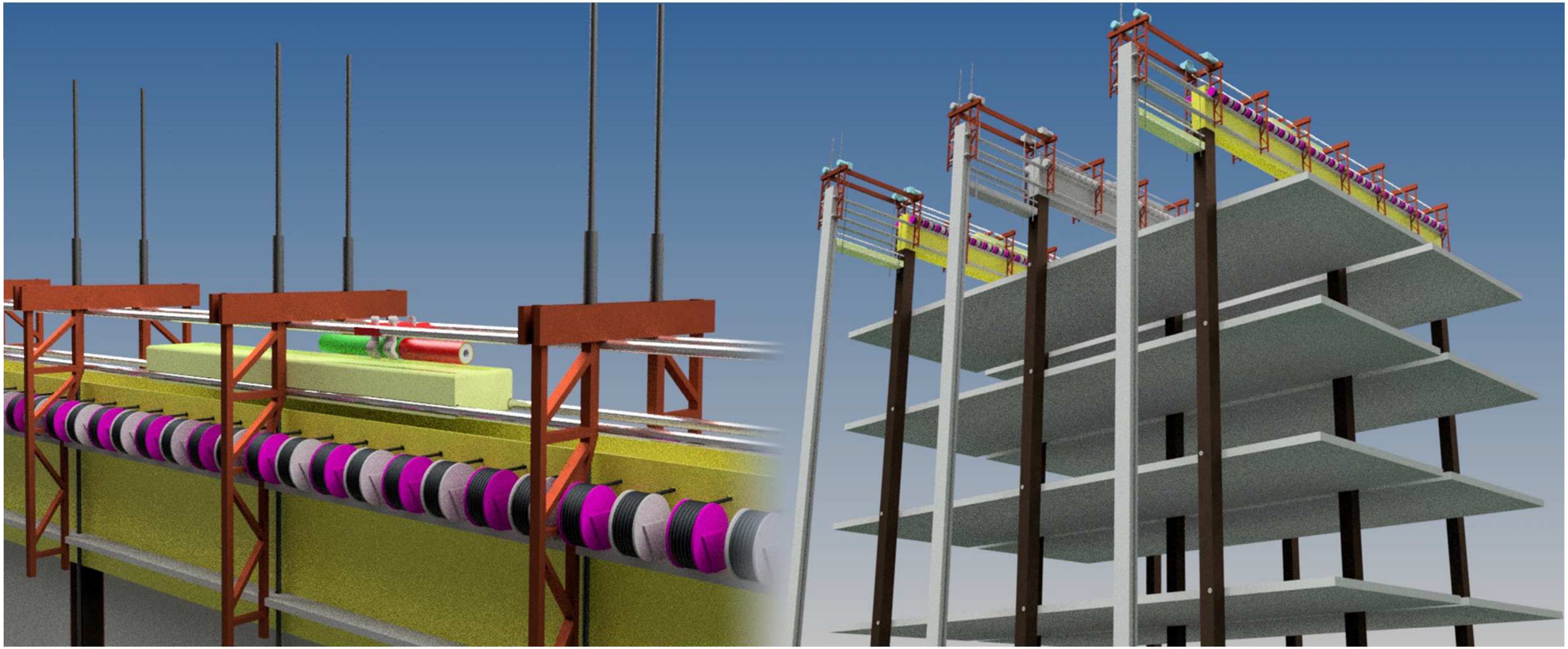


Vertical Printing Technology

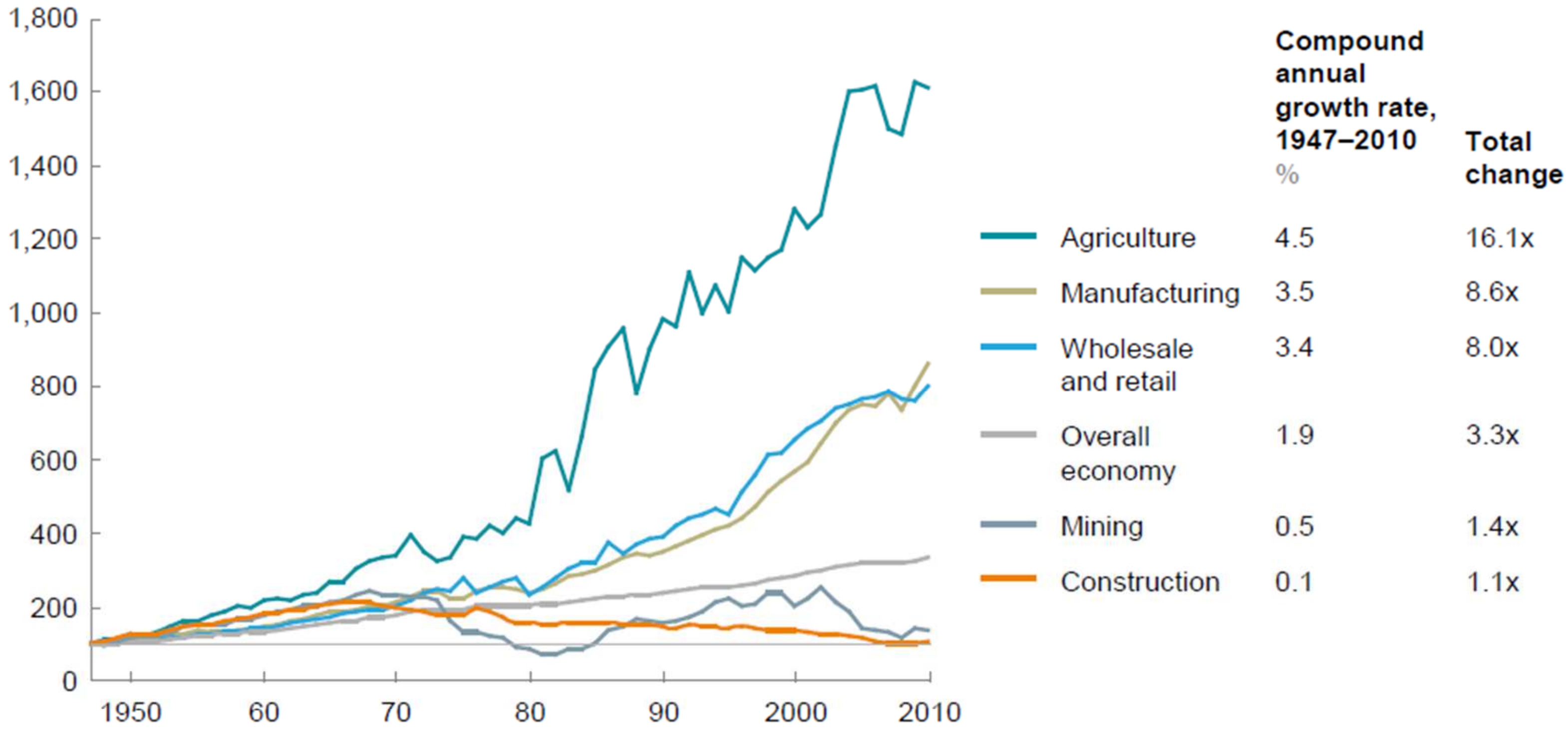
Moscow, 2018

The Problem

In the United States, labor productivity in construction has declined since 1968, in contrast to rising productivity in other sectors

Gross value added per hour worked, constant prices

Index: 100 = 1947



Many sectors have transformed and achieved quantum leaps in productivity; construction has changed little, limiting productivity gains

Key advances, 1947–2010

McKinsey Global Institute   Reinventing construction: A route to higher productivity

Construction Automation

