

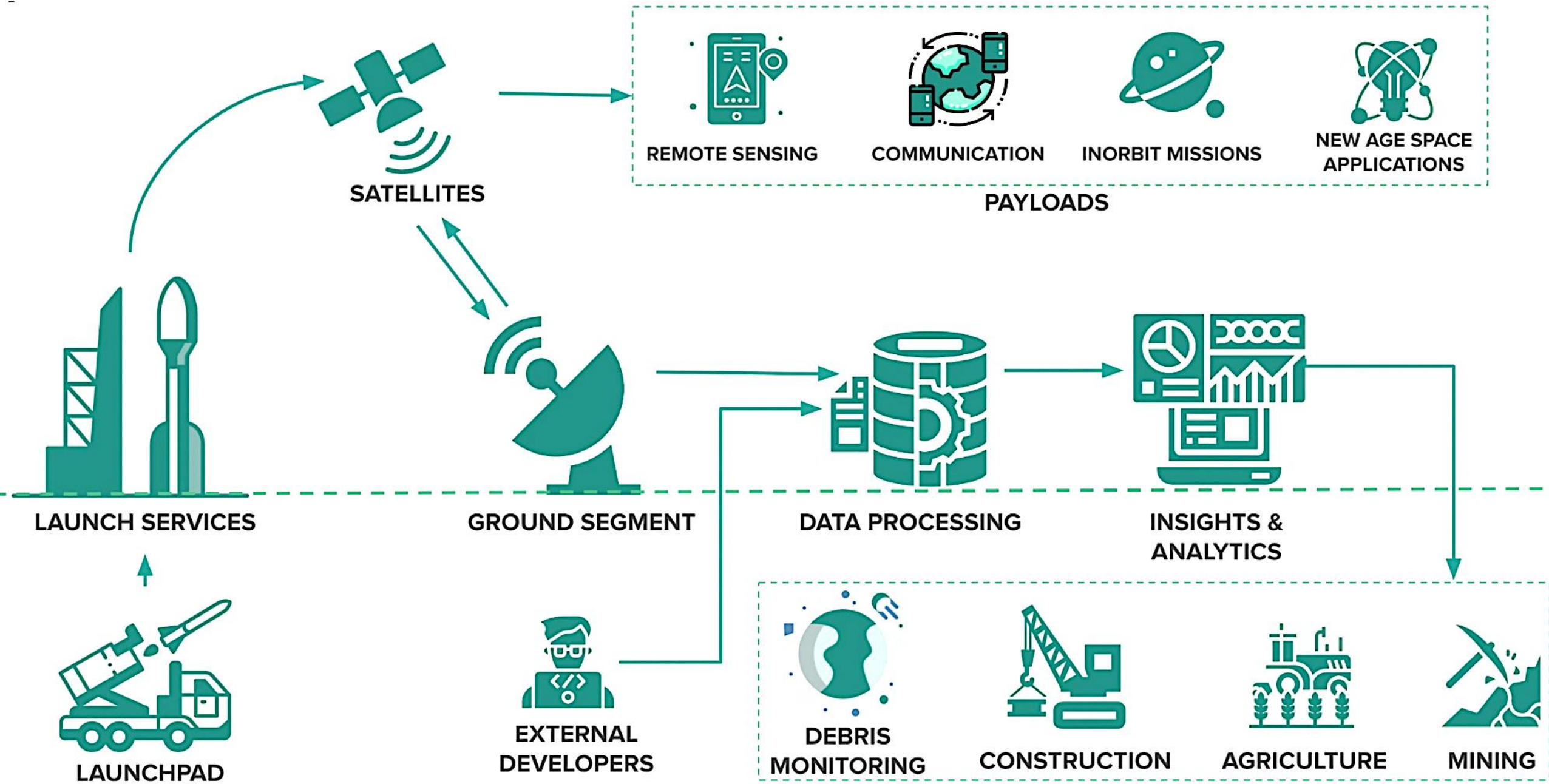
Mobile launching 3D printed rocket engine based modular launch vehicles

