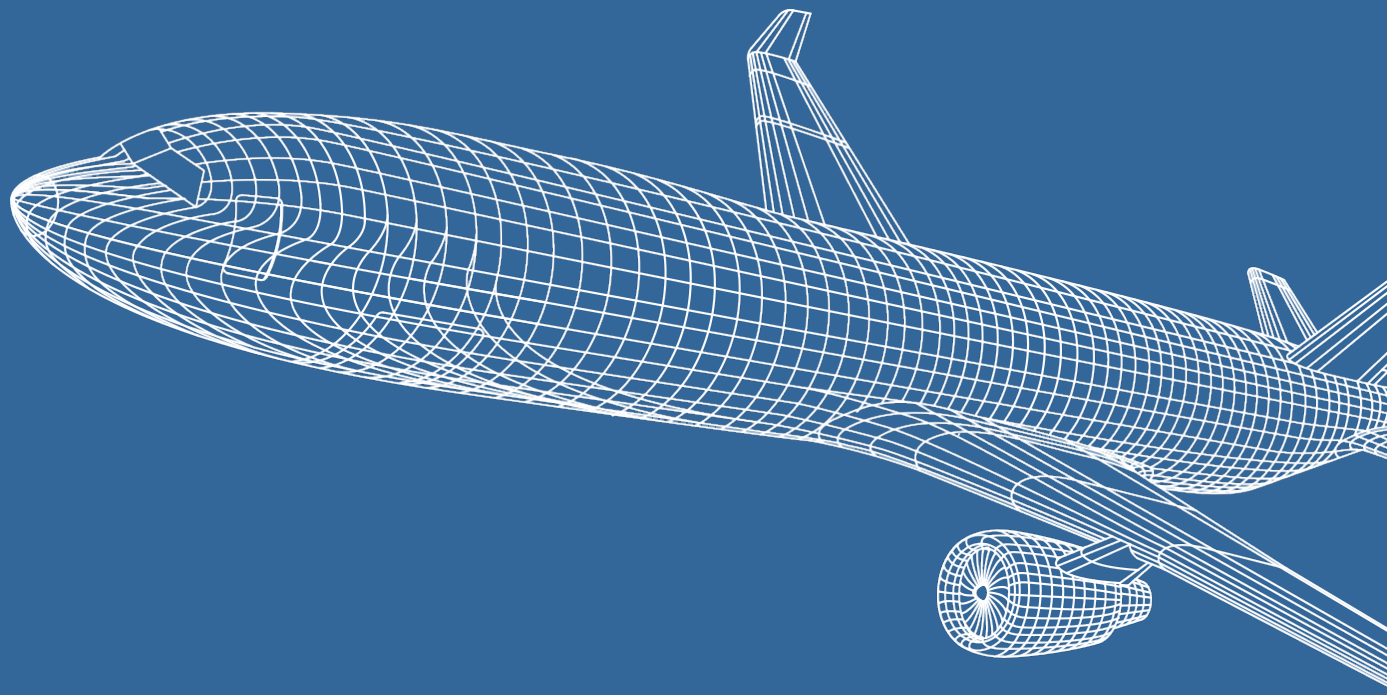

Launcher Evolution

Space Rendezvous KTH 2016

Li Forsberg | 13 October 2016

This document contains no technical data.

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GKN TECHNOLOGY: MAKING THINGS FLY

Launcher Evolution

GKN: A Global Engineering Group

Every day at GKN…

In numbers

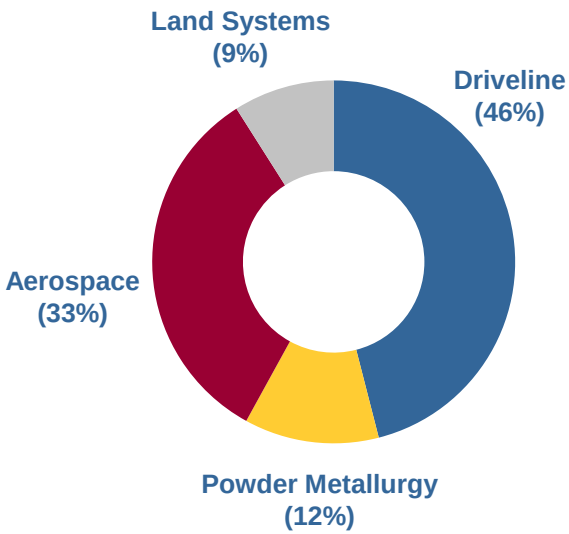
- 56,000 employees
- Locations in more than 30 countries
- £8bn sales

We drive the wheels of hundreds of millions of cars…

We help thousands of aircraft to fly…

And we deliver the power to harvest crops and move earth.