- The level of automation in construction industry is low compared with other sectors of economy worldwide
- Potentially, 3D printers will speed up construction process, reduce labor costs and improve quality
- The market for 3D printers is still forming and includes the following major players:

  123 DUS Architects (Netherlands), Skanska (Sweden), Fosters + Partners (U.K.), WinSun Global (China), HuaShang Tengda (China), ApisCor (Russia), «Spetsavia» (Russia), Sika (Europe), LafargeHolcim (Europe), Balfour Beatty (U.K.), Carilliom Plc (U.K.) etc.

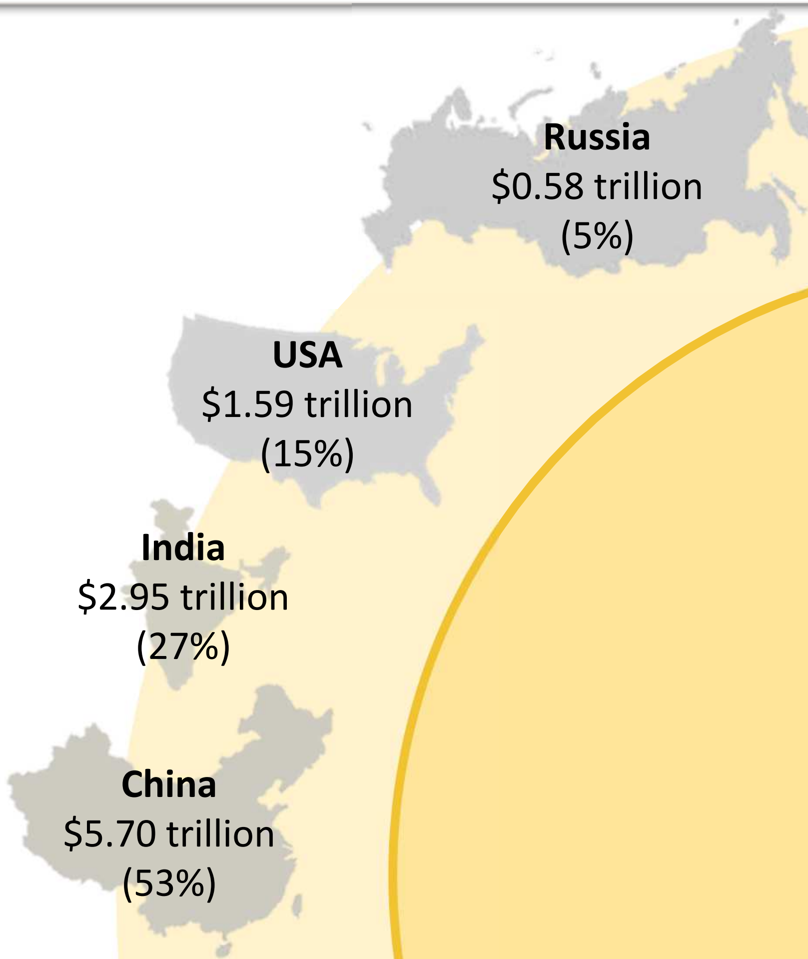
https://www.3dprintingmedia.network/category/construction-3d-printing