S. R. Chakravarthy

National Centre for Combustion R&D

IIT Madras

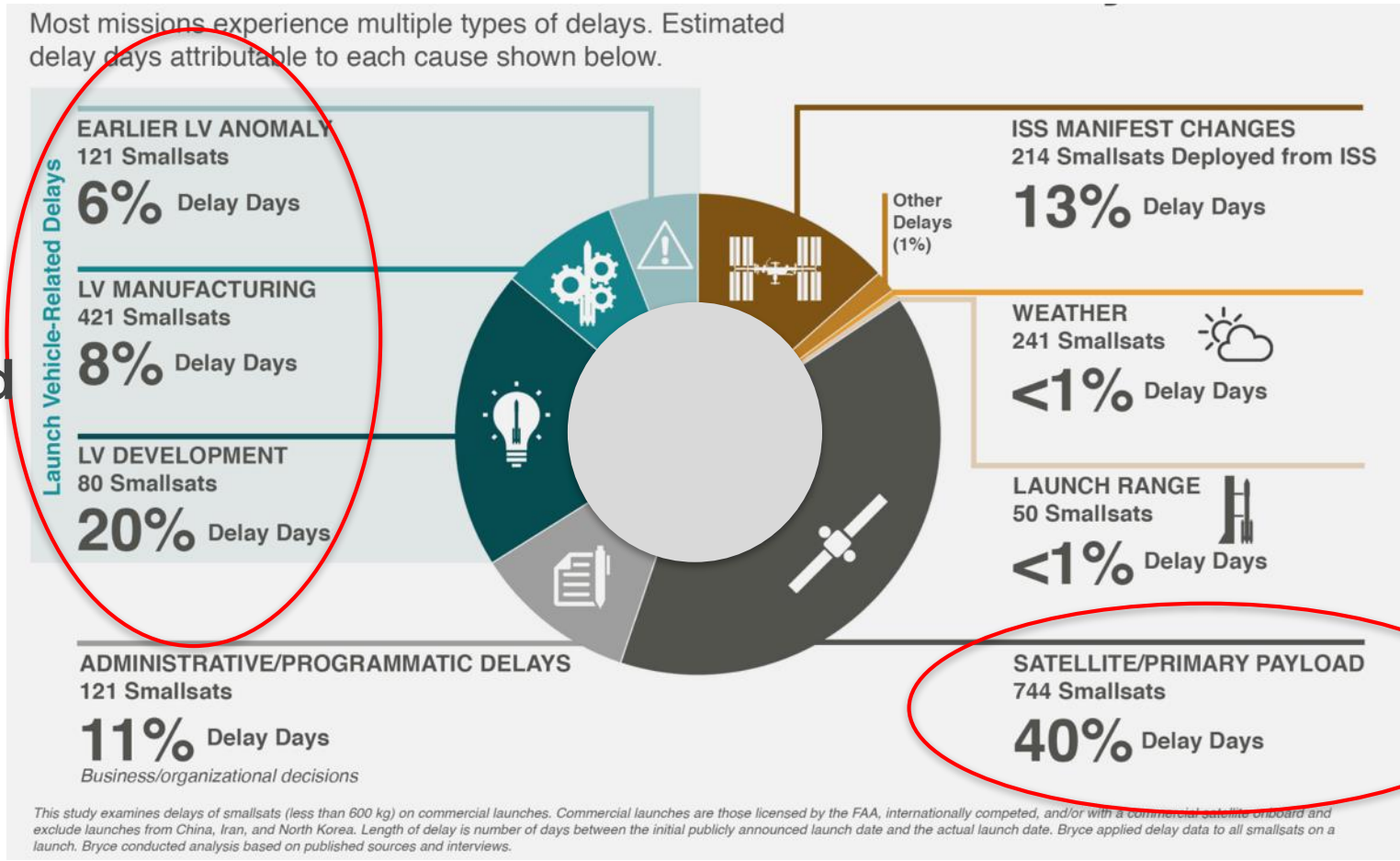
The Space Tech Value Chain





Satellite launch bottlenecks

34% of launch problems is because of **lack of launch-on-demand vehicles**



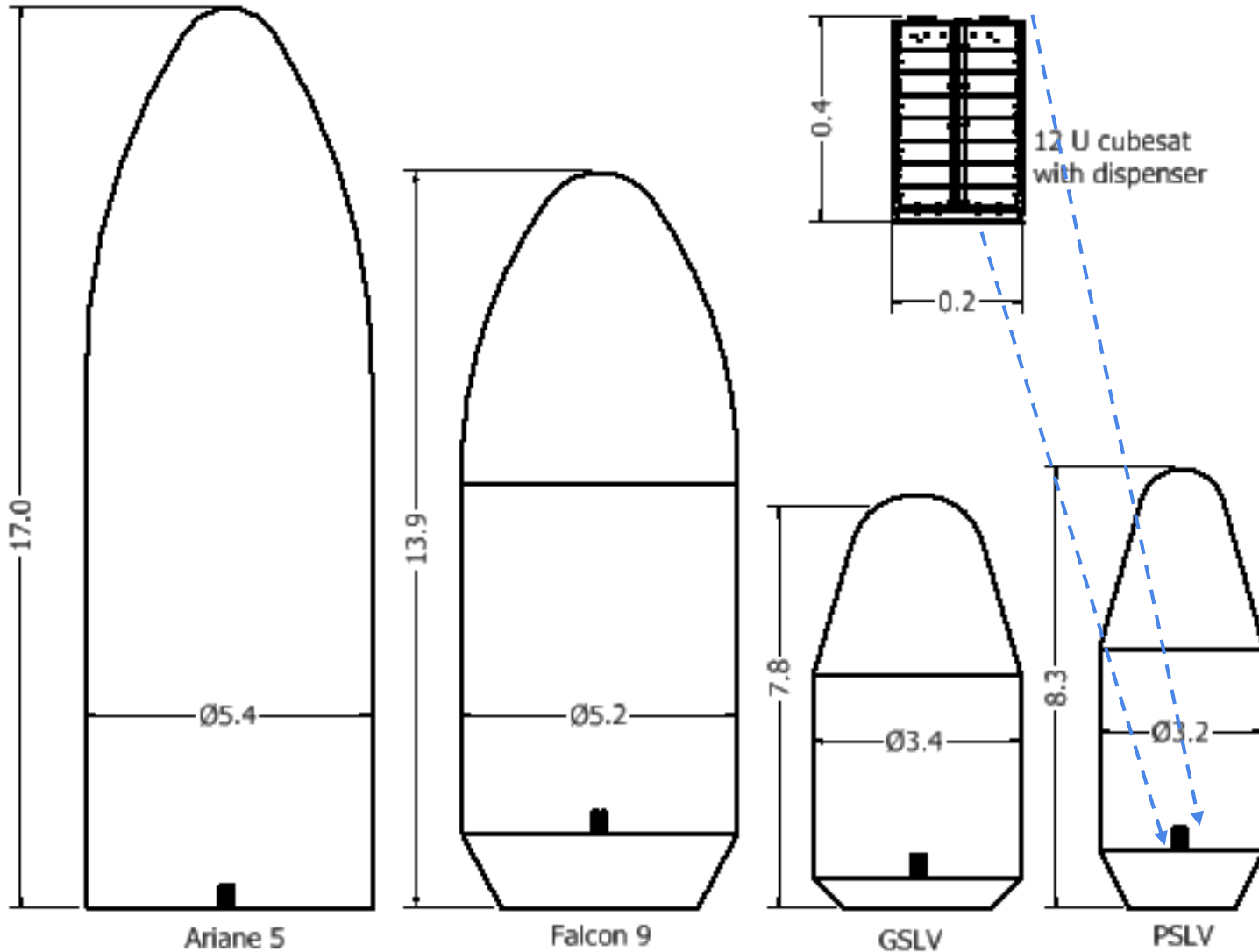
40% of launch problems are due to **ridesharing**

