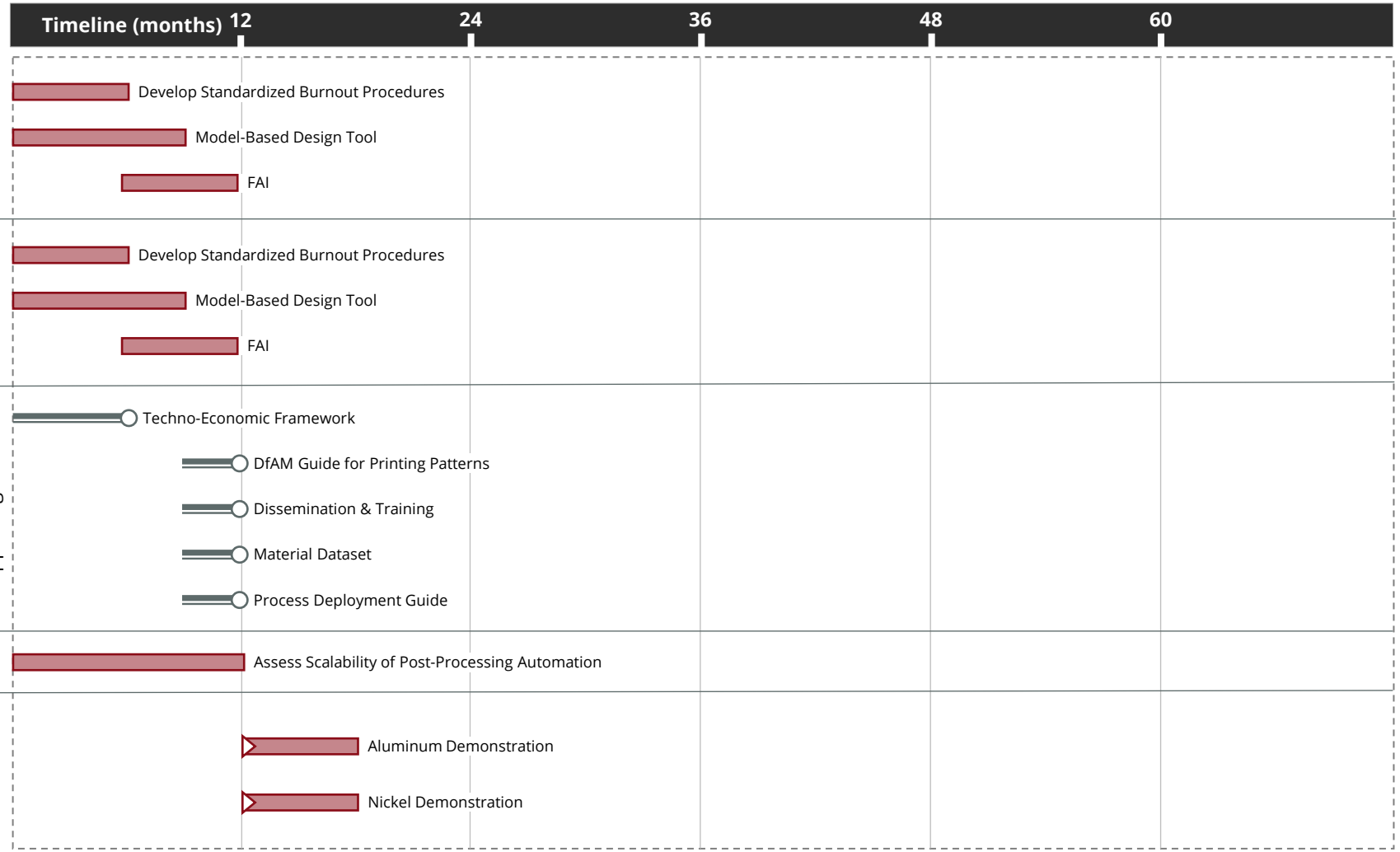
Scale Pattern Printing Capability

Develop and disseminate leading practices and promote adoption of 3D printed patterns for casting

Casting  Forging



First Capability Deployment | Deliverable | Supporting Efforts

Priority, Cost, & Duration

Priority: 5
Casting Projects

18 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Techno-Economic Framework
- DfAM Guide for Printing Patterns
- Material Dataset
- Process Deployment Guide

Outcomes
- 2 material systems characterized: Aluminum and Nickel
- 2 products assess through FAI
- Transferability of outcomes assessed

Impact
- Reduced engineering development cost by 10%+
- Demonstrate 25%+ lead time reduction potential

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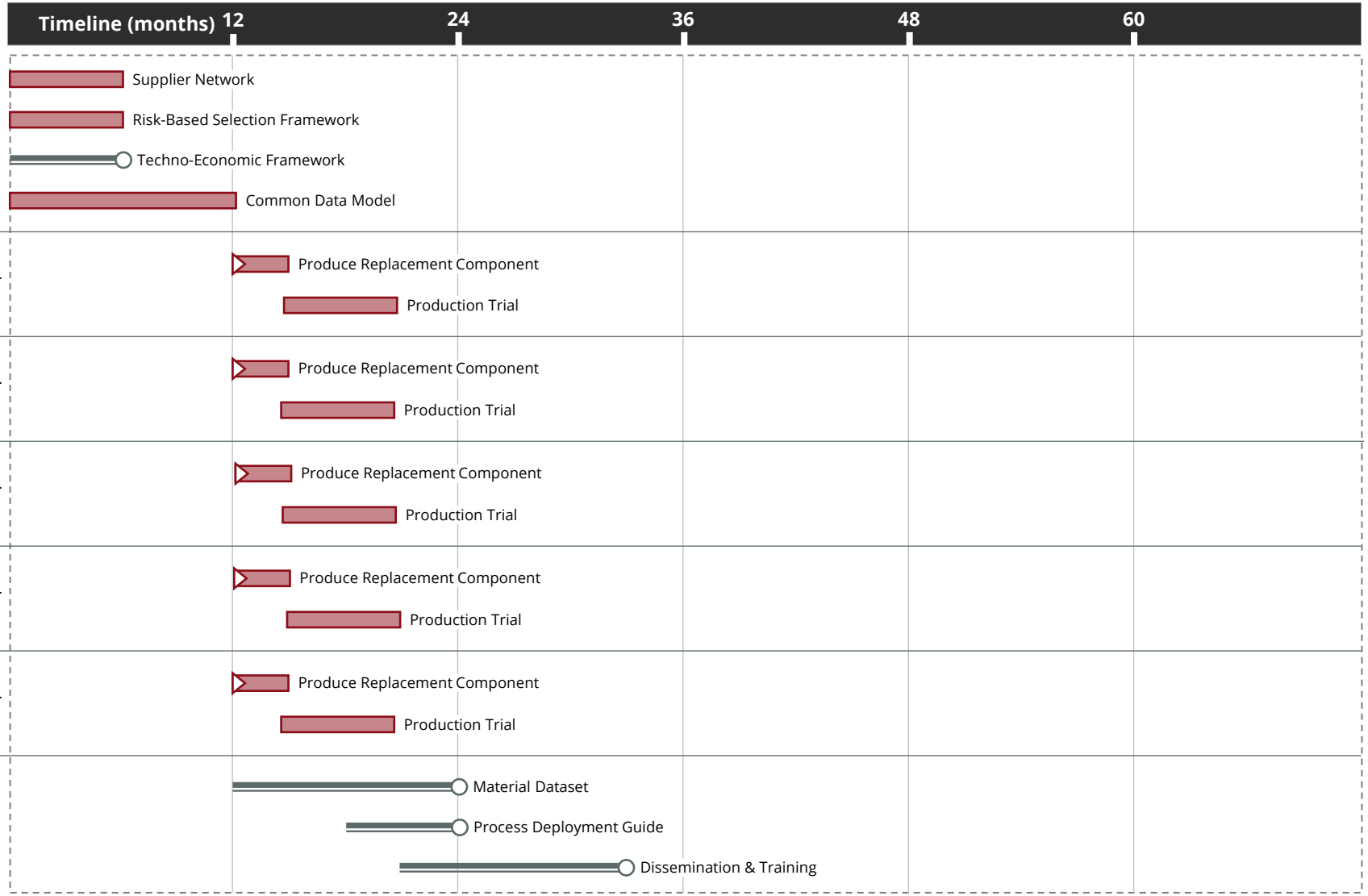
Ensure Operational Recovery of Industrial Production

Establish scalable sourcing model for AM industrial equipment replacement parts to keep critical production equipment running

Casting  Forging



Priority, Cost, & Duration

Priority: 1
Shared Projects

33 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Common Data Model for Industrial Equipment Replacement Parts
- Techno-Economic Framework
- Process Deployment Guide for Industrial Equipment Replacement Parts (including process selection)

Outcomes
- Produce and Validate 5 Components
- Deploy to 5 production facilities

Impact
- Drive reduction in equipment downtime
- Build common understanding of when and how to implement industrial equipment replacement parts

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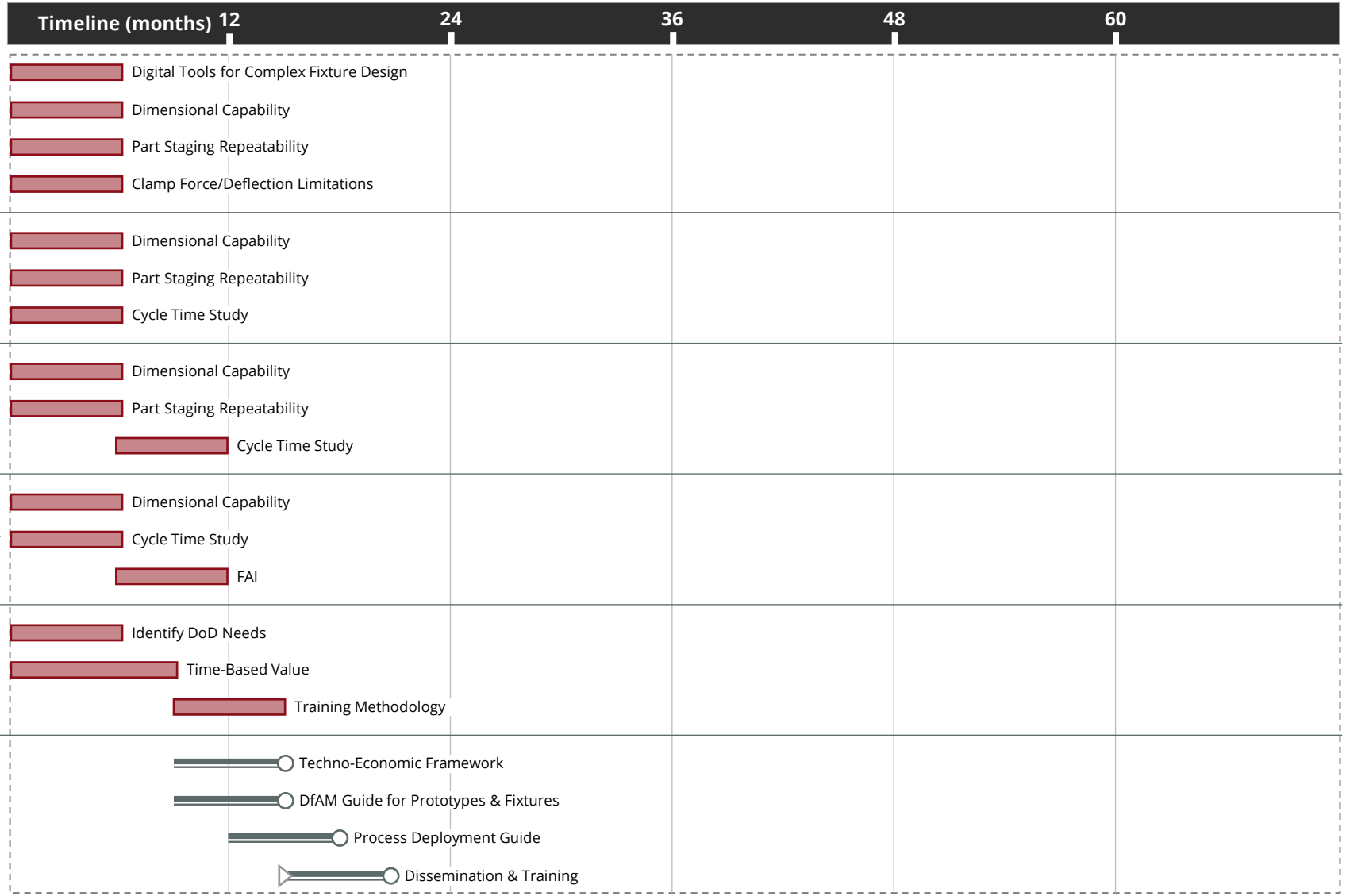
Scale-Up Strategy via Prototypes and Fixtures