Competing technologies

Modern 3D construction printers have following disadvantages:

1. Construction of floors is performed in a traditional way - laying floor slabs or placing beams with a crane
2. Thus, printing only low-rise buildings is possible
3. Only special structural mixes can be used to print walls
4. Inability to automate laying reinforcement of walls and floors
5. Complex printer design and high metal usage

Market Size



560 million people → cities

$10.81 trillion housing market in Russia, USA, India, and China alone (2017-2030)

$3.78 trillion high-rise market

Market for new monolithic, high-rise buildings in the select countries is ~35% of total (2017-2030)

$200 billion

VPT printed high-rises make up 6.5% (150,000 buildings) of the total new monolithic high-rises (2017-2030)

1 - PR News Wire. Residential Construction: Global Industry Almanac (2016)
2 - McKinsey Global Institute - Reinventing Construction Report (2017)

The technology - vertical printing of floors

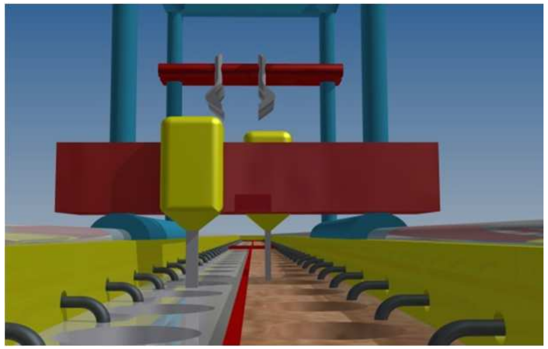
Key advantages:

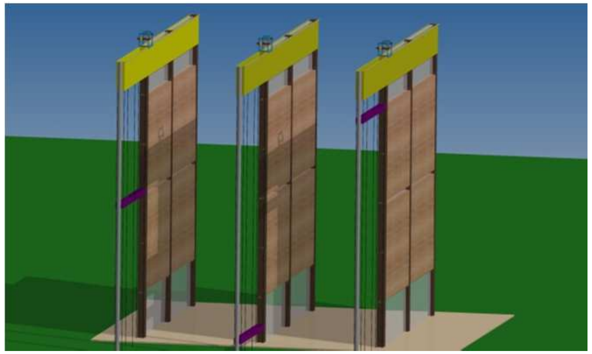
- rapid construction of high-rise buildings with the speed of construction up to 4 m/day.
- with minimum engaging additional heavy equipment.
- with high-level automation of construction.

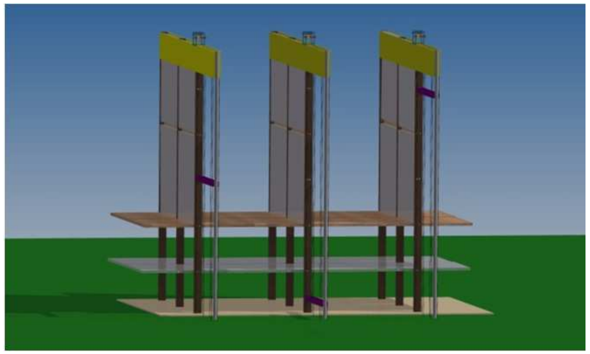
Key features:

- columns and slabs are formed vertically like in a sliding formwork method
- reinforcement bars are positioned by the printer
- floor slabs are turned into horizontal position without need for heavy equipment
- slabs are joined together and with the columns by means of post-tensioning cables