~75% of all launches are delayed due to today's launch services construct

Launch vehicle capacities today



All dimensions are in meter.



Imagine a single passenger wanting an entire train for himself...

Forced rideshare

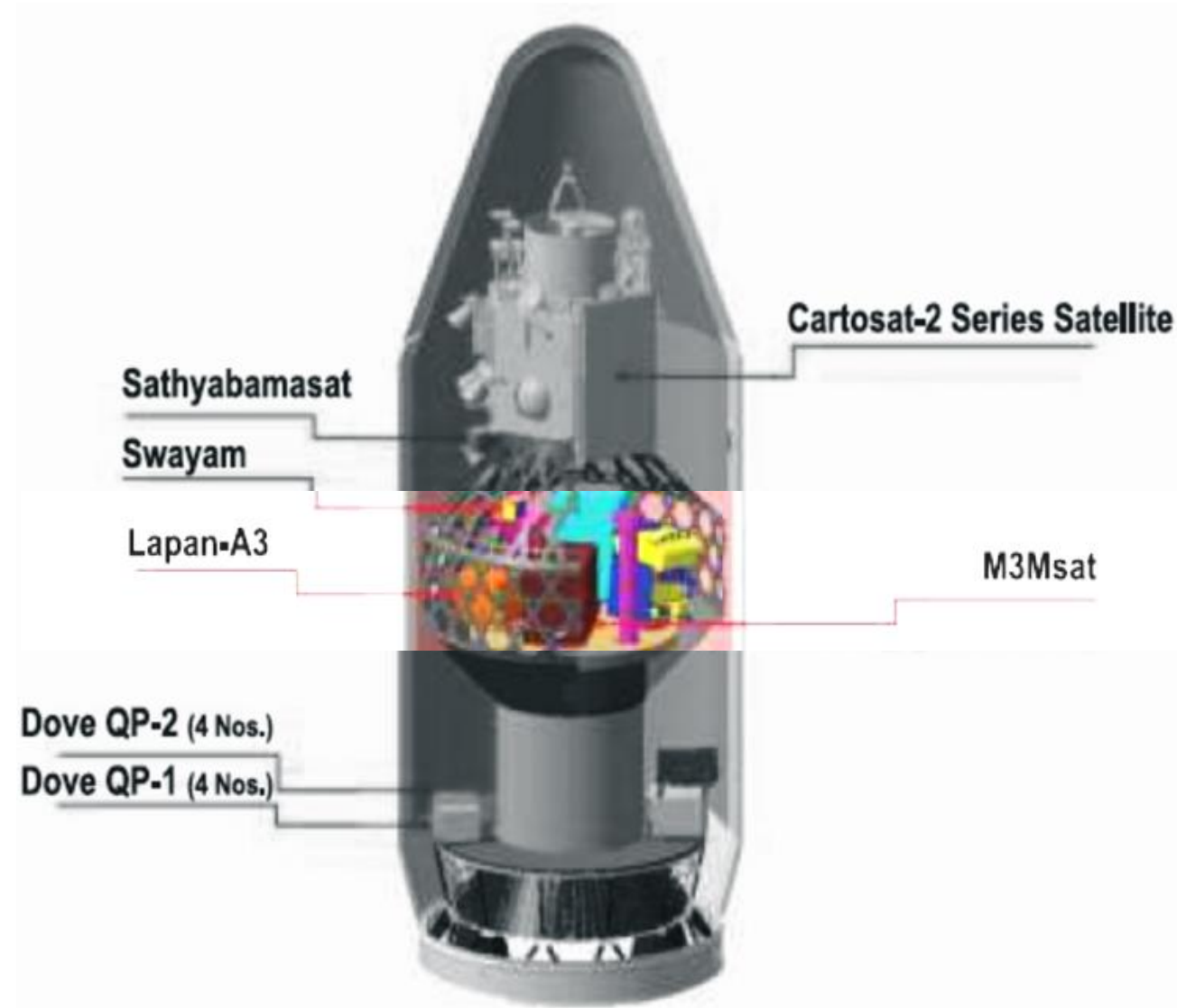


Small sats are forced to “rideshare”, so small sats take

- 6 months to build
- 2 years to launch



Typical cubesat size



Schematic of PSLV C-34 payload fairing



