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Fibonacci Innovation Acceleration (FIA): the ecosystem model for future manufacturing scale

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1 Introduction

Indian manufacturing industry wants to drive faster innovation to indigenize and reduce imports to be more competitive in the global market. However, most leaders are concerned about the speed and global quality of products that will come out, even when they invest in their internal innovation programs or look at start-ups within India. This situation leads to an increase in imports of these technologies and products. In this article, we analyse the issues and provide a case study with outcomes and the process followed to address these challenges.

We started by noting sudden surge in imports of robotic and autonomous systems in the last 5 years. This was driven by increased spending on autonomous mobile robots (AMRs), manipulators, collaborative robots, and drones by manufacturing, defense, commercial, and government enterprises. Given the technology, products, and global trade environments, it was important to drive indigenization and innovation to build strategic independence with respect to the security and safety of these in products in India. The **Ministry of Heavy Industries (MHI)**, Government of India (GoI) was working on schemes to drive indigenization to retain and strengthen India's position in the future of manufacturing.

Given the global scenario and massive technological changes, it was absolutely essential to create an ecosystem that could create such future-ready products and technologies for Bharat's manufacturing ambitions. At this point, India lags behind in the development scale of several such strategic technologies, products, and machinery that the US, UK, EU, Japan, and China have invested in the last decade.

A proven ecosystem model was needed to drive the accelerated innovation in this context engaging startups, large industries, Venture Capitalists (VCs), academia and autonomous research institutes in the development of these advanced manufacturing technologies. Several past initiatives failed to deliver this outcome with the speed needed for synergistic integration between these entities. We required an ecosystem model to jumpstart today while also allowing the development of products/technologies that will be differentiated in the next 5-10 years. Our approach was to ensure that we:

(1) Quickly develop products, leveraging existing Technology Readiness Level (TRL) 3 technologies and be the best in class for next 5-10 years w.r.to global competition.
(2) Focus on what products and supply chains to create a stronger manufacturing economy with strategic independence in these areas by 2030.

In this paper, we present the **Fibonacci Innovation Acceleration (FIA)** ecosystem model, closely working with MHI that attempts to solve this challenge given our current constraints, using its **Center for Advanced Manufacturing for Robotics and Autonomous Systems (CAMRAS)** program as a case study. Metaphorically, and in typical financially administered programs, one would prefer the Exponential[1] innovation growth model, but given our initial starting point, we built the FIA using the Fibonacci[2] foundation for our innovation ecosystem growth model.

In the next section, we describe the strategic technology gaps of next 5 years and what we need to be ready by 2030, keeping the CAMRAS program objectives in focus. We shift our attention to the drivers needed for the FIA model that was innovated under the 'Enhancement of Competitiveness in the Indian Capital Goods Sector Phase II' scheme of MHI, GoI. CAMRAS was conceptualized in July 2022, approved as an MHI Accelerator program under the scheme in November 2022 and operational in January 2023 with a target completion date set to March 2026. MHI had already designed the framework to develop the ecosystem in the scheme and to enable the integration of current and existing manufacturing units in it. We conclude the paper with learnings and possible scaling of the FIA model to accelerate India's manufacturing ecosystem to achieve its strategic objectives.

2 Investible Technologies and business model analysis

Much literature is already available on the key technologies [3,4] that impact the future global manufacturing economy. The 5 factory models, in Hyper-Automated factories [3], provide great insight. From a technological perspective, AI, robotics, autonomous systems, Industry 5.0 technologies, sustainable material advancements, energy optimization, self-managed products, advanced sensors, and assistive technologies will play a critical role. Global import-export shifts due to geopolitical scenarios [5] pose additional challenges to the creation of this ecosystem. To innovate the CAMRAS program model, it was important for us to analyse the approaches and industrial policies adopted by China[6], EU Fraunhofer[7], UK[8] and Japan [9] to build manufacturing scale momentum. Here is a short analysis of these innovation models:

(1) China[6] adopted an MNC collaboration model to establish manufacturing bases for local consumption and in parallel invested in collaborative research between Chinese and US universities to develop future technology products for MNCs and evolved local best practices to move forward. The focus remained on driving lower costs and mass production at speed in this journey since 2012.
(2) Fraunhofer IPA[7], started in 1959, focused on organizational and technological tasks in production with respect to processes, components, devices and systems that were developed, tested and applied. The production and automation expertise continuously innovated in 11 research areas. Fraunhofer with the University of Stuttgart and the

state government of Baden-Württemberg have jointly initiated the S-TEC to advance future-oriented research topics and bring them to the market quickly.