Watch it! https://youtu.be/136TBxB71Ck

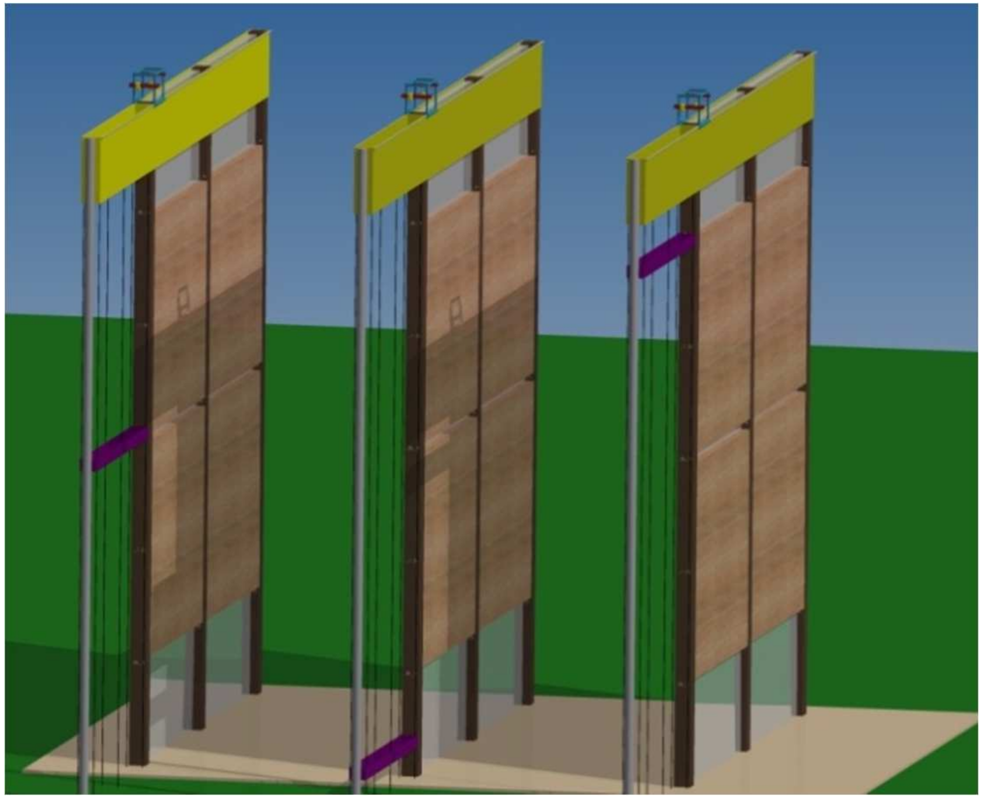




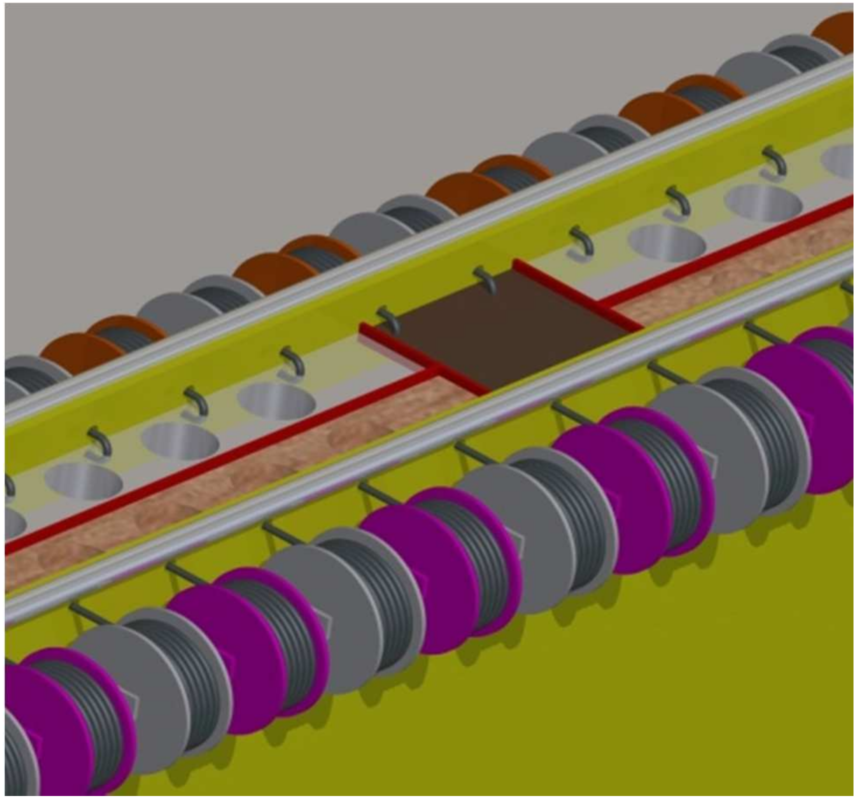


Armoring

Columns and slabs are printed vertically