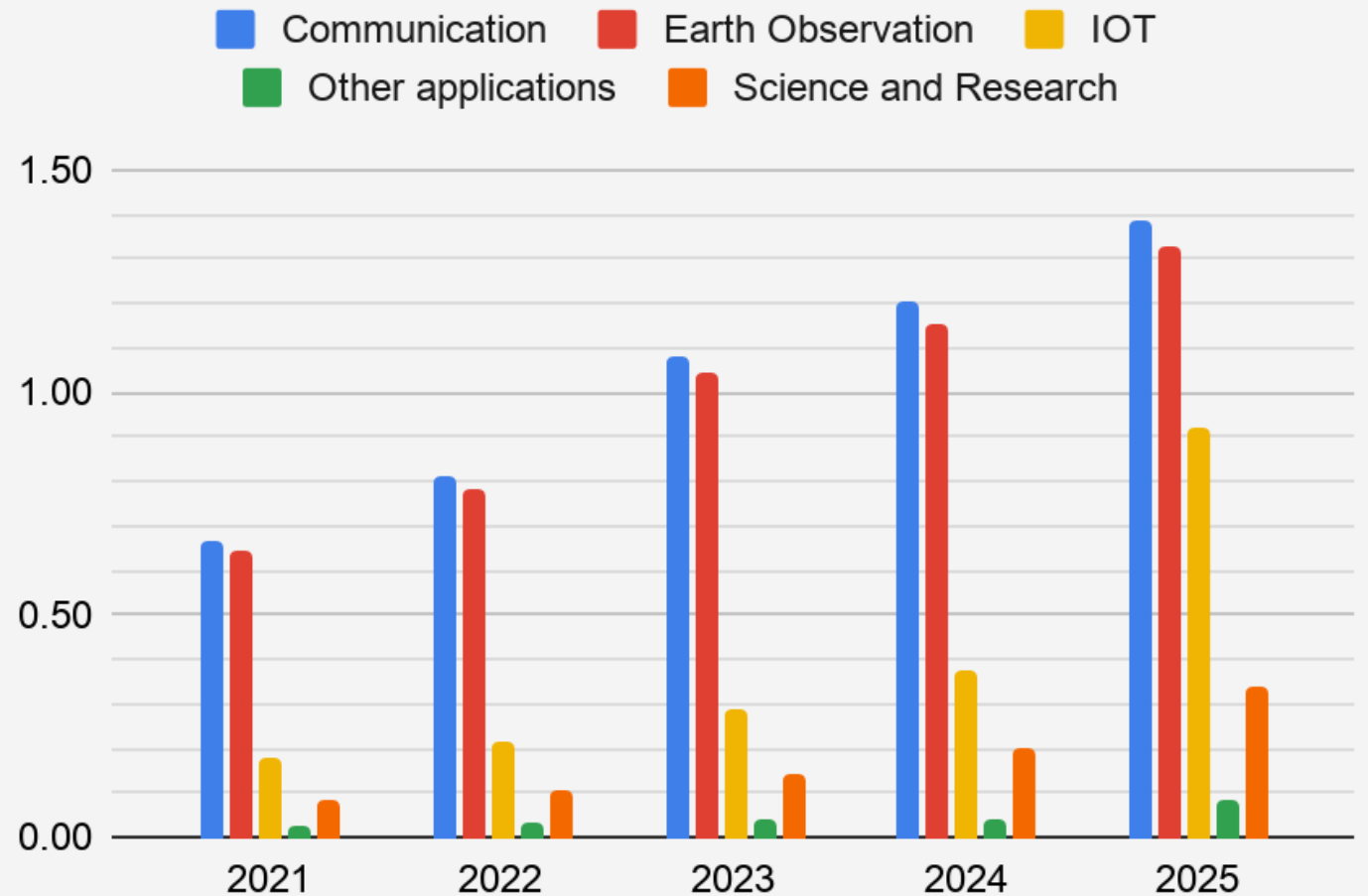
Addressable Market (\$4B / year by 2025)

- Market today: \$1.9B / year
- In 2025, \$4B / year

Growth sectors:

- Communication
 - OneWeb, Swarm, NSL comm
- Earth Observation
 - Satellogic, Sat Revolutions, Planet, Spire
- IOT
 - Kepler, Alen, Fleet, Nano Avionics
- Science and Research
 - Cosmic -2, GeoOptics, RAVAN
- Other applications
 - Cloud Constellation, ALE

Growth In Addressable Market (in USD Billion)