(3) The United Kingdom[8] used its "High Value Manufacturing Catapult" to value add their manufacturing industry by developing advanced technologies increasing their performance and productivity through seven centers. These centers supported start-ups, large industry and academia by providing bridge funding support, innovation infrastructure including experts to address the strategic gap that is identified by these collaborative teams.

(4) Japan[9] has invested heavily in manufacturing engineering and automation through initiatives such as (i) Society 5.0 and government support, (ii) integration of digital technologies with human capabilities, leading to advancements in areas like AI powered robotics, Internet of Things (IoT) and cloud-based automation and (iii) increased productivity, reduced costs, and improved product quality in various sectors.

A key point to note was the quantum of investments over the years, continuity, and strategic focus on the initiatives by these countries. Our challenges lied in all three aspects and we were looking on creating an innovation accelerator model in 2022, that gave us agility and better outcomes while requiring reduced investment, focusing on technologies and products needed in robotics, autonomous systems and Drones areas through the CAMRAS program. Table 1, covers the import summary of products/components when we conceptualized the CAMRAS program in May 2022. It is evident from Table 2 that our focus

HS Code	Commodity	Imports (CR)
84795000	Industrial Robots	787
84834000	Gears & Gearing	4,683
90328910	Electronic Controllers	1,296
90230010	Teaching Aids	70
84111200	Turbo-Jets of Thrust ≥ 25kN	23,569
84119100	Propellers and Rotors	39
85340000	Printed Circuits	9,342
85044030	Battery Chargers	1,071
	Total	**42,030**

Table 1 Import summary (2022-23) of HS Codes relevant to the CAMRAS Program objectives (Source)

was not just to create autonomous systems, but also to establish supply chain ecosystems to indigenize them. We had to provide the momentum and funds to build product scale and compete with global benchmarks.

3 FIA ecosystem model – case study of the MHI-CAMRAS Program

Based on the previous MHI initiatives at IISc-SID for the AMCoE and Industry 4.0 CEFC programs in 2018, it was obvious that India needed to further accelerate the speed and scale of impact. MHI had conceptualized the Accelerator program in 2022, under their phase-2 scheme of Capital Goods. Thus, our analysis at IISc and MHI converged to initiate the CAMRAS program after a thorough evaluation. We started this program through another IISc entity, focused on AI and Robotics Technologies, named ARTPARK. The aim was to target the creation of new startups with the Project Implementing Organization (PIO) acting also as the Industry Partner (IP), in these areas under the new model and drive the creation of market-ready products and technologies (TRL-7/8) to create the supply chain ecosystem in these areas by 2026. The intention was not only to create these companies, but also to create a replicable model that allowed operational flexibility for speed, IP development with startups in these advanced technology areas (Table 2) and to get large industry players to become their customers to scale this model within India at different places.

We analysed several studies available on business innovation model measurements [10,11], measurement in innovation management [10] and organizational capital [12,13] to gain insight in evolving our approach. Given the strict timelines of the CAMRAS program, the maturity of the technology at the start, and the complexity, the authors identified key drivers to work on and innovate the FIA model. The objective was to ensure the success of this new CAMRAS program and its start-ups and create a proof for larger industries, MSMEs and ministries to use this innovation model and make India a sizeable global manufacturing hub. The identified drivers were:

(1) Leadership talent to initiate these projects with the goals to create a company during the course of the program and then accelerate growth as a company after 3 years.
(2) Operating model to evolve the project into a company with market-ready products.
(3) Break down plans into timelines to drive the movement of technology from TRL 3-4 to TRL 7-8 in the course of 3 years.
(4) Drive innovation and indigenization with patents to develop Indian suppliers for the newer product or components.
(5) Provide industry-standard infrastructure for product development, certifications, team scaling, prototyping, and manufacturing ready scale for attracting venture-backed or strategic investments.
(6) Drive startups to secure industry and defense players as early anchor clients.
(7) Ensure that startups are able to generate revenues from clients and also leverage each other w.r.to technologies, products, and create a supply chain internally for core strategic technologies.

MHI identified metrics (m_j) to evaluate accelerator performance, under the Capital Goods Scheme Phase II (a-e). The CAMRAS program added metrics (f-h) to achieve the larger goals of establishing successful and scalable companies through this program (denoted by subscript 'j'). We used the metrics below to measure the CAMRAS program and the success of the FIA model,

(a) New companies, technologies and products created
(b) Patents filed in India
(c) Extent of innovation and indigenization in technologies w.r.to products and components
(d) Revenues generated by the companies against targets.
(e) Core talent created within the program, startups and skilling of larger pools for new areas.
(f) Number of Indian suppliers created to build these new product components to scale the ecosystem.
(g) Extent of investments raised by the companies and their valuation
(h) Potential for future technology development that will put us ahead of global players beyond 2030.