Post-tensioning cables are positioned inside the slabs



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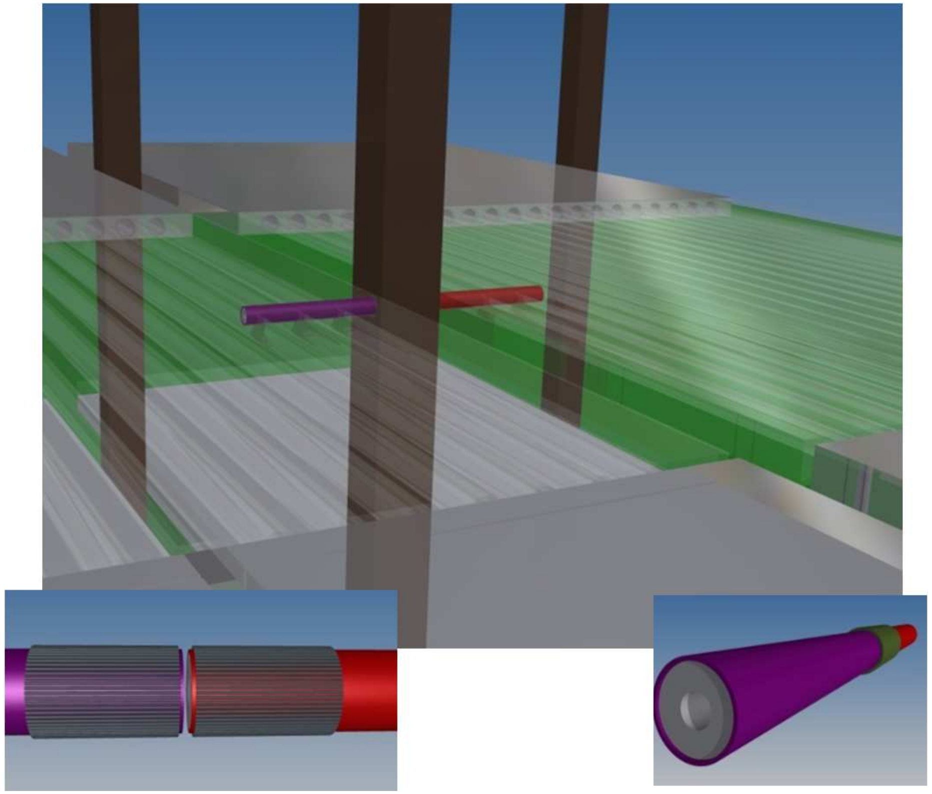
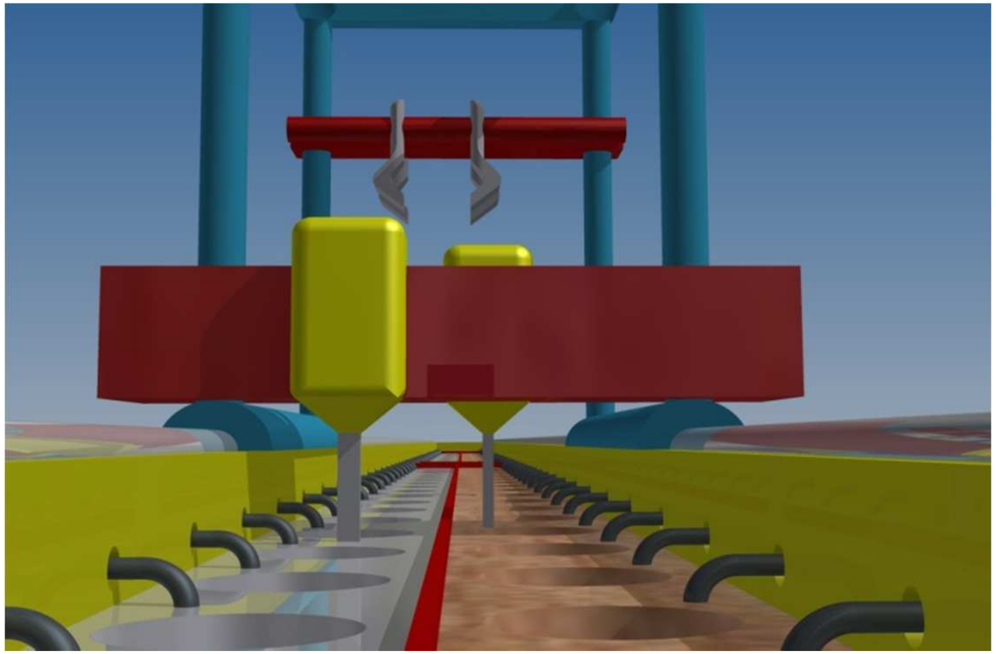
Printing