Define an optimal dissemination strategy for design/deployment guides through prototypes & fixtures

Casting  Forging



Priority, Cost, & Duration

Priority: 4
Shared Projects

21 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Techno-Economic Framework
- DfAM Guide for Prototypes and Fixtures
- Process Deployment Guide

Outcomes
- 5 products assessed through stages of development cycle
- 3 AM materials assessed through stages of development cycle
  - 2 polymer (ABS/Nylon)
  - 1 composite

Impact
- Shorten development cycles by 10%+ by parallelizing activities
- Build a common training and knowledge dissemination strategy

Prove Production Capability

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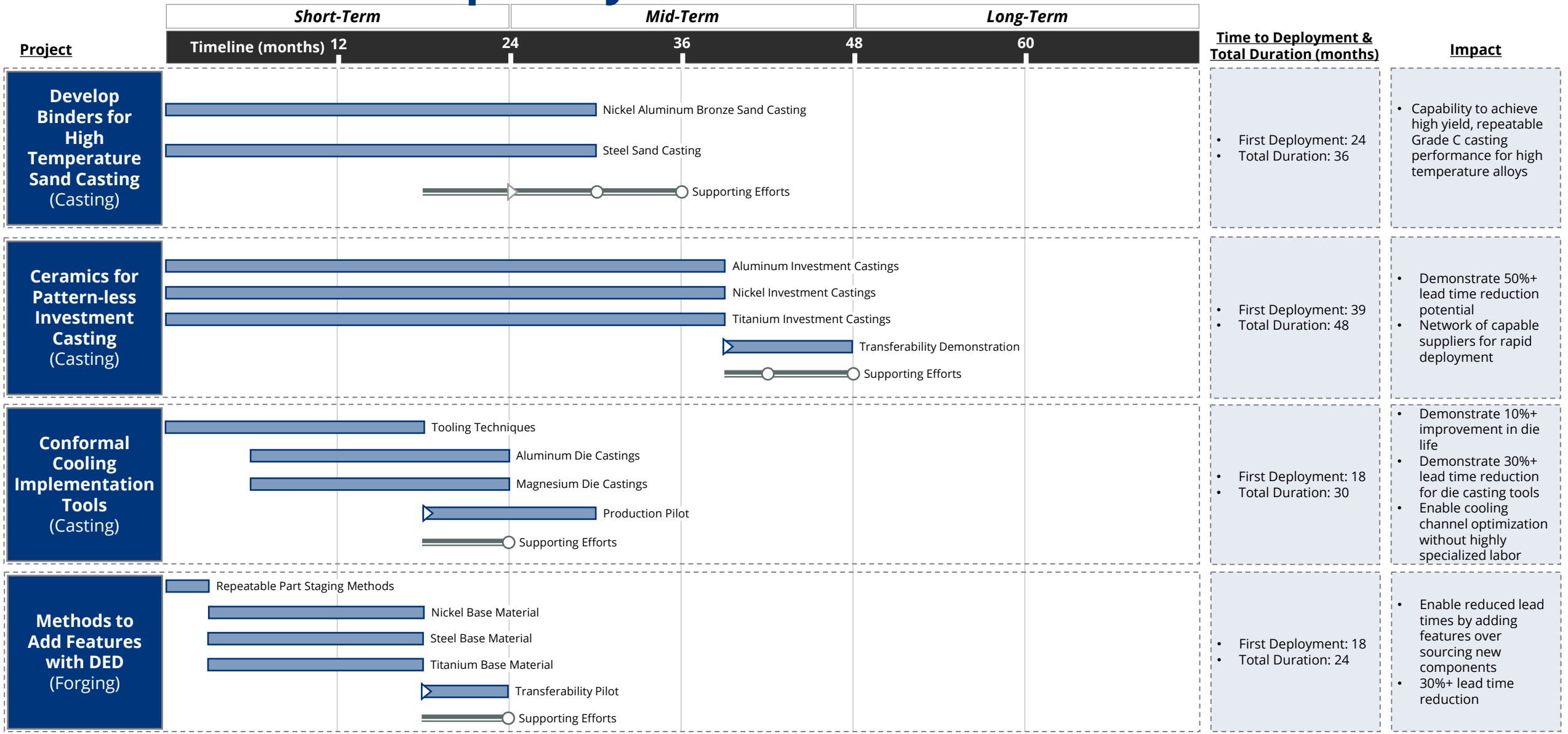
Prove Production Capability



First Capability Deployment | Deliverable | Scale Current State | Prove Production Capability | Build Digital Foundation | Supporting Efforts

Indicates this activity is interdependent of an activity in another swim lane

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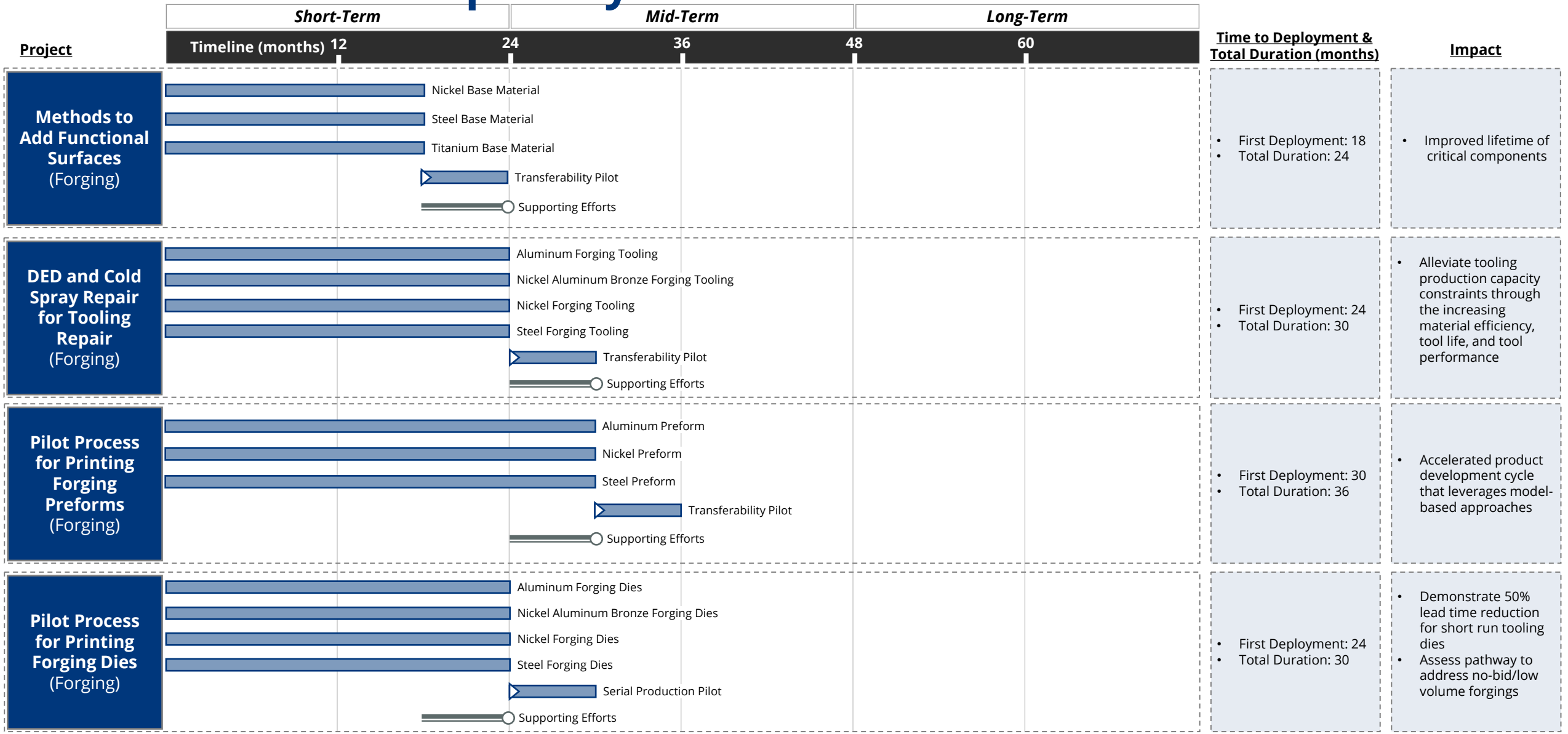
Prove Production Capability



First Capability Deployment | Deliverable | Scale Current State | Prove Production Capability | Build Digital Foundation | Supporting Efforts

Indicates this activity is interdependent of an activity in another swim lane

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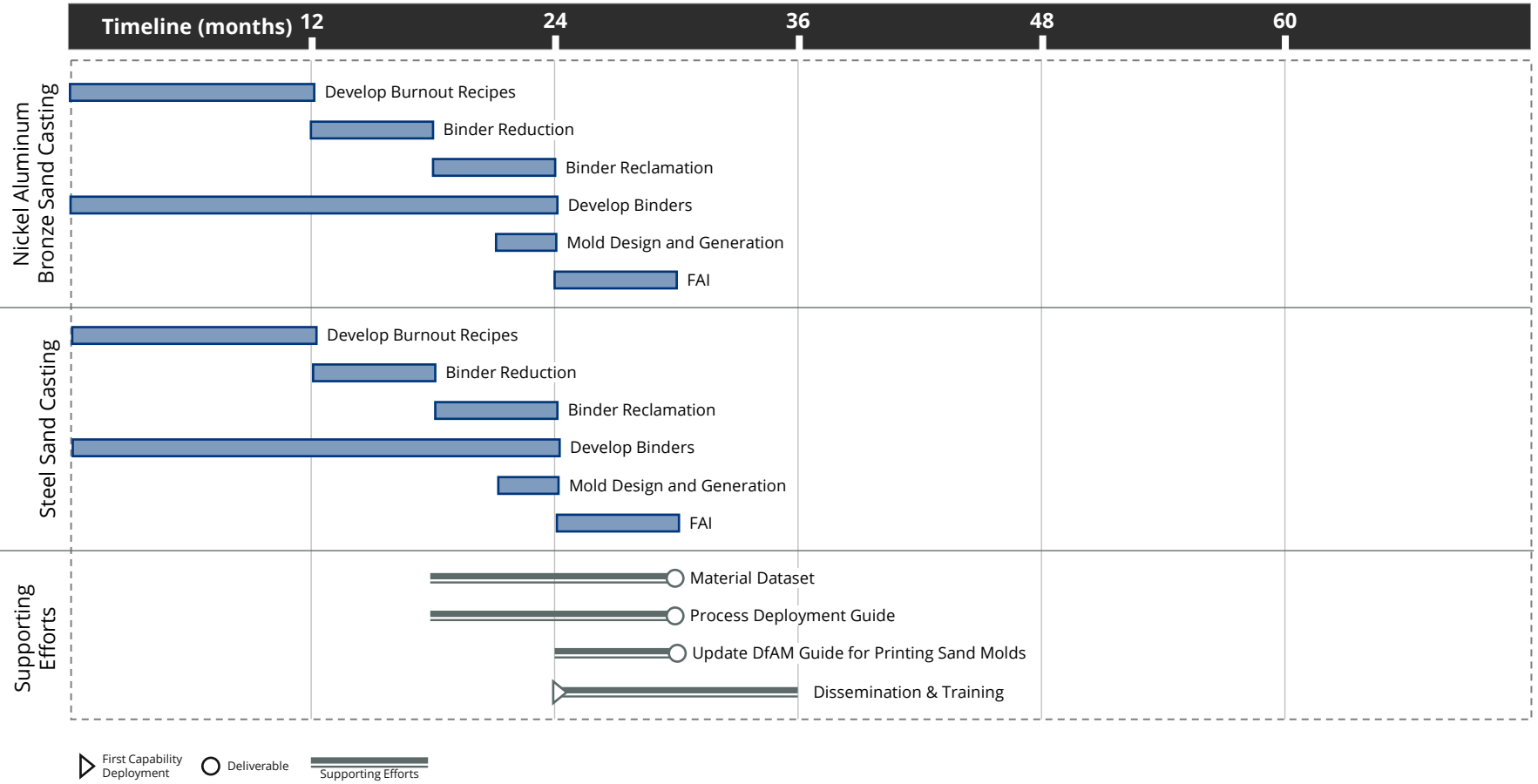
Develop Binders for High Temperature Sand Casting