Let us now explain why the authors converged on the use of the FIA as compared to the Exponential growth model for the CAMRAS program. Table 3 shows the dynamics of pressure on a metric as one innovates and accelerates product development and business for startups in time (t), given various objectives shared previously. The table provides a reflection of a 10-year innovation acceleration window by comparing two models. Assuming the metric (m_j), as "revenue" in this example, and a start point value for that at INR 0.8 Cr in the 2nd year, the pressure on the newly innovated business in first 5 years is lesser in the FIA model and by $t = 10$ (10th year) it meets the exponential growth model target, assuming funding support for the projects in first 3 years.

With the same assumption for the exponential growth model with a growth rate (R) of 48.4% from the third year, it implies a target growth of 120% from the second to the third year, which is a huge jump right in the innovation outcomes in that model. One can note that this greater growth rate can be targeted only in startups for new product development if products exist at the

Project Title	Target Cost	Competitor 1 Cost	Competitor 2 Cost
Robotic Actuators	$900	$1,000 (IGUS GmbH)	$2,000 (Amber AIOS-Pro)
Planar Magnetic Drive System	25% less	NA (E-Circuit Motors Inc.)	NA (Infinitum Electric)
Legged Walking Robots	$60,000	$74,500 (Boston Dynamics)	$150,000 (Ghost Robotics)
Distributed IMUs	$1,200	$4,000 (Xsense MVN)	-
Soft Robotics	$1,500	$4,000 (Soft Robotics Inc.)	$2,500 (Wegard GmbH)
Advanced Intelligent Controllers	$900	$2,000 (VOXL)	$1,579 (Auterion)
Flexible Structures	$100,000	$300,000 (Mightyfly)	$300,000 (Volansi)
Autonomous Charging Systems	$1,00	$4,000 (SkyCharge)	$6,999 (Heisha)

Table 2 Target products/technologies and global competitive benchmarks for CAMRAS program objectives

Time	FIA Model		Exponential Model	
(t)	Value	Growth%	Value	Growth%
1	0.0	-	0.0	-
2	0.8	-	0.8	-
3	0.8	0%	1.8	120%
4	1.6	100%	2.6	48%
5	2.4	50%	3.9	48%
6	4.0	67%	5.8	48%
7	6.4	60%	8.5	48%
8	10.4	63%	12.7	48%
9	16.8	62%	18.8	48%
10	27.2	62%	27.9	48%

Table 3 FIA versus Exponential Model scaling w.r.to a metric, having same value at time $t = 1$ and $t = 2$

TRL-6/7 stage at the start (series A or B typically, not pre-series or seed stage). However, in this case, the advanced technologies/products were at a lower TRL or 2-3. Given the budgetary support from MHI, with no VCs/industry players coming forward to invest at that stage, it was clear to us that exponential growth model will not work for CAMRAS. Consequently, it was decided to implement the FIA model, setting the stage for startups to switch to the exponential model at a later point. In Table 3, the revenue at $t = 2$ depends on the TRL, competitive differentiation, IP, market size, and global potential. The CAMRAS program was initiated with the Entrepreneurs in Residence (EIRs) who were to create the startups with the program head in the targeted areas.

4 Mathematical Foundation for the FIA model

Metrics $m_{1,t}$ to $m_{8,t}$ as listed earlier. Time t_0 as program start time, t as time of evaluation, t_n as program end (after n time units), $w_{j,t}$ as weightage for metrics, O_t (output at evaluation time t), V_t is the actual Metric L^2 Weighted Norm value at time t, $V_{t,F}$ is the target Metric L^2 Weighted Norm value expected at time t, R is the compounded growth rate (YoY) expected for exponential model, $p_{j,t}$ is probability of success of $m_{j,t}$ at time t. With the above defined variables, Fibonacci formulations would work as follows:

$$\text{FIA Model: } O_t = \frac{\sum_{t=t_0+1}^{t_n} (V_t + V_{t-1})}{\sum_{t=t_0}^{t_n} V_{t,F}}$$

$$\text{Exponential Model: } O_t = \frac{V_1(1+R)^n}{\sum_{t=t_0}^{t_n} V_{t,F}}$$

The objective is to maximize the O_t and V_t at any time t, where:

$$V_t = \left. \frac{(\sum_{j=1}^{8} p_j w_j m_j^2)^{1/2}}{(\sum_{j=1}^{8} w_j)^{1/2}} \right|_{t \in [t_0, t_n]}$$

5 CAMRAS Program Outcomes and Results

In this section, we provide the summary of key outcomes of the program (Tables 4 and 5).