Turning elements (hinges) are placed at the slab's center of mass



Adjacent slabs are separated by a plastic layer during printing



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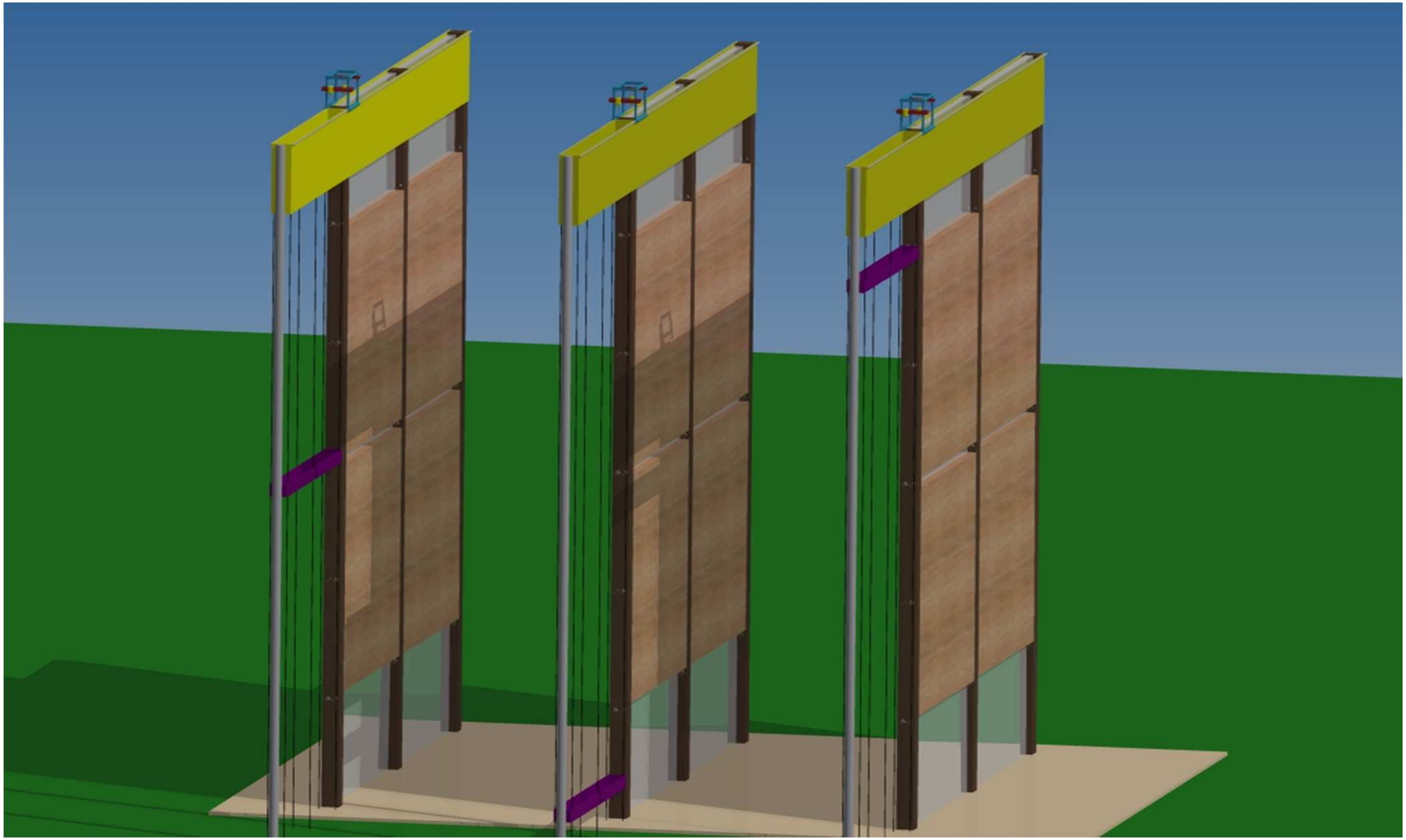
Post-stressing



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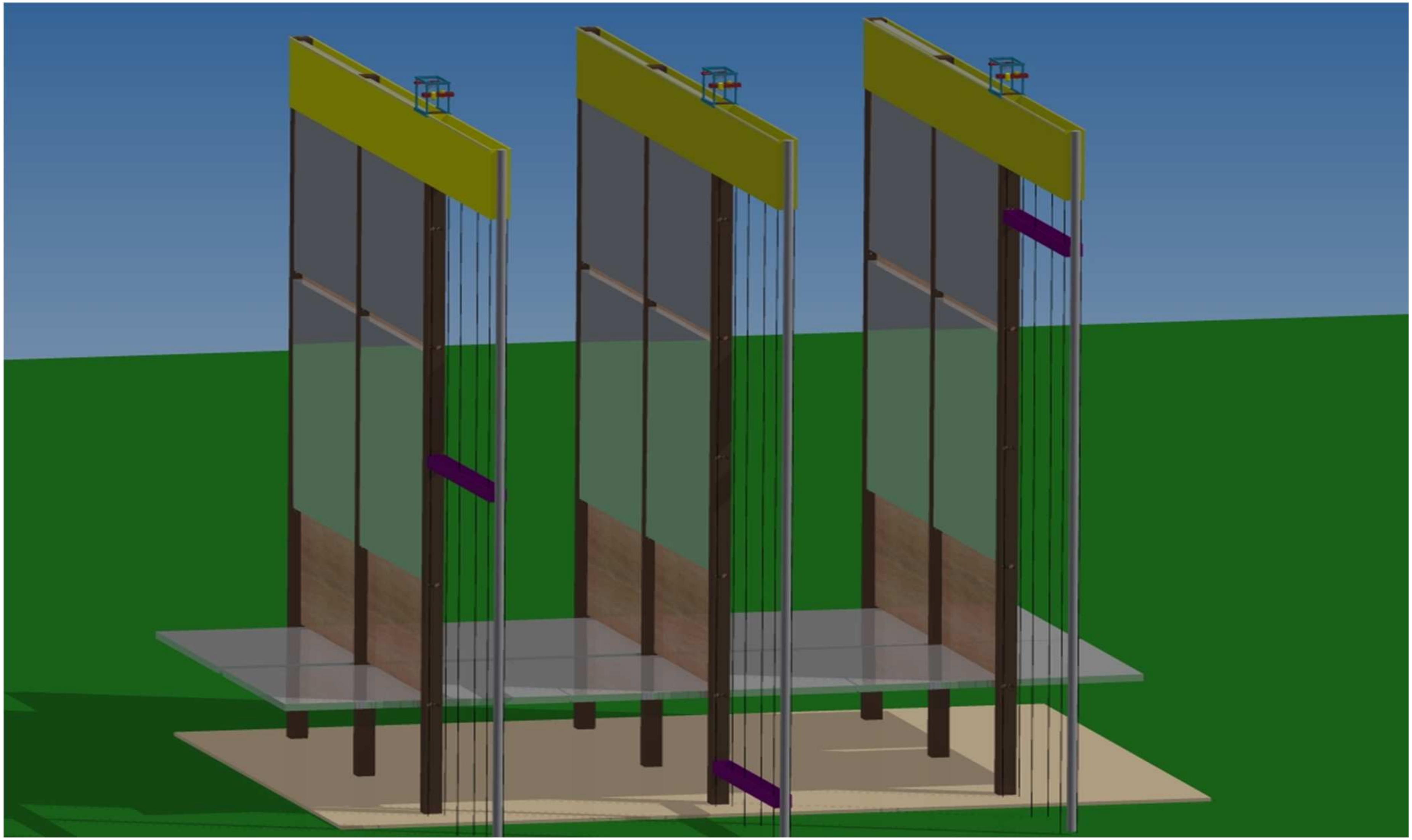
Turning floor slabs