Agnibaan

- **Dedicated & fully customizable launch vehicle for small satellites**
 - 40x faster launch (2 weeks instead of 78): Linearly scalable from 30 - 300 kg at the same \$/kg
 - 10x cheaper per vehicle - potential for high margins or lowest cost in the world
- **Engines :**
 - Agnite : each engine produces 25kN at sea level (4, 5, 6 or 7 engines), electric pump fed cycle, single piece semicryo engines
 - Agnilet : 9kN at vacuum, electric pump fed cycle, single piece semicryo engine



Scale model of Agnibaan

Agnibaan



Agnibaan Stage 2 - 1:1 assembly version

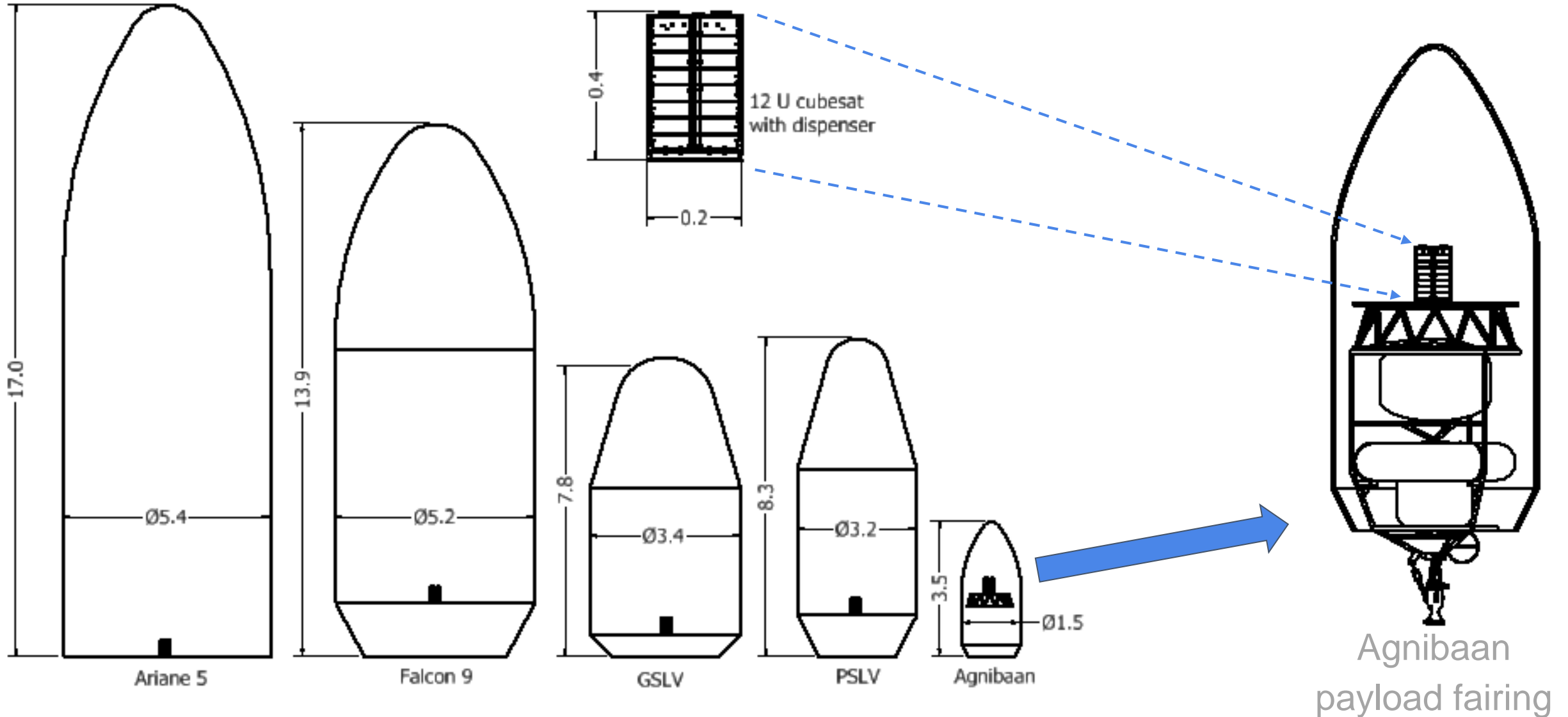


Agnibaan (complete vehicle) - 1:1 assembly version

Where does Agnibaan fit?



All dimensions are in meter.



Solid vs. liquid propulsion systems



	Solids	Liquids
Complexity / No. of parts		
Import / Export \Leftrightarrow		
Mobility Insurance & running costs		
Flexibility (scaling down)		



De-risking complexity with 3D printing

A Liquid Oxygen / Kerosene rocket engine in a single piece : 1000 parts -> 1 part