6 Key risks and scale potential of the FIA model

We note from the outcomes shared above, that the model is proven to be successful. The authors recognize that there are improvements possible, and those are important to be shared here. We note three key risks which this model faces (Figure 1).

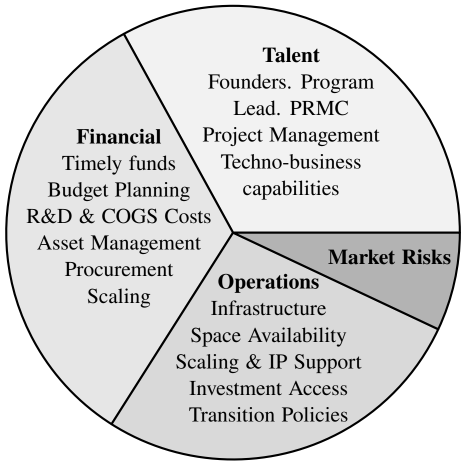

Fig. 1 FIA Model Program Risk Factors.

(1) **Talent** – It is absolutely important to understand that program success depends on the choice of people identified as leaders (EIR), core teams for start-ups, PIO/ministry leadership support, and the overall program leader. The competencies have to range from leadership, behavioural, financial management, program and project management, business management, industry relationships, investment/VC relations, team management, and technology integration capabilities. This enables culture building in start-up teams and their leaders. They must develop these competencies as part of their journey. This is not an easy task, and various environmental operating factors impact that. We would rate this risk handling as 8.75/10 for the CAMRAS program.

(2) **Financial** – Timely flow of funds, asset management, expense management, technology development, budget tracking, COGS handling, customer business scaling costs, support models and other policies have a significant impact on the success of the program. For CAMRAS, we will rate this risk handling as 9/10 for MHI due to timely cashflow support, and the parent institution (PIO) as 7.5/10, given their dependence on other support funds with their cashflow related challenges.

(3) **Operating Policies and Freedom** - Manufacturing set-up scale support, common infrastructure identification and creation, transition support for start-ups, investment raise and business sustainability planning, space availability and its allocation, people-transition mechanisms from EIR to startup teams, common financial/HR/Operations/patent services support structures, etc., of the PIO are extremely important aspects. In this regard, given the evolving scenario of the PIO itself, parent institutional dynamics, and

Metric	Outcome (t = 2.25)
New companies, technologies and products created	6, 30+, 24
Patents filed in India	15+
Extent of indigenization with competitive cost level w.r.to products and components	70-85%
Revenues generated by the companies compared to program goals	Table 5
Amount of core talent created within the program, companies and skilling of larger pool	170+
Indian suppliers created to build program products to scale Indian manufacturing ecosystem	465+
Extent of investments raised by companies and valuation	417 CR (3/6 companies)
Potential for future technology development that will put India globally ahead in 2030	67% (4/6 companies)

Table 4 Outcomes of the metrics in Section 3 at the end of 27 months (t = 2.25)

Project Title	Revenue Target (2023-2029)	Forecast (Q2 2025)	Revenue (Q2 2025)	Order Book (June 2025)	Forecast (Q3 2025)	Order Book (Q3 2025)
Legged Walking Robots	400	90	-	105	103	-
Flexible Structures	300	200	30	80	30	250
Robotic Actuators	400	31	6	19	12	28
Planar Magnetic Drive System	70	-	-	-	-	-
Soft Robotics	400	3	8	-	1.6	1.6
Distributed IMUs	30	20	40	25	20	20
Advanced Intelligent Controllers	500	20	33	45	15	20
Autonomous Charging System	200	40	37	224	100	200
Total	**2,300**	**404**	**154**	**498**	**281.6**	**519.6**

Table 5 Revenues (INR Lakhs) of the program after completion of 27 months (t = 2.25)

the PIO scale to generate private/industry investments in short times while innovating its own model, we rate this risk handling score as 7/10.

For the FIA model to scale for other innovations that are needed for the Atmanirbhar Bharat campaign of the Prime Minister, given the current geopolitical and economic context, the following actions should be considered:

(1) GoI may scale/replicate this model and develop multiple Fibonacci Innovation Accelerators (FIAs), by creating independent implementation mechanisms, with GoI affiliated public sector/autonomous institutes/academia (as PIOs).
(2) The defined policies and guidelines should provide talent, operating, financial/board creation, and other flexibilities based on the risks identified here to enable investments from private companies/VCs in the program.
(3) PIOs with large private industries/VCs should become part of this journey at the beginning of the program itself.
(4) Industry partners/VCs with PIOs together should be investing atleast 25-35% of the program money, from their CSR commitments, where the government may support with 65-75% based on their focus to develop such strategic technologies and products.

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