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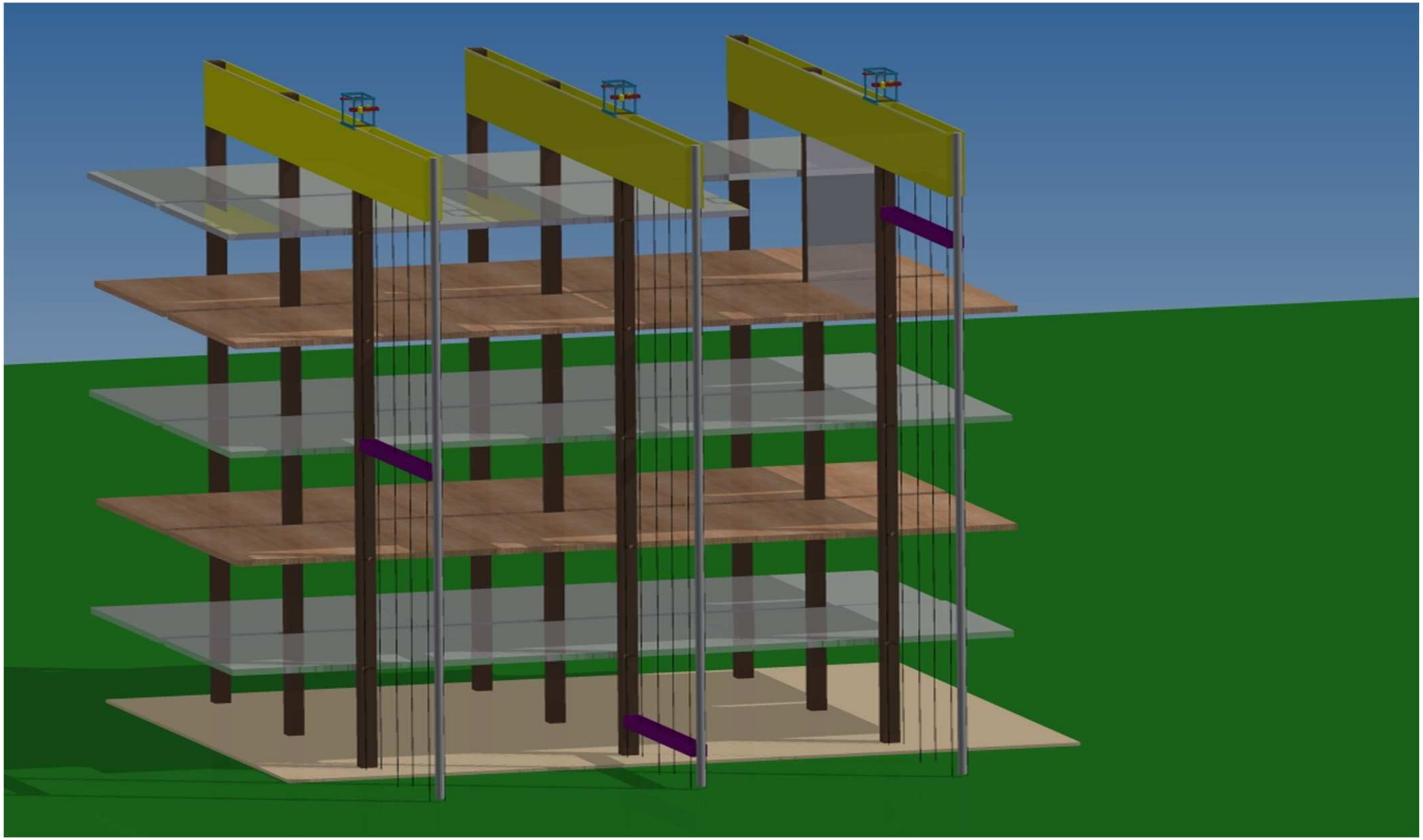
Post-tensioning the building's frame



https://youtu.be/136TBxB71Ck

Advantages of vertical printing over conventional 3D printing

1. Designed to construct high-rise buildings
2. High speed of construction (1 day – 1 floor)
3. Use of standard concretes
4. Simple logistics: only printer, reinforcement cables and concrete are delivered to a construction site
5. Compactness, ease of transportation, high speed of equipment installation
6. No need in heavy equipment on site