Develop enhanced binder materials and strategies to drive processing efficiency of 3D printed sand

Casting Forging



Priority, Cost, & Duration

Priority: 2
Casting Projects

36 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Process Deployment Guide
- Material Dataset
- Common method(s) for performing and testing the debind process
- Plug and play burnout cycle(s) for developed binder system

Outcomes
- 2 material systems characterized: Nickel and Steel
- 2 products assessed through FAI

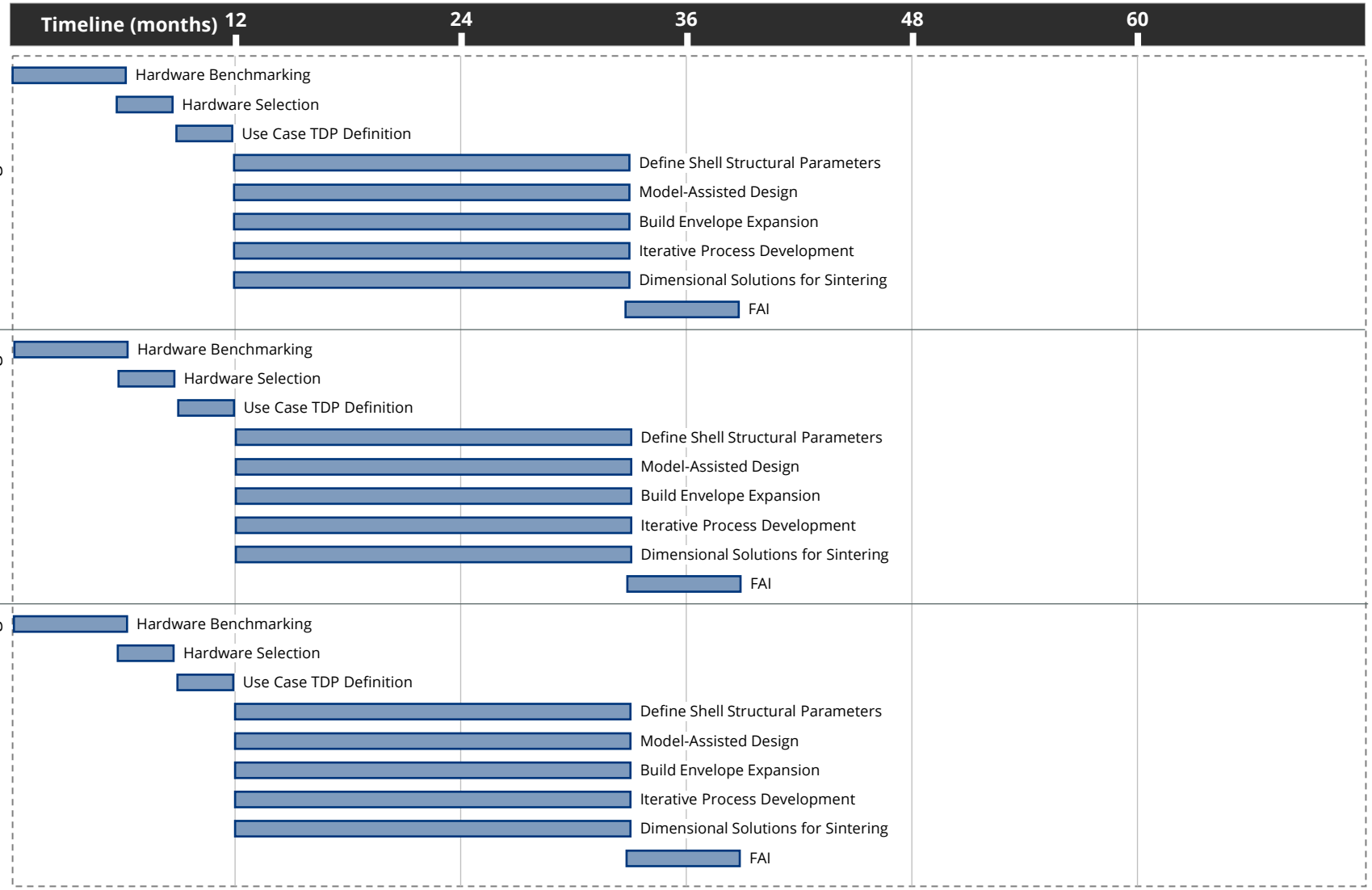
Impact
- Capability to achieve high yield, repeatable Grade C casting performance for high temperature alloys

America Makes

Ceramics for Pattern-less Investment Casting (1 of 2)

Mature ceramic AM technology to enable rapid pours into integrated shell and cores

Casting Forging



Priority, Cost, & Duration

Priority: 3
Casting Projects

48 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Techno-Economic Framework
- Process Deployment Guide

Outcomes
- AM ceramic technology selection for 3 materials systems
- Grade C performance of material assessed
- 3 products assess through FAI
- Transferability of outcomes assessed

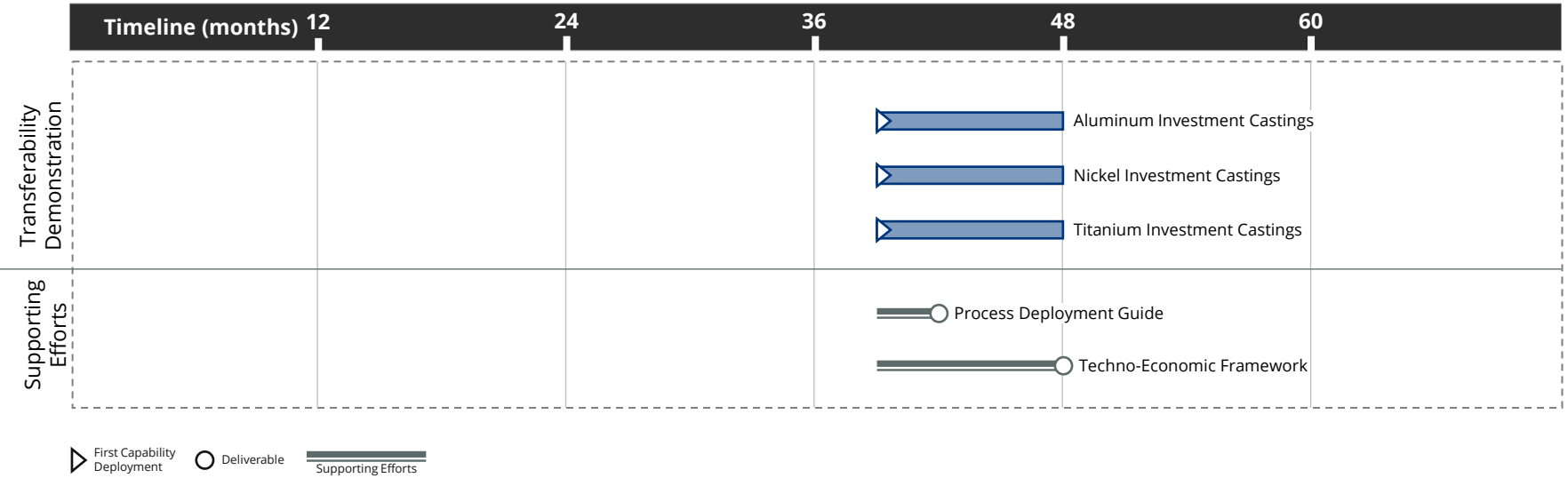
Impact
- Demonstrate 50%+ lead time reduction potential
- Network of capable suppliers for rapid deployment

America Makes

Ceramics for Pattern-less Investment Casting (2 of 2)

Mature ceramic AM technology to enable rapid pours into integrated shell and cores

Casting Forging



Priority, Cost, & Duration

Priority: 3
Casting Projects

48 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Techno-economic framework
- Process deployment guide

Outcomes
- AM ceramic technology selection for 3 materials systems
- Grade C performance of material assessed
- 3 products assess through FAI
- Transferability of outcomes assessed

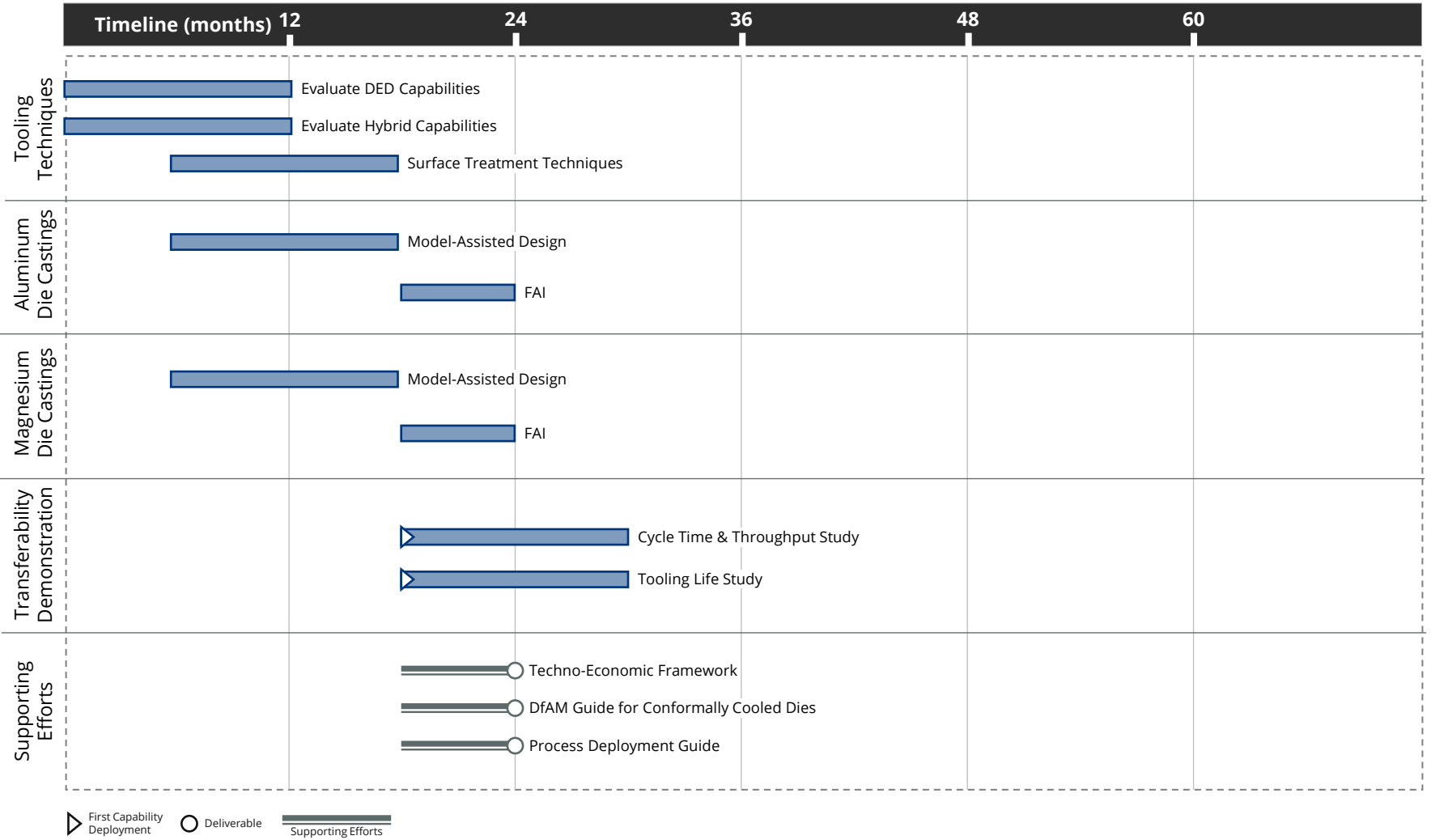
Impact
- Demonstrate 50%+ lead time reduction potential
- Network of capable suppliers for rapid deployment