Launch-when-you-want

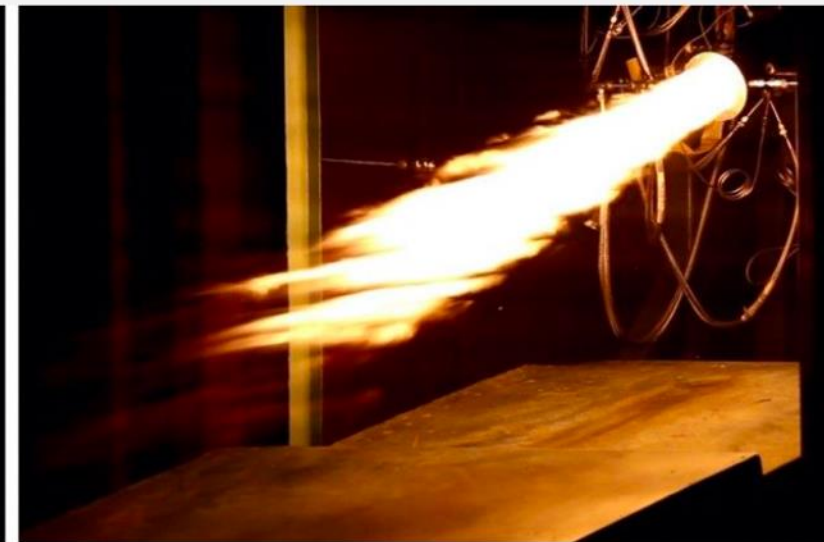


All in one piece

- Igniter
- 100+ cooling channels
- 70+ plumbing passages
- 8 injector elements
- Combustion chamber
- Nozzle

Flightworthy engine of Agnibaan - Agnilet

Multiple variants / multiple firings

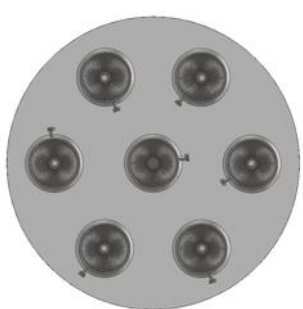


Left: First successful firing on this hardware. Middle : Thermal qualification burn on this hardware. Right Repeatability burn