Competitive Advantage over conventional techniques

Increasing level of sophistication

Construction type:	Low cost	High quality	Quick	Flexible internal layout	High worker effectivenes s	Aesthetic	No need for an industrial base nearby
VPT printer	x	x	x	x	x	x	x
Mobile 3D printer builds on-site, minimizing material and labor costs							
Pre-fabricated modules		x	x		x	x	
Fully-made rooms built off-site are transported to the construction zone, stacked and attached to one another							
Carcass or carcass-monolithic	x	x	(x)	x		x	
Pre-made concrete plates are brought from off-site to the construction area and are assembled using cranes							
Monolithic				x			x
Concrete is continuously poured at the construction site to create the floors and walls of the building							

An example of labor and equipment cost reduction

22-story house, the scope of monolith construction work is 8195 m3	3D-printer (1 floor - 1 day)	High-speed monolith construction (1 floor - 3 days)	Standard monolith construction (1 floor - 6 days)
Construction time	22 days – construction, 30 days - the required strength, tension reinforcement, the rotation of the plates, the embedment of joints. Total - 52 days	2,7 months (80 days)	5,4 months (160 days)
Number of construction workers	Number of printers(6)*5=30	101	85
Labor costs including overhead and taxes	$70K	$281K	$325K
Costs of 1 m3 of concrete	$12,4	$34	$40
Day-work m3 per person	3.6	1,2	0,7
Rent: - formwork for vertical structures	Number of printers*(1/24 of a printer production costs ~ $250K)=$62,5K	$53K (1201 m2)	$85K (960 m2)
- formwork for horizontal structures		$27K (1224 m2)	$28K (642 m2)
- tower crane		$29K	$59K
- concrete pump		40...60 m3/h- $16K	10...20 m3/h - $22K
Total costs of monolith construction work	$131,6K	$407K	$518K

An example of overall cost reduction

22-story house: The volume of monolith construction is 8195 m3	**Void coefficient of the slabs**	**Volume of concrete, m3**	**Price for building material**	**Equipment and labor**	**Total cost**	**Savings**
Standard monolith (1 floor - 6 days)	1	8195	\$693K	\$518K	\$1211K	-
High-speed monolith (1 floor - 3 days)	1	8195	\$693K	\$407K	\$1100K	9%;
Vertical Printing Technology (1 floor - 1 day)	0,68	5573	\$503K	\$131,6K	\$635K	**47%**

50% cost reduction for frames of monolith high-raised building

Collaboration options

- Technology licensing
- Joint venture with a equipment manufacturer
- Joint venture with a construction company

Commercialization Timeline

Sales	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
	2018	**2019**	**2020**	**2021**	**2022**	**2023**
# Printers # Service Contracts	*Demo*	*Prototype*	40 3	120 9	240 20	360 20

Stage #1 (Years 0 - 1)
Pilot

1) Build a full-scale prototype
2) Recruit technical team
3) Receive patents in 2+ countries

Stage #2 (Years 2 - 3)
Commercialization

1) Set up manufacturing facility
2) Complete 2 pilot projects
3a) Pre-sell 60 VPT devices
3b) Secure 12 servicing contracts

Stage #3 (Years 4+)
Growth

1) Ramp up VPT device sales from 60 to 120 units / yr
2) Service 20 VPT-enabled sites / yr
3) License VPT devices to large-scale manufacturers

Next phase of the technology development

1. Develop and test a demo printer (length ~2-3 m) with a semi-automatic control system
2. Demonstrate feasibility in a lab environment
3. Construct a building frame at a test site (to be identified)
4. Design a high-raised building to be printed
5. File international patents

Investment needed	**$k**
Rental of premises	75
Equipment, tools	100
Materials	75
Services of outside organizations	200
Salary and insurance	200
Patenting	150
Consumables	100
Total	900

Seeking

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
	2018	**2019**	**2020**	**2021**	**2022**	**2023**
Investment	*Round 1*: $0.9 million	*Round 2*: $2.4 million	*Round 3 - Expansion:* $3.1 million (TBD)			
Net Present Value (NPV) Valuation	$43,0 million	$83,2 million	$179,6 million	$411,3 million	$832,2 million	$865 million
Printers Service Contracts	*Demo*	*Prototype*	40 3	120 9	240 20	360 20

Team

Highlights:

- Russian and American backgrounds
- Material and nuclear engineering R&D domain expertise
- Large-scale planning and construction experience
- 2 of the co-founders previously designed and built a large-format 3D printer

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