America Makes

Conformal Cooling Implementation Tools

Develop and disseminate performance-enhancing tools for implementing AM conformal cooling

Casting Forging



Priority, Cost, & Duration

Priority: 4
Casting Projects

30 Months
Total Duration

Output, Outcomes, and Impacts

Output
- DfAM Guide for Conformally Cooled Dies
- Techno-Economic Framework
- Process Deployment Guide

Outcomes
- 1 Al die casting FAI using conformally cooled tool
- 1 Mg die casting FAI using conformally cooled tool
- Cycle time, thruput, and tooling life assessed
- DED and Hybrid methods evaluated for Al and Mg die casting tooling

Impact
- Demonstrate 10%+ improvement in die life
- Demonstrate 30%+ lead time reduction for die casting tools
- Enable cooling channel optimization without highly specialized labor

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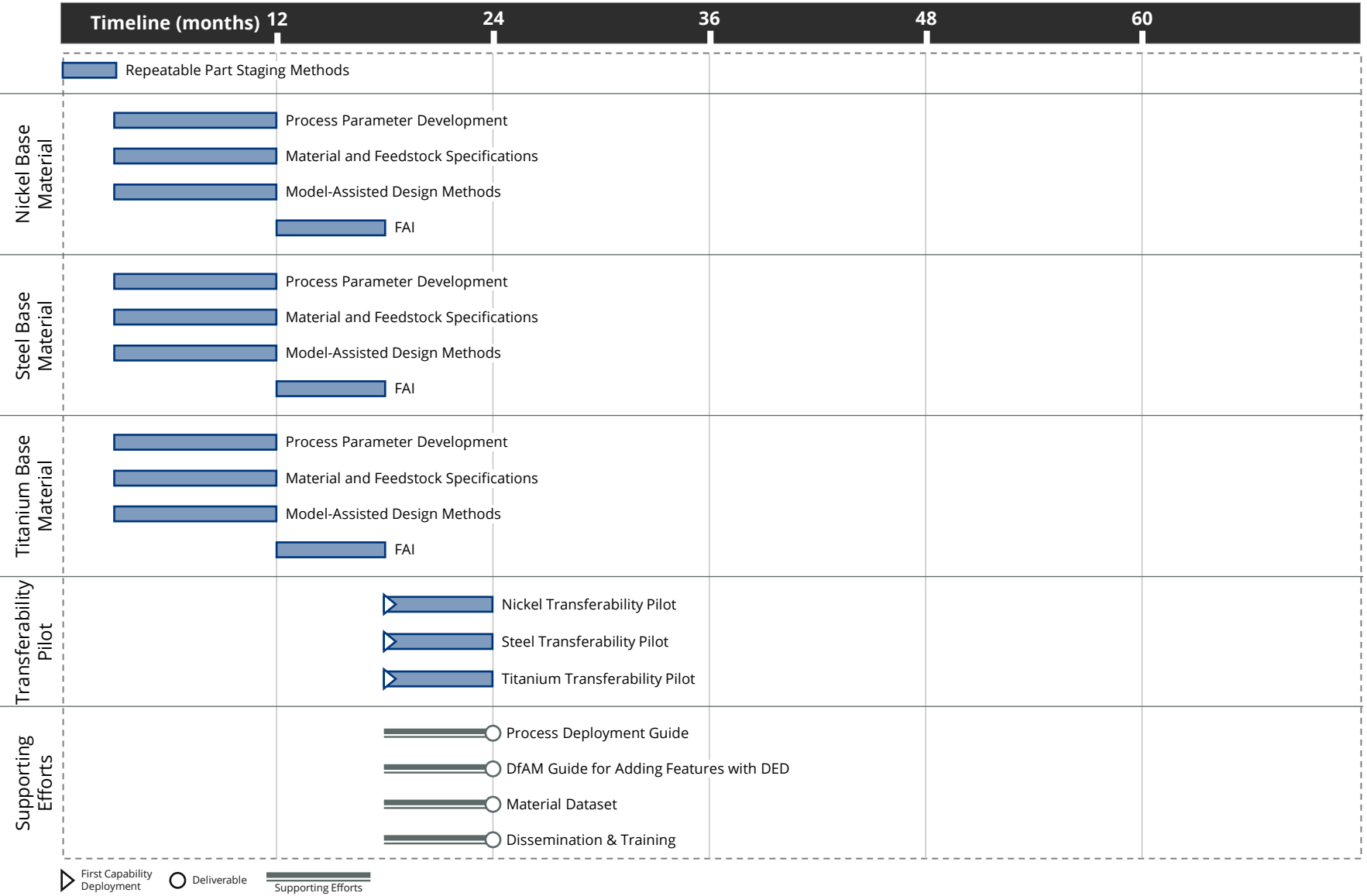
Methods to Add Features with DED

Established, assess, and demonstrate transferable capability to add complex geometric features to forgings

Casting — Forging



Priority, Cost, & Duration

Priority: 1
Forging Projects

24 Months
Total Duration

Output, Outcomes, and Impacts

Output
- DfAM Guide for Adding Features with DED
- Material Dataset
- Process Deployment Guide

Outcomes
- 3 base material systems characterized
- 3 products assessed through FAI
- 3 pilot demonstrations to reproduce outcomes at new supplier

Impact
- Enable reduced lead times by adding features over sourcing new components
- 30%+ lead time reduction

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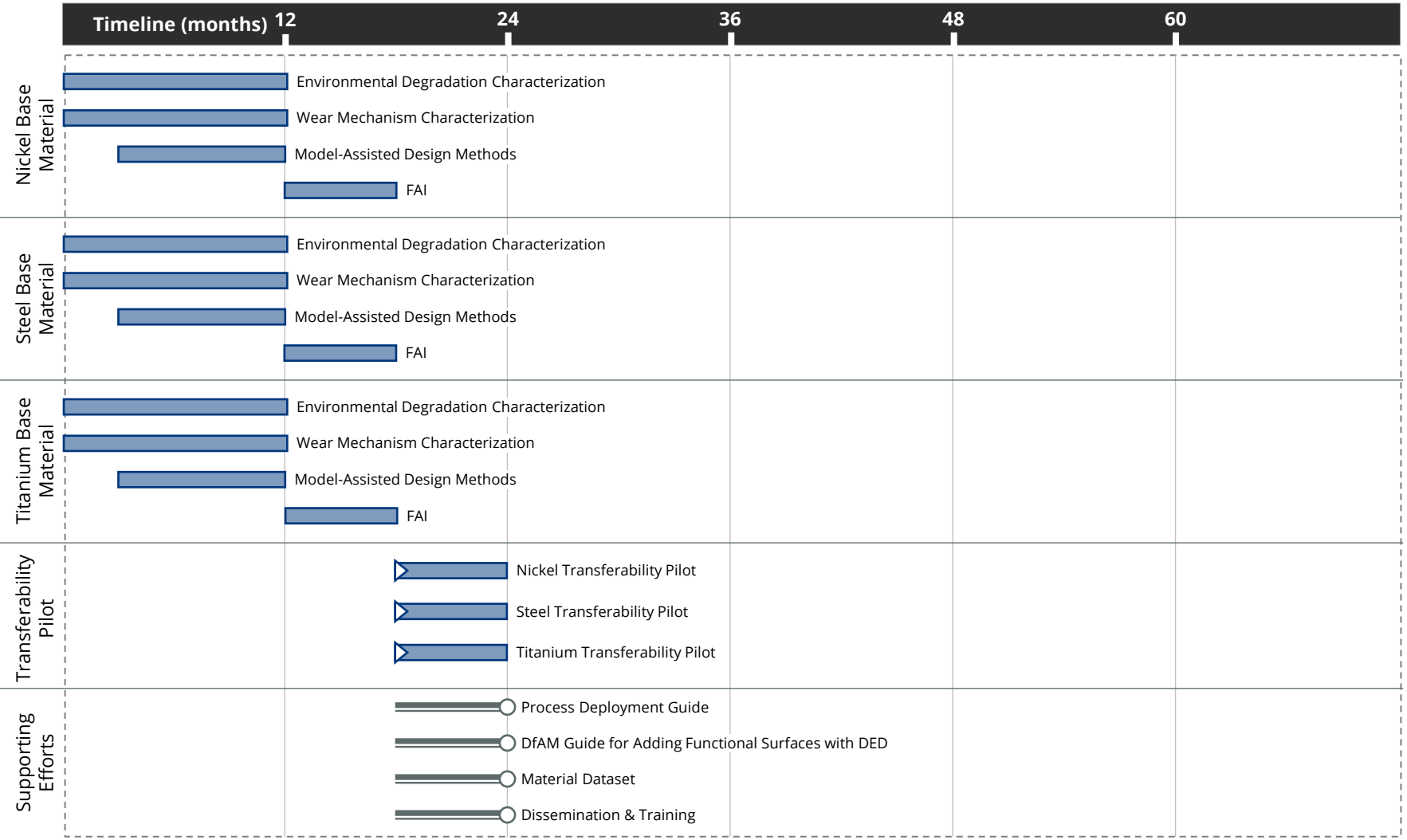
Methods to Add Functional Surfaces

Established, assess, and demonstrate transferable capability to add functional surfaces to forgings

Casting — Forging



Priority, Cost, & Duration

Priority: 2
Forging Projects

24 Months
Total Duration

Output, Outcomes, and Impacts

Output
- DfAM Guide for Adding Functional Surfaces with DED
- Material Dataset
- Process Deployment Guidance
- Dissemination and Training

Outcomes
- 3 base materials characterized
  - Environmental degradation and wear mechanism studied for each
- 3 products assessed through FAI
- 3 pilot demonstrations to reproduce outcomes at new supplier

Impact
- Improved lifetime of critical components

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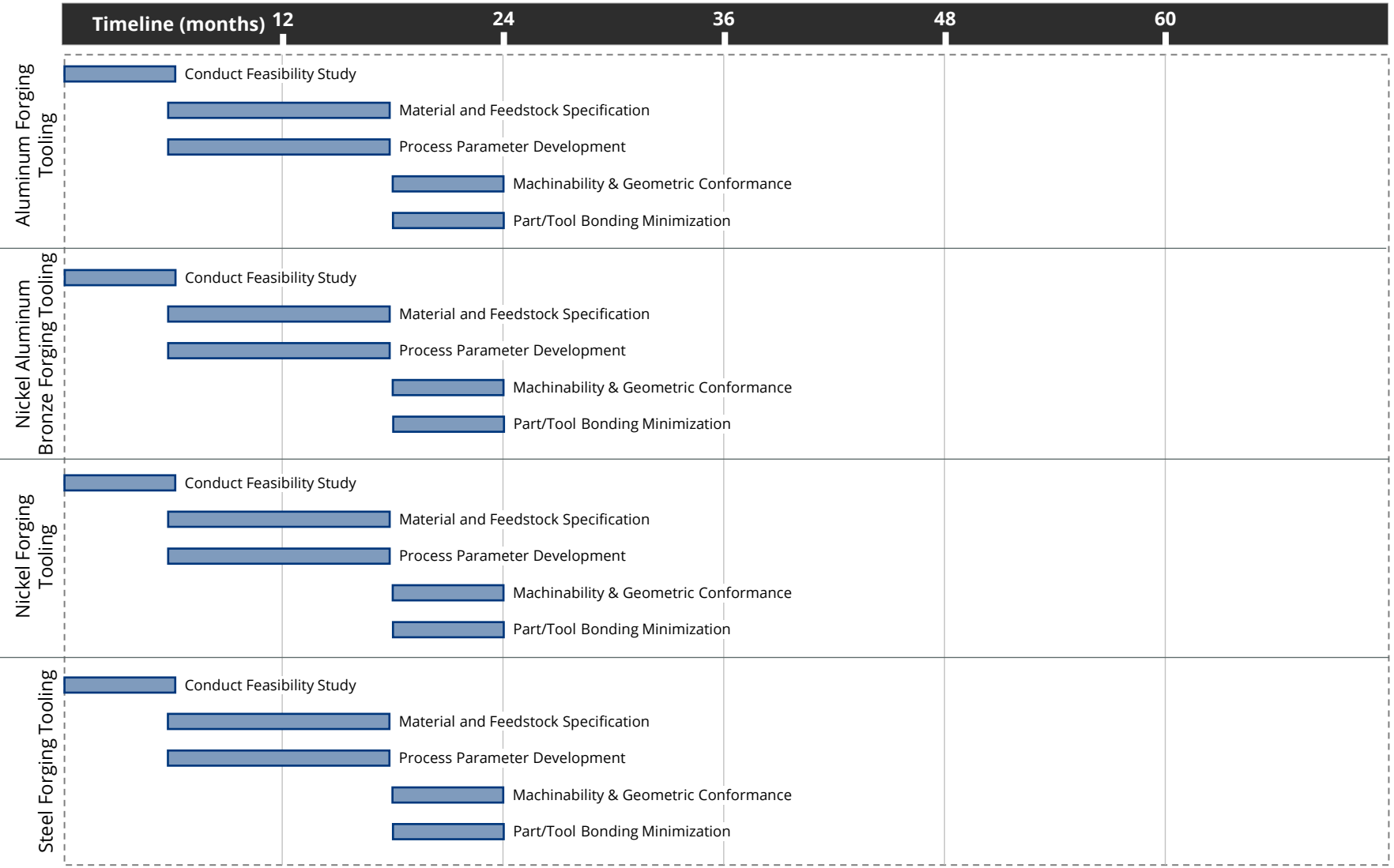
DED and Cold Spray for Tooling Repair (1 of 2)