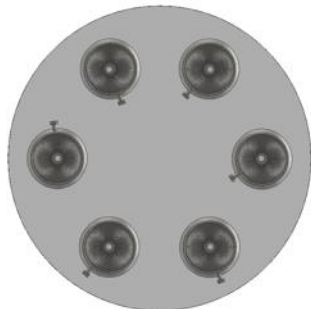
Modular design => “Flat” cost curve



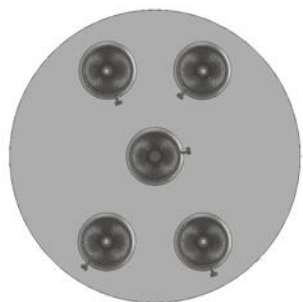
Unit engine module



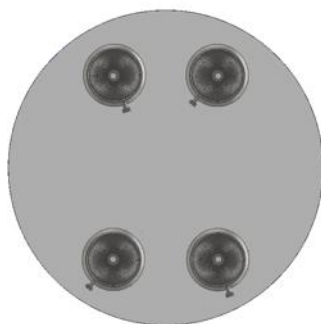
7 engines



6 engines



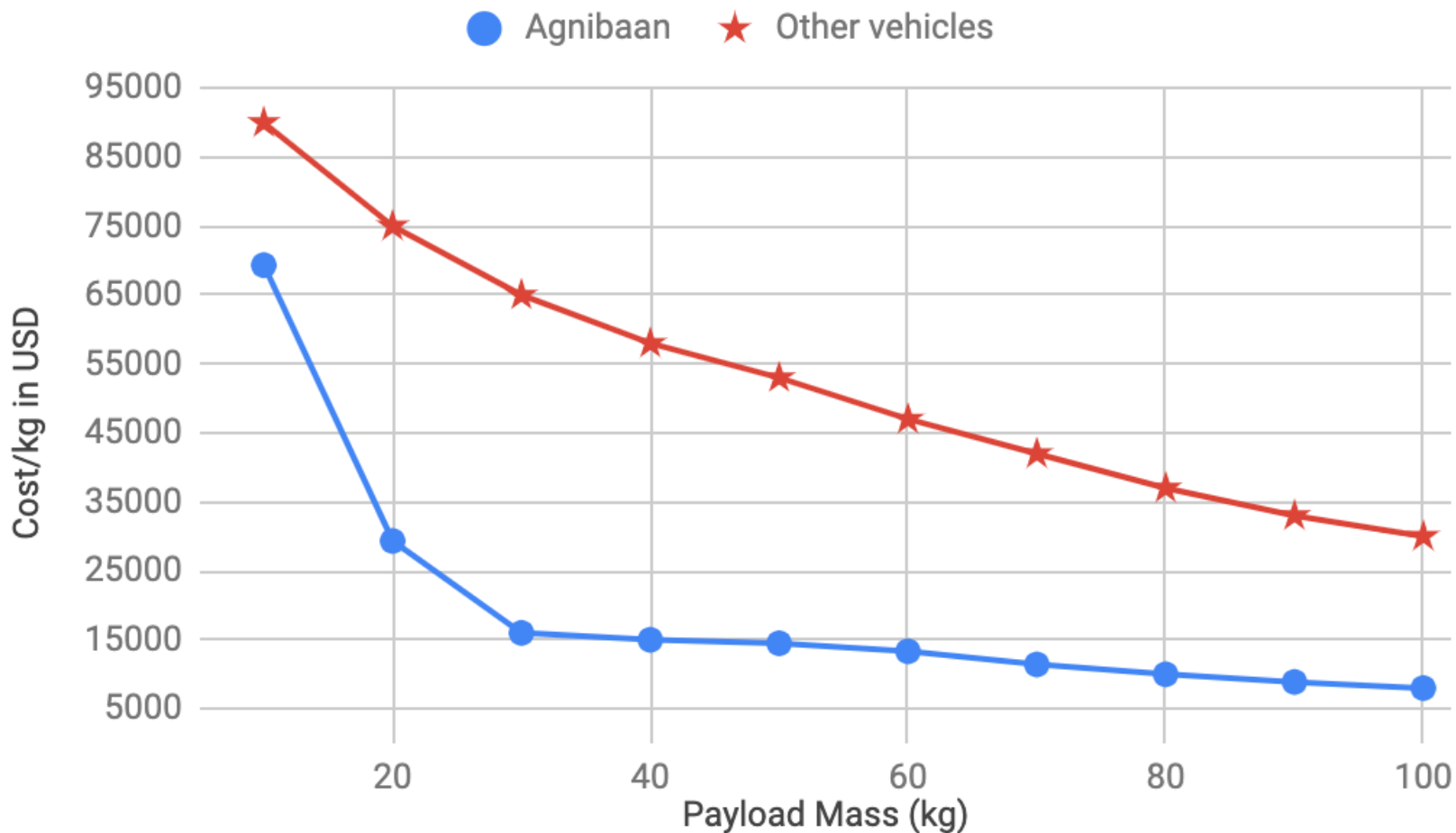
5 engines



4 engines

Engine layout in the first stage

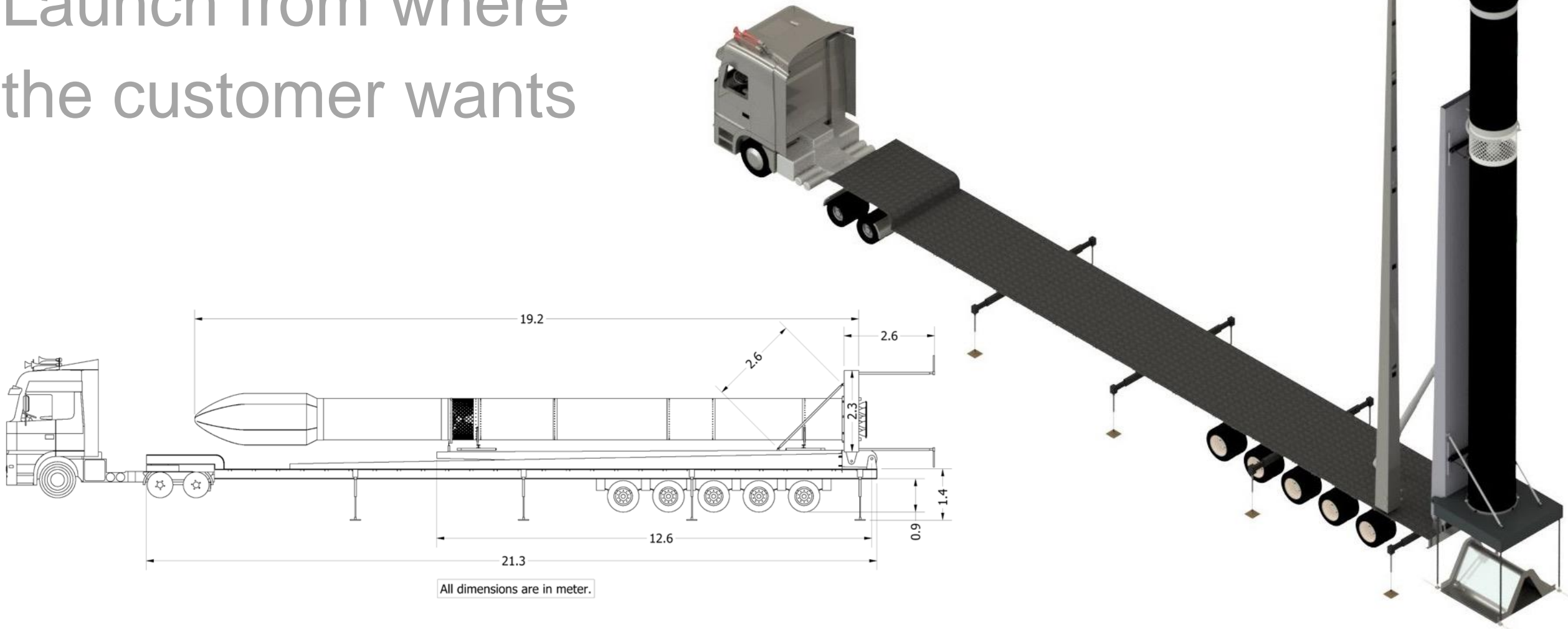
Cost/kg in USD - Agnibaan vs. Other vehicles today



Mobile launchpad (launch anywhere)