Establish methods for planned and unplanned tooling repair and modification applications

Casting — Forging



Priority, Cost, & Duration

Priority: 3
Forging Projects

30 Months
Total Duration

Output, Outcomes, and Impacts

Output
- DfAM Guide for DED Repair for Tooling
- Techno-Economic Framework
- Process Deployment Guidance
- Dissemination and Training

Outcomes
- 4 material systems studied for AM tool repair
- Establish technical foundation for printing dies

Impact
- Alleviate tooling production capacity constraints through increasing material efficiency, tool life, and tool performance
- Demonstrate improvements to:
  - Cost benefit 1.5-3x
  - Lead time reduction 5-10x
  - Scrap reduction 2x

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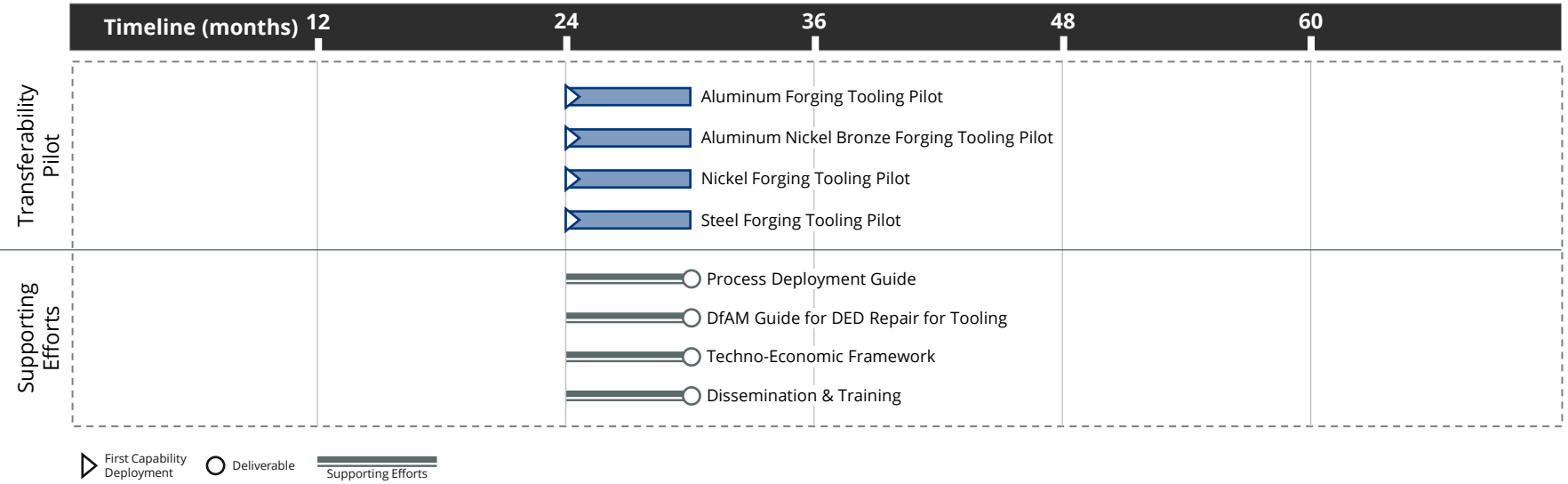
DED and Cold Spray for Tooling Repair (2 of 2)

Establish methods for planned and unplanned tooling repair and modification applications

Casting — Forging



Priority, Cost, & Duration

Priority: 3
Forging Projects

30 Months
Total Duration

Output, Outcomes, and Impacts

Output
- DfAM Guide for DED Repair for Tooling
- Techno-Economic Framework
- Process Deployment Guidance
- Dissemination and Training

Outcomes
- 4 material systems studied for AM tool repair
- Establish technical foundation for printing dies

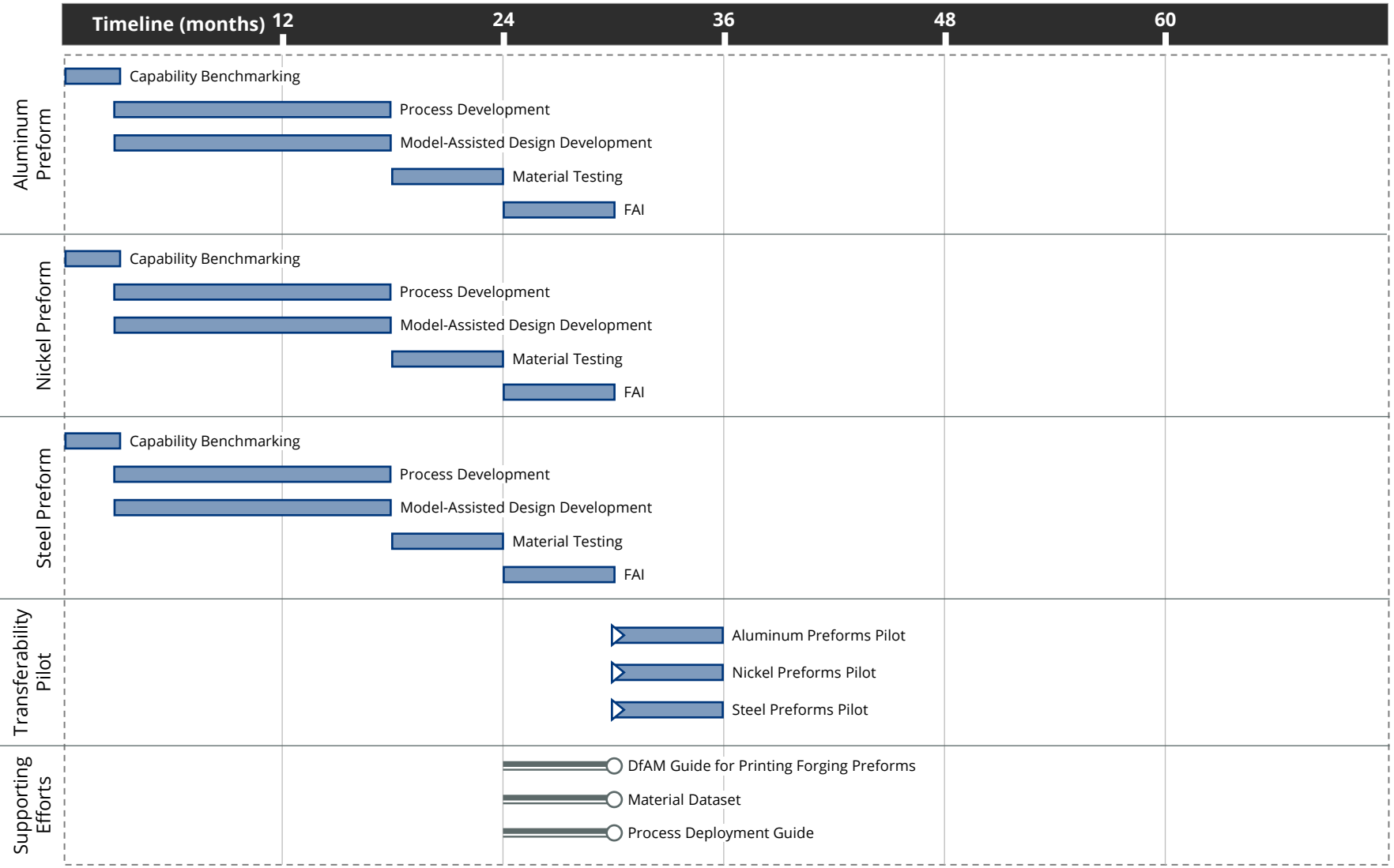
Impact
- Alleviate tooling production capacity constraints through increasing material efficiency, tool life, and tool performance
- Demonstrate improvements to:
  - Cost benefit 1.5-3x
  - Lead time reduction 5-10x
  - Scrap reduction 2x

America Makes

Pilot Process for Printing Forging Preforms

Pilot the industrialization of AM preforms to expedite the forging process for low volume components

Casting — Forging



Priority, Cost, & Duration

Priority: 4
Forging Projects

36 Months
Total Duration

Output, Outcomes, and Impacts

Output
- DfAM Guide for Printing Forging Preforms
- Process Deployment Guide
- Material Dataset

Outcomes
- 3 material systems characterized
- 3 products assessed through FAI
- Transferability of outcomes tested for new part numbers

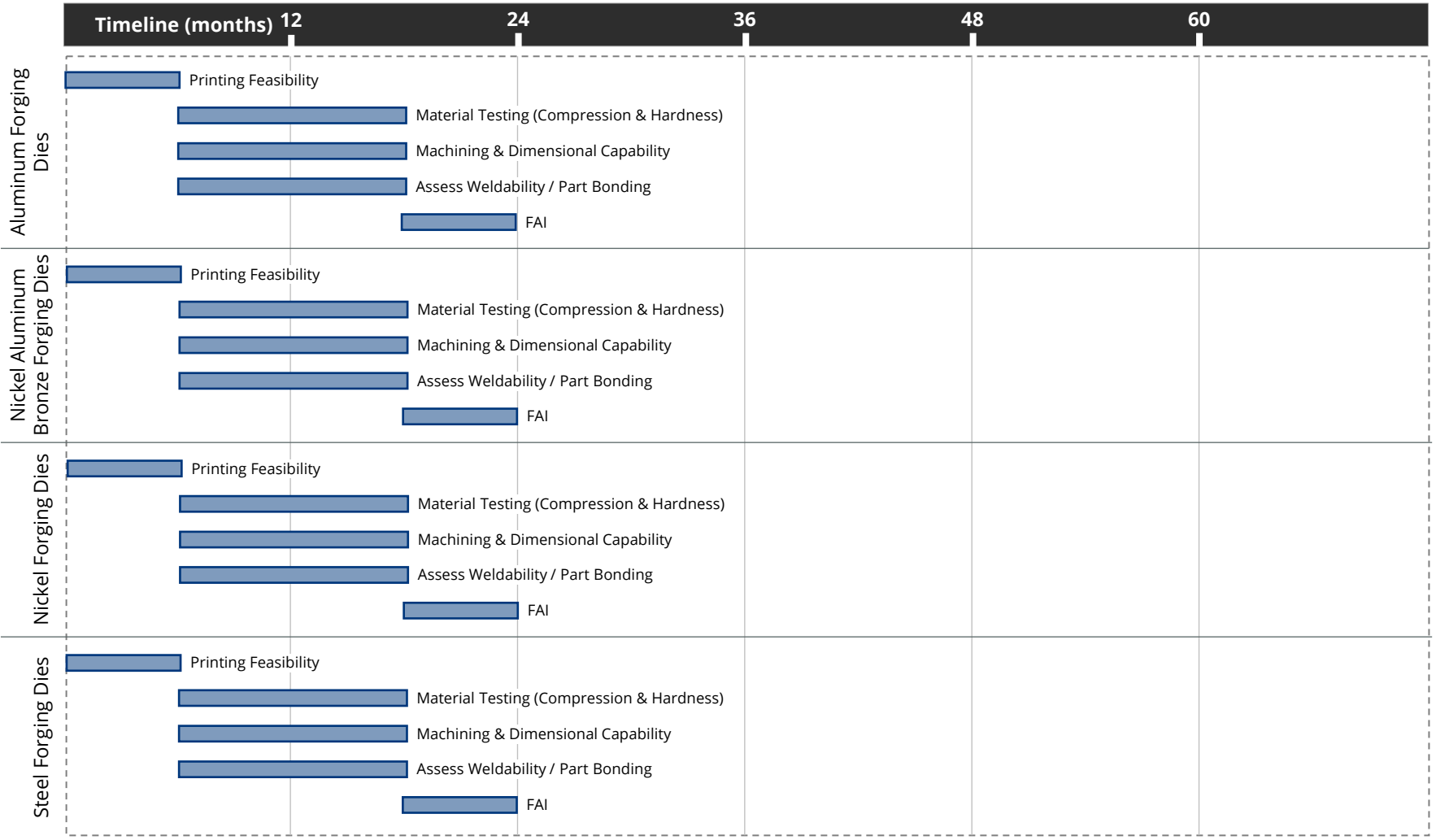
Impact
- Accelerated product development cycle that leverages model-based approaches

America Makes

Pilot Process for Printing Forging Dies (1 of 2)

Pilot the industrialization of AM dies to expedite the forging process for low volume components

Casting — Forging



Priority, Cost, & Duration

Priority: 5
Forging Projects

30 Months
Total Duration

Output, Outcomes, and Impacts

Output
- DfAM Guide for Printing Forging Dies
- Material Dataset
- Techno-Economic Framework

Outcomes
- 4 material systems characterized
- 4 products assessed for dimensional capability
- Lifecycle metrics for die performance

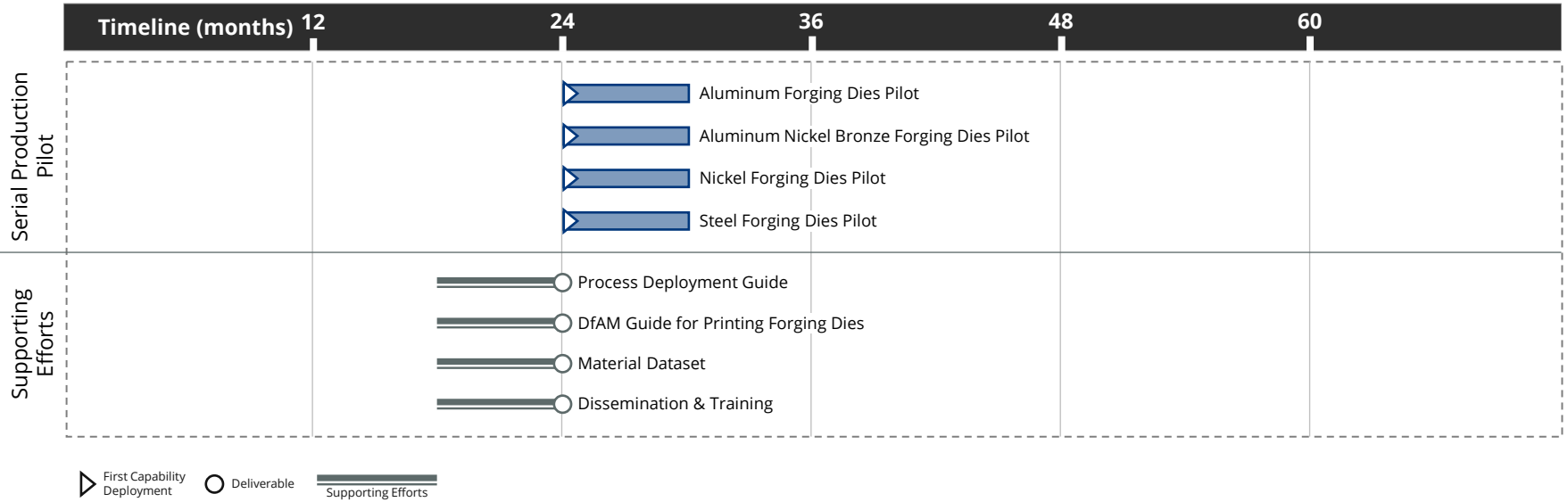
Impact
- Demonstrate 50% lead time reduction for short run tooling dies
- Assess pathway to address no-bid/low-volume forgings

America Makes

Pilot Process for Printing Forging Dies (2 of 2)

Pilot the industrialization of AM dies to expedite the forging process for low volume components

Casting  Forging



Priority, Cost, & Duration

Priority: 5
Forging Projects

30 Months
Total Duration

Output, Outcomes, and Impacts

Output
- DfAM Guide for Printing Forging Dies
- Material dataset
- Techno-economic framework

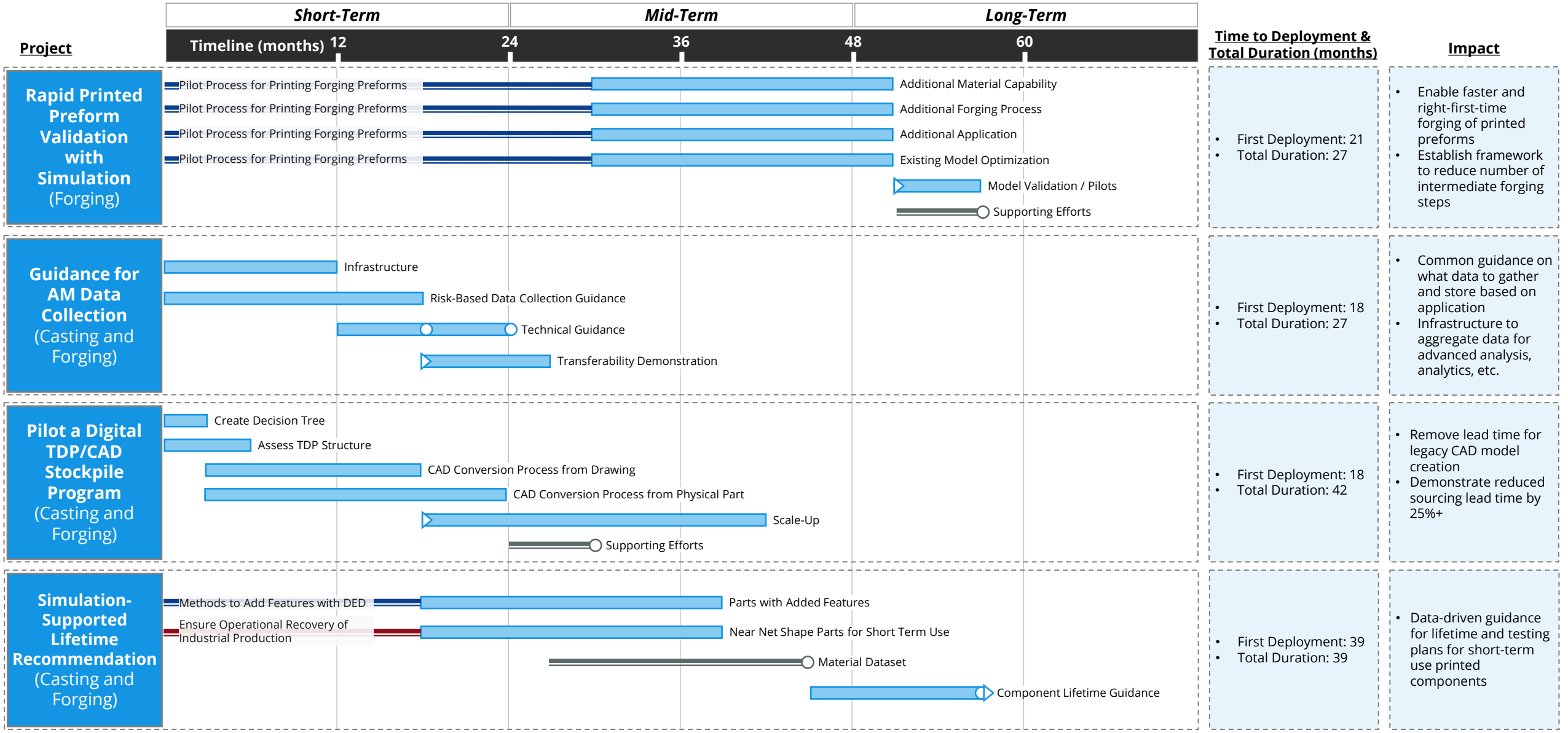
Outcomes
- 4 material systems characterized
- 4 products assessed for dimensional capability
- Lifecycle metrics for die performance

Impact
- Demonstrate 50% lead time reduction for short run tooling dies
- Assess pathway to address no-bid/low-volume forgings

Build Digital Foundation

America Makes

Build Digital Foundation



First Capability Deployment | Deliverable | Scale Current State | Prove Production Capability | Build Digital Foundation | Supporting Efforts

Indicates this activity is interdependent of an activity in another swim lane

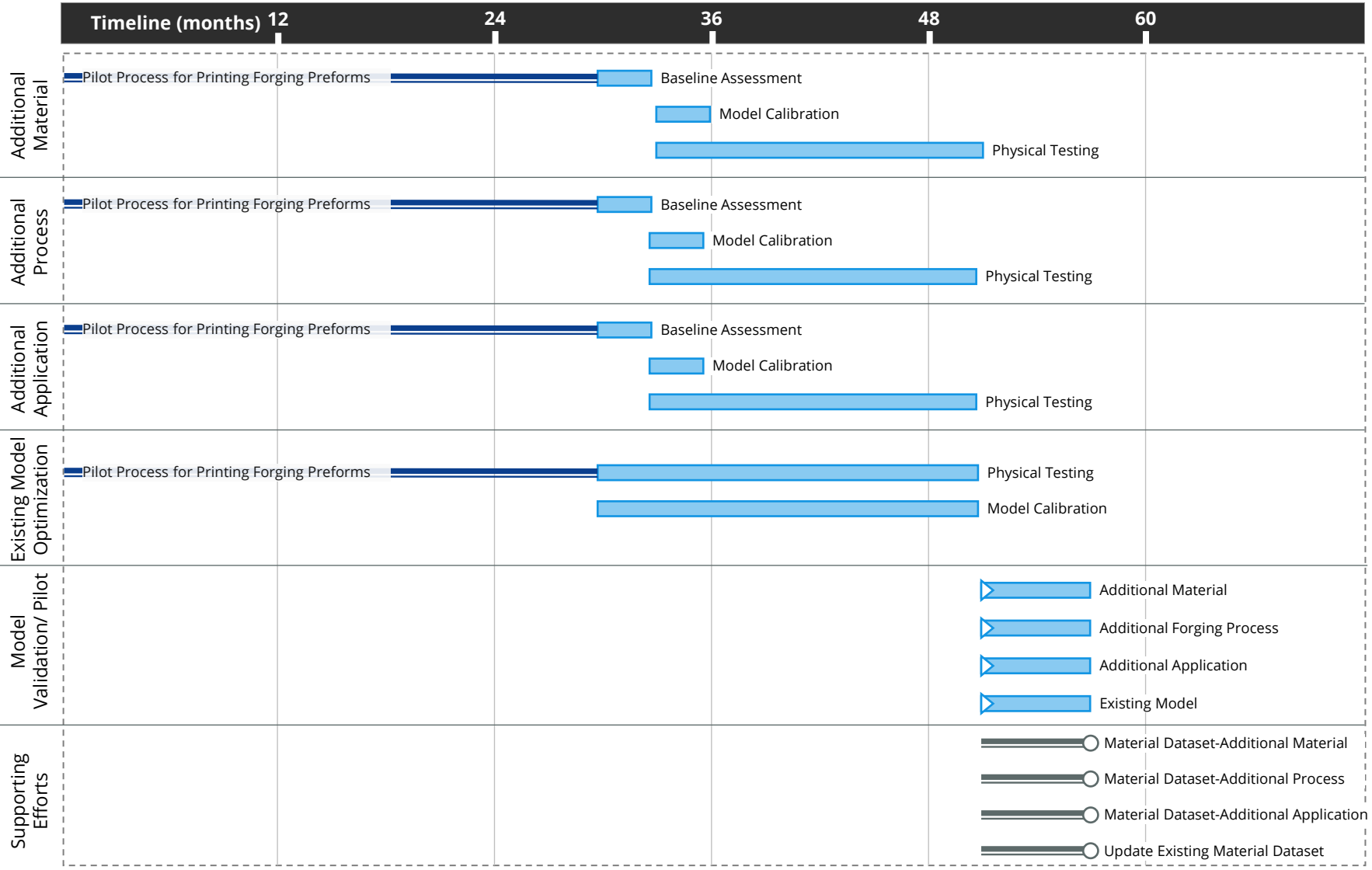
 |

America Makes

Rapid Printed Preform Validation with Simulation

Enable optimized process setups with predictable performance using preforms with heterogenous microstructures