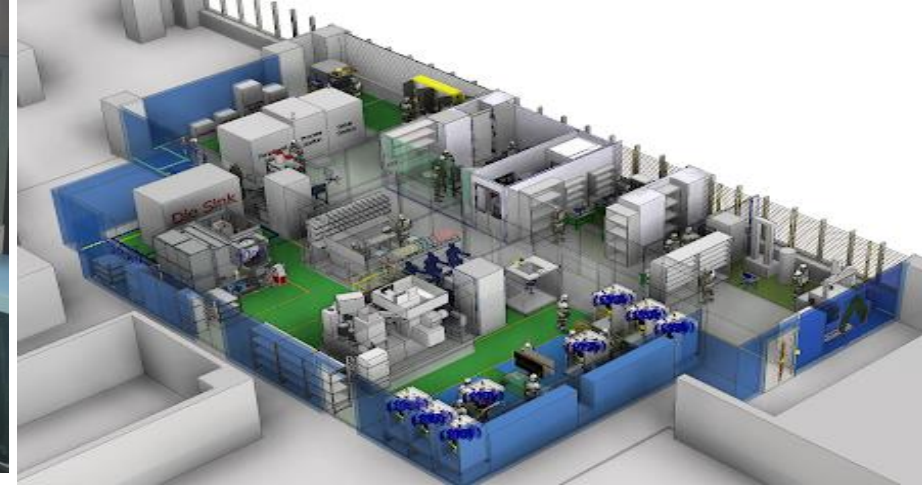
Launch from where
the customer wants



Multiple facilities, 80 members, 12 ex-ISRO scientists



Engine test facility



Rocket Factory - 1



Assembly facility





Recognition For Agnikul



First company in the country to sign an agreement with ISRO under IN-SPACE



Encouraged directly by the Hon'able PM of India



MOU signed with ISRO under IN-SPACE for access to development and testing of subsystems/systems in ISRO Facilities

Only space startup to receive National Startup India Award 2021

Founder of \$2 Billion Biocon Group



Kiran Mazumdar-Shaw @kiranshaw · Feb 10

Kudos to Indian #space #startup @AgnikulCosmos as it becomes the world's first company to successfully test a fully 3D printed rocket engine.

Chairman of Mahindra Group



anand mahindra @anandmahindra · Feb 10

AGNIKUL is a startup that will build launch vehicles to carry micro/nano satellites to low earth orbit on demand. They recently test-fired a fully 3D printed semi cryo rocket engine at IIT Madras. Terrific champions of the future. I've personally invested in the company



Narendra Modi @narendramodi

India is buzzing with opportunities.

Proud of your efforts and innovative zeal. Such work is what will make India a leader in the space sector.

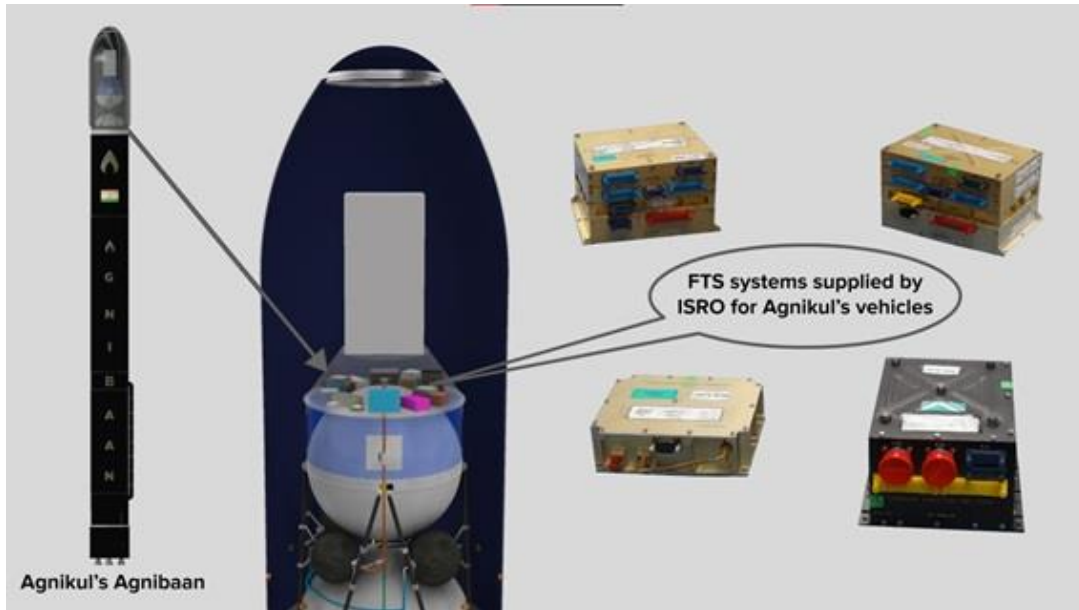


Srinath Ravichandran @srinathr155 · Dec 14

Now when people ask me whether I did the right thing by moving back to India to build hardware-I can show this & say-yes. Thank you Shri. @narendramodi Shri. @DrJitendraSingh Shri. @nsitharaman @isro for enabling private space in India #AatmaNirbharBharat #madeinindiafortheworld twitter.com/AgnikulCosmos/...

Recent developments: Major role of InSPACe

Flight termination system provided by ISRO



Thank you

For listening