Casting — Forging



Priority, Cost, & Duration

Priority: 6
Forging Projects

27 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Material Datasets

Outcomes
- 1 material system assessed
- 1 forging process assessed
- 1 product assessed
- Pre-existing model optimized

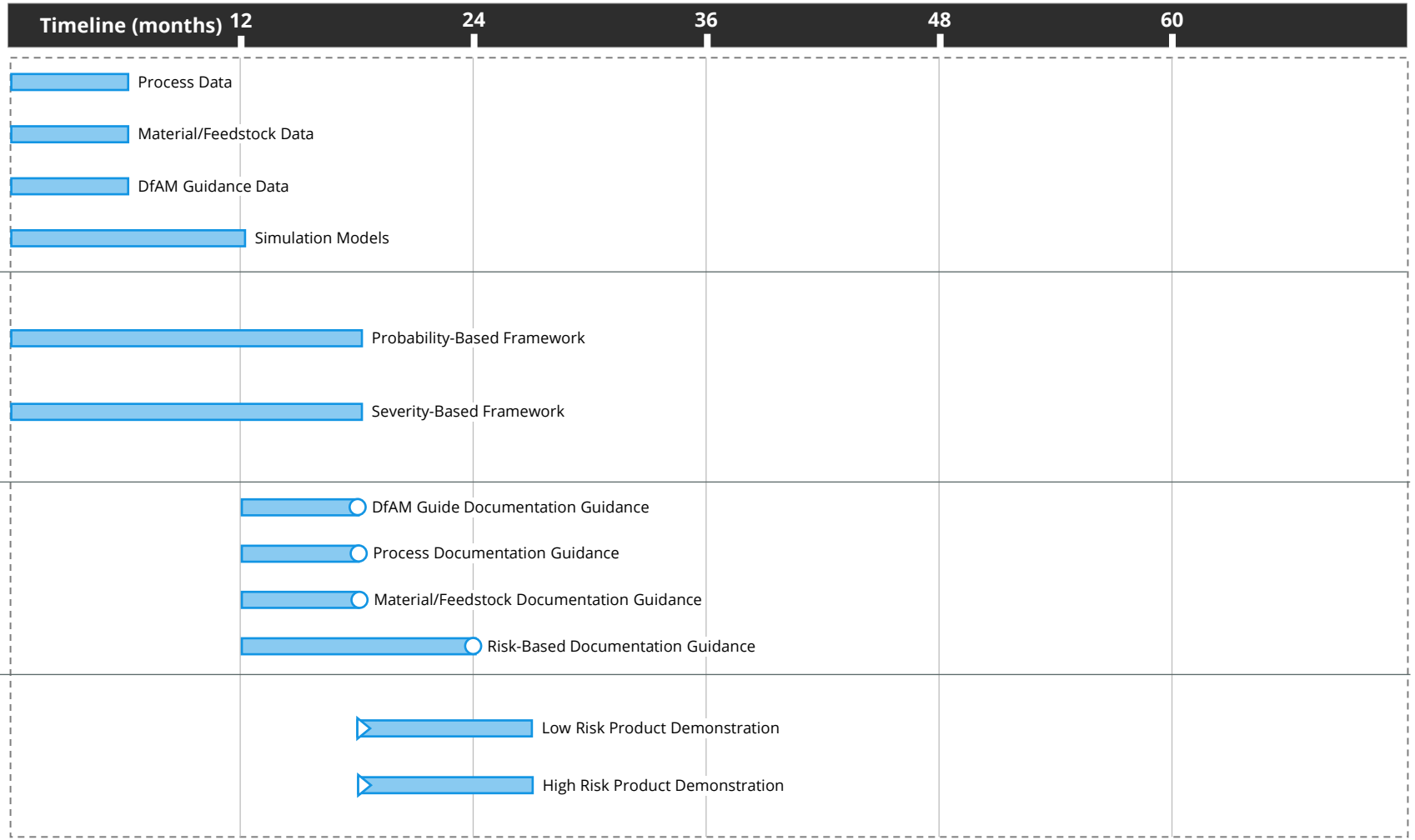
Impact
- Enable faster and right-first-time forging of printed preforms
- Establish a framework to reduce the number of intermediate forging steps

America Makes

Guidance for AM Data Collection

Establish data infrastructure and application-based guidance to collect store data spanning AM process flows

Casting  Forging



First Capability Deployment ▷ Deliverable ○

Priority, Cost, & Duration

Priority: 2
Shared Projects

27 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Guidance on collection and storage of data from design, material, process
- Guidance on application-specific data collection

Outcomes
- Simulation training delivered to 5 DoD depots

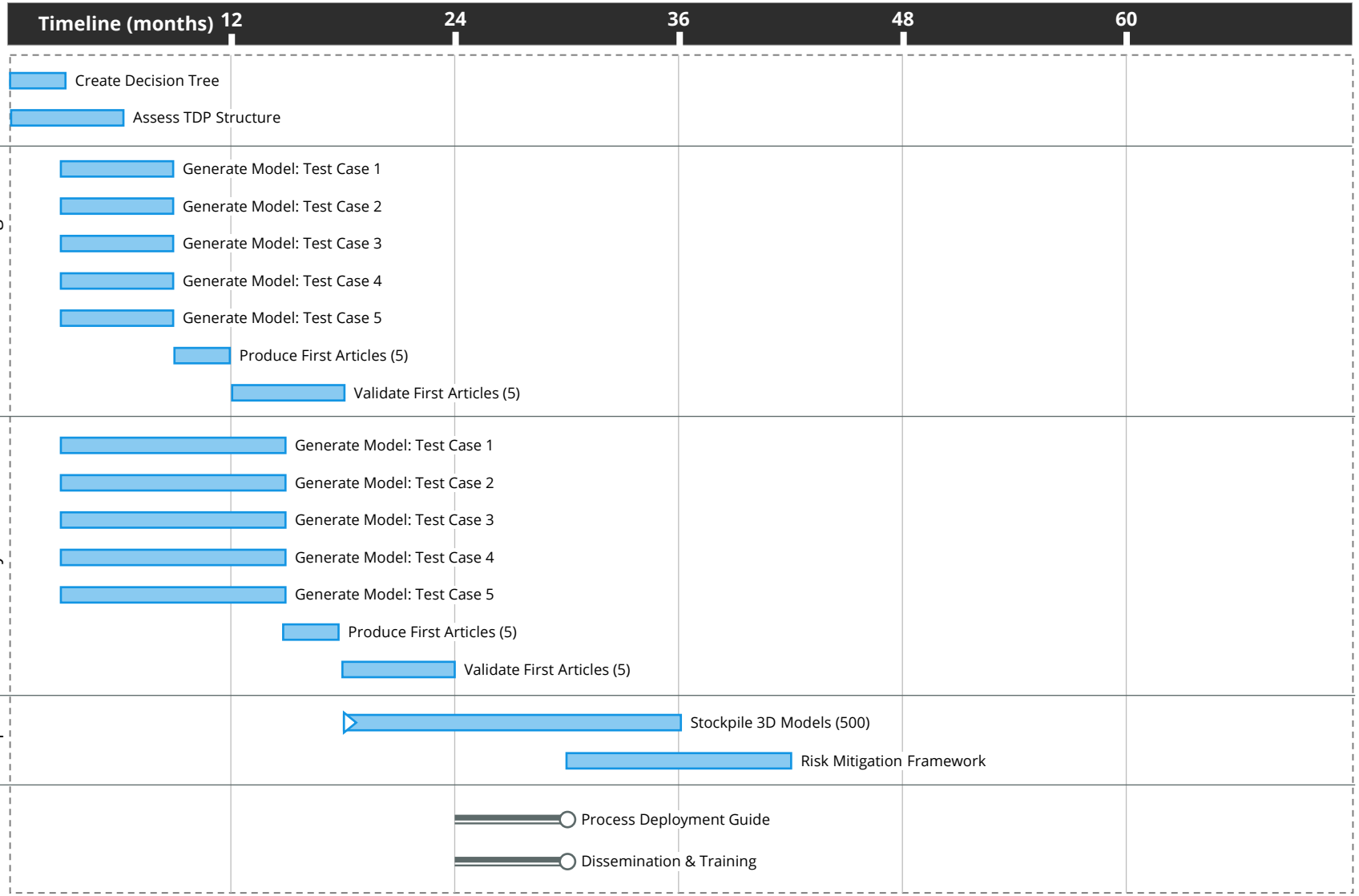
Impact
- Common guidance on what data to gather and store based on application
- Infrastructure to aggregate data for advanced analysis, analytics, etc.

America Makes

Pilot a Digital TDP/CAD Stockpile Program

Accelerate the creation of TDPs and CAD models for legacy components by building a program of record for continued conversion

Casting  Forging



Priority, Cost, & Duration

Priority: 3
Shared Projects

42 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Common CAD conversion processes
  - From physical part
  - From 2D drawing
- Scenario-based decision tree
- Guidance document for risk mitigation

Outcomes
- 500+ CAD models created for legacy components
- 10 test models and physical parts produced/verified

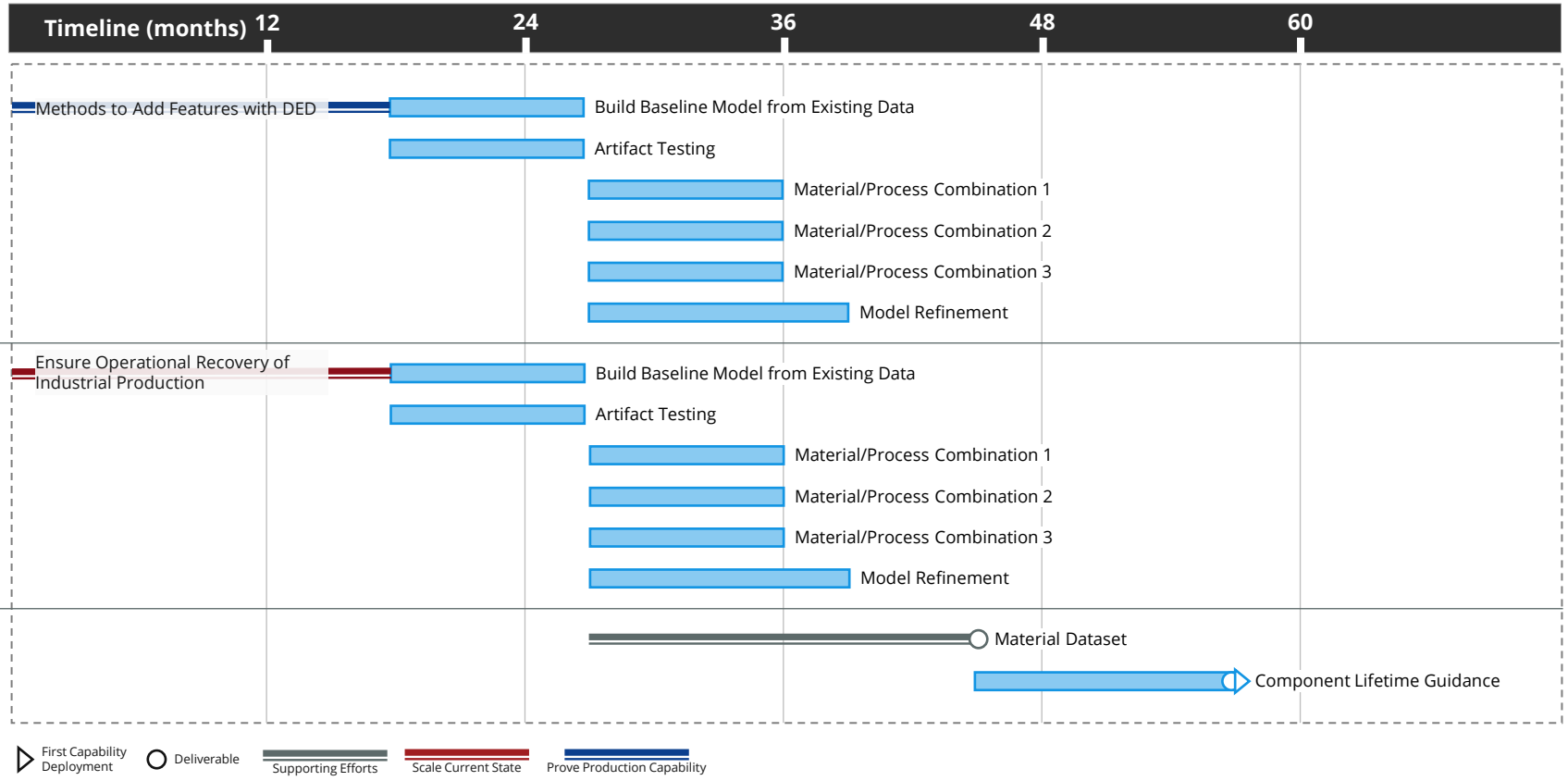
Impact
- Remove lead time for legacy CAD model creation
- Demonstrate complete reverse engineering workflow for DoD component(s)
- Demonstrate reduced sourcing lead time by 25%+

America Makes

Simulation-Supported Lifetime Recommendation

Develop material and geometric performance software solutions to integrate into DoD process flows

Casting  Forging



Priority, Cost, & Duration

Priority: 5
Shared Projects

39 Months
Total Duration

Output, Outcomes, and Impacts

Output
- Material Dataset
- Simulation models
- Component Lifetime Recommendation Guidance

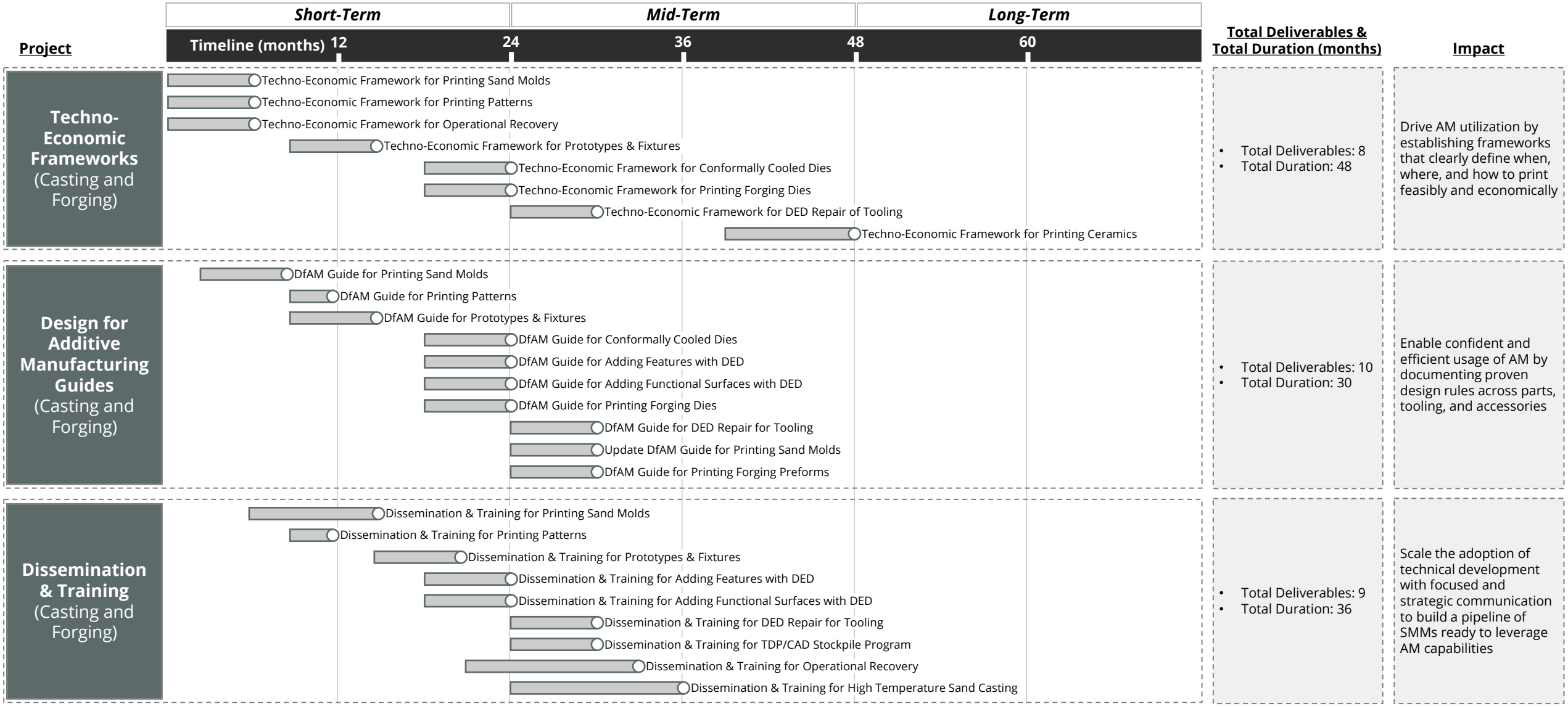
Outcomes
- 2 AM modalities assessed
- 6 material/process combinations assessed

Impact
- Data-driven guidance for lifetime and testing plans for short-term use printed components

Supporting Efforts

America Makes

Supporting Efforts



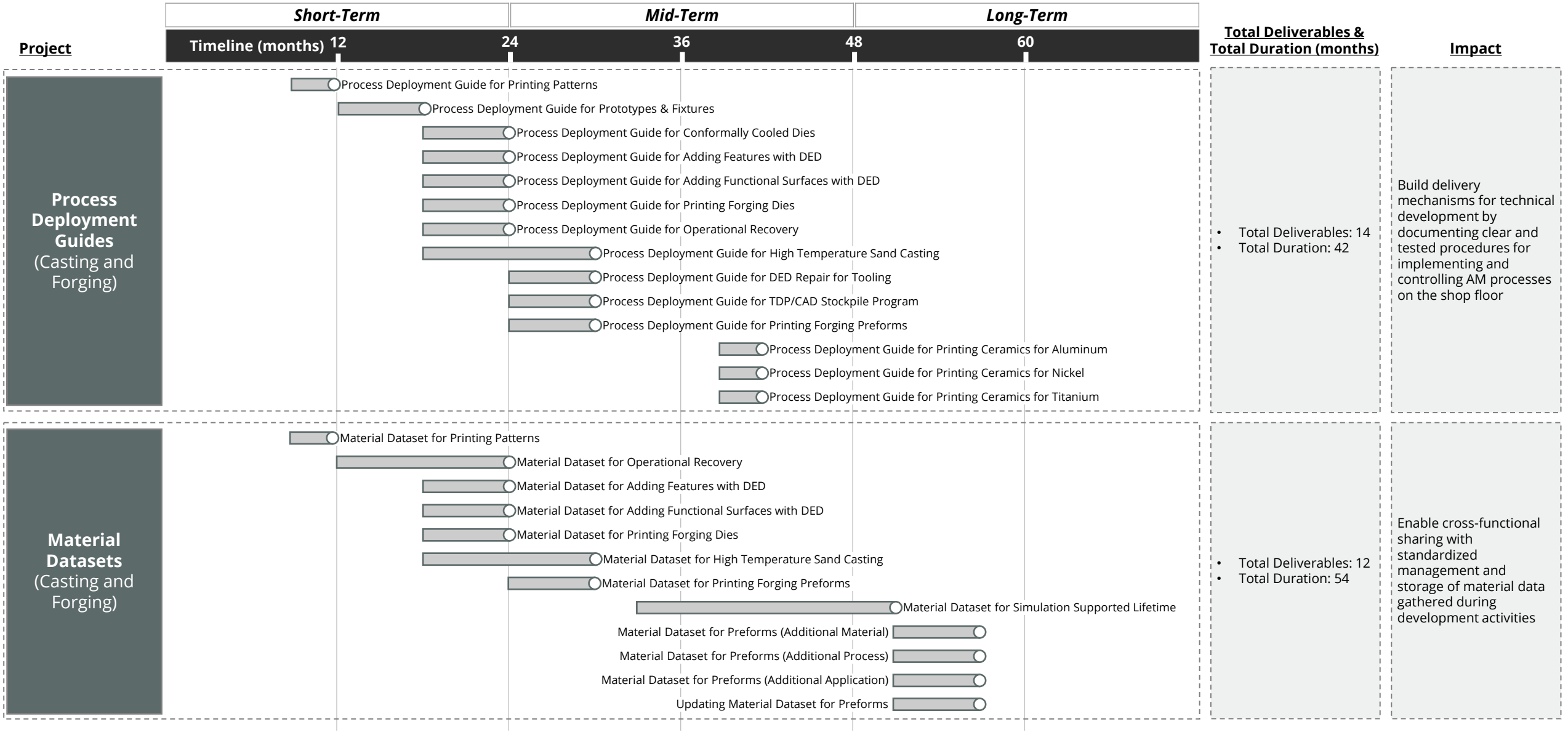
Project	Total Deliverables & Total Duration (months)	Impact
Techno-Economic Frameworks (Casting and Forging)	• Total Deliverables: 8 • Total Duration: 48	Drive AM utilization by establishing frameworks that clearly define when, where, and how to print feasibly and economically
Design for Additive Manufacturing Guides (Casting and Forging)	• Total Deliverables: 10 • Total Duration: 30	Enable confident and efficient usage of AM by documenting proven design rules across parts, tooling, and accessories
Dissemination & Training (Casting and Forging)	• Total Deliverables: 9 • Total Duration: 36	Scale the adoption of technical development with focused and strategic communication to build a pipeline of SMMs ready to leverage AM capabilities

First Capability Deployment | Deliverable | Scale Current State | Prove Production Capability | Build Digital Foundation | Supporting Efforts

Indicates this activity is interdependent of an activity in another swim lane

America Makes

Supporting Efforts



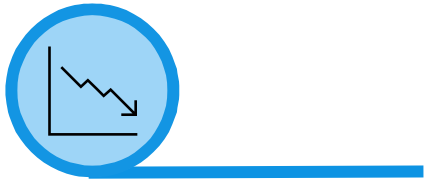
First Capability Deployment | Deliverable | Scale Current State | Prove Production Capability | Build Digital Foundation | Supporting Efforts

Indicates this activity is interdependent of an activity in another swim lane

No Regrets Next Steps

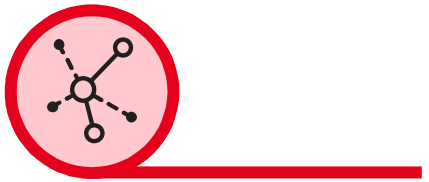
No Regrets Next Steps

It is imperative to enhance national security by maturing our industrial base with investments that free up CF capacity and streamline throughput



Lower adoption risk by disseminating resources and tools to make informed decisions for when to use AM.

Invest in technology deployment by transferring key capabilities and outcomes to the shop floor



Incentivize knowledge sharing by early adopters to replicate advanced capabilities at scale across the industrial base

Incorporate non-technical solutions to policy and workforce issues that will generate long-term success

To improve our nation's wartime readiness, we must address CF supply chain challenges and build on the momentum generated during roadmap development through continued ecosystem collaboration and targeted investment