Sales by division



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GKN Aerospace Sweden

- Design and Manufacturing of Commercial and Military aircraft engines and Rocket Engines
- GKN Aerospace Engine Systems
  - 4500 employees in Sweden, Norway, USA and India
  - HQ in Trollhättan, ~2000 employees
- Space
  - European Center of Excellence for rocket engine turbines and nozzles: applied research, product development and serial production
  - 150/400 employees

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GKN Components on Ariane Rockets

Vulcain 2 (main engine)

Oxygen Turbine

Hydrogen Turbine

Ariane 5

Nozzle

Vinci (Upper stage)

Oxygen Turbine

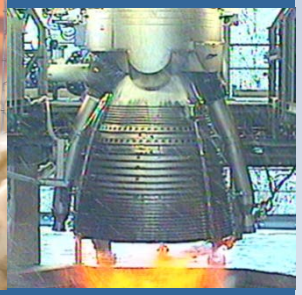
Hydrogen Turbine

In development
First flight 2020

Vulcain 2.1 (main engine)

Oxygen Turbine

Hydrogen Turbine



Ariane 6

Nozzle

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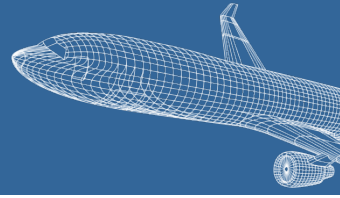
Market Changes



Up to ~2010, commercial satellite launches dominated by Arianespace (Ariane 5) and ILS (Proton)

Reliable but expensive launchers

What has changed?

- New players on market – game changers
  - 2009: SpaceX publishes official launch prices
  - 2013: First successful SpaceX launch to GEO – realization of low cost promise
  - 2016: Blue Origin announces New Glenn reusable heavy launcher
- Demand for manned flights, both tourism and scientific missions
- Explosive growth of nano/micro satellite market

→ **Serious competition on all levels**

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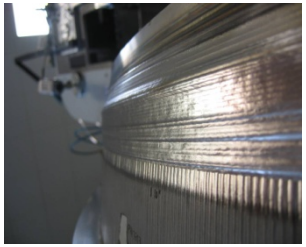
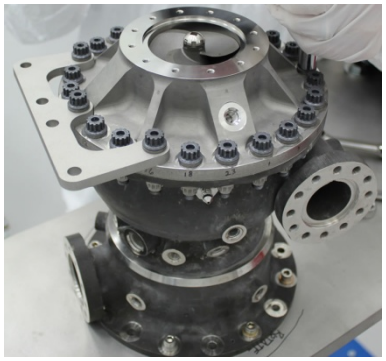
Heavy Launcher Competition

Challenge for all competitors: Cost, Cost, Cost

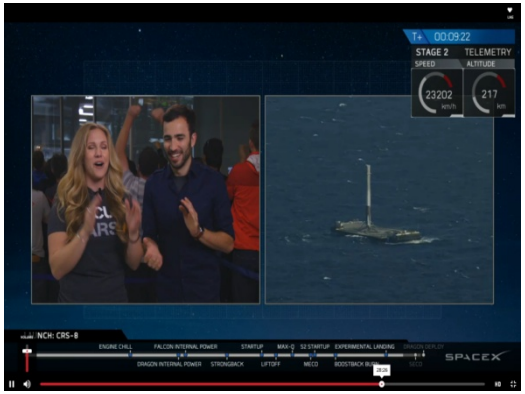
New launchers are needed, with short time to market





How?

- Rocket design and manufacturing
  - Additive Manufacturing
  - “Back to basics”
- Reusability?
- Streamline industrial structure, reduce bureaucracy



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Heavy Launchers – Global Competition

Heavy Launchers in Development

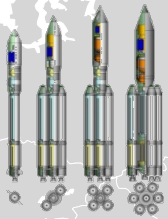
Blue Origin
New Glenn

SpaceX
Falcon 9
Falcon Heavy

ULA
Vulcan family

ASL
Ariane 6-2
Ariane 6-4

ILS
Angara family



CALT
Long March V

ISRO
GSLV –III

Modular rockets
Reusability (US rockets)
First flight within 2020

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Arianespace – Ariane 6-2 and 6-4

“Ariane 6 will have twice the mass and twice the volume of the Falcon 9, at less than twice the price” – Patrick Bonguet, Ariane 6 program director

Flexibility

- Modular for different missions (institutes vs. commercial satellites)
- Restartable upper stage engine (Vinci)

Heritage from Ariane 5

- Main engine is improved Vulcain 2 (reduced number of parts, new technologies)

Technology sharing with Vega rocket (common engine P120)

Changed industrial structure

First flight 2020

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SpaceX

End goal is human exploration and colonization of solar system

→ Falcon rockets are steps on this path

- Successes with Falcon 9, 5 T to GTO
- Reusability proven, low price confirmed
- Falcon Heavy in development, 12 T to GTO

- ”Back to basic”: modular rockets, robust manufacturing
- Additive manufacturing

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Blue Origin

Very little information available. End target?

Jeff Bezos: *"Our vision is millions of people living and working in space, and New Glenn is a very important step. It won't be the last of course. Up next on our drawing board: New Armstrong. But that's a story for the future."*

New Shepard

- Sub orbital space tourism, start 2017
- 400 AM parts
- Test bed for future rockets

New Glenn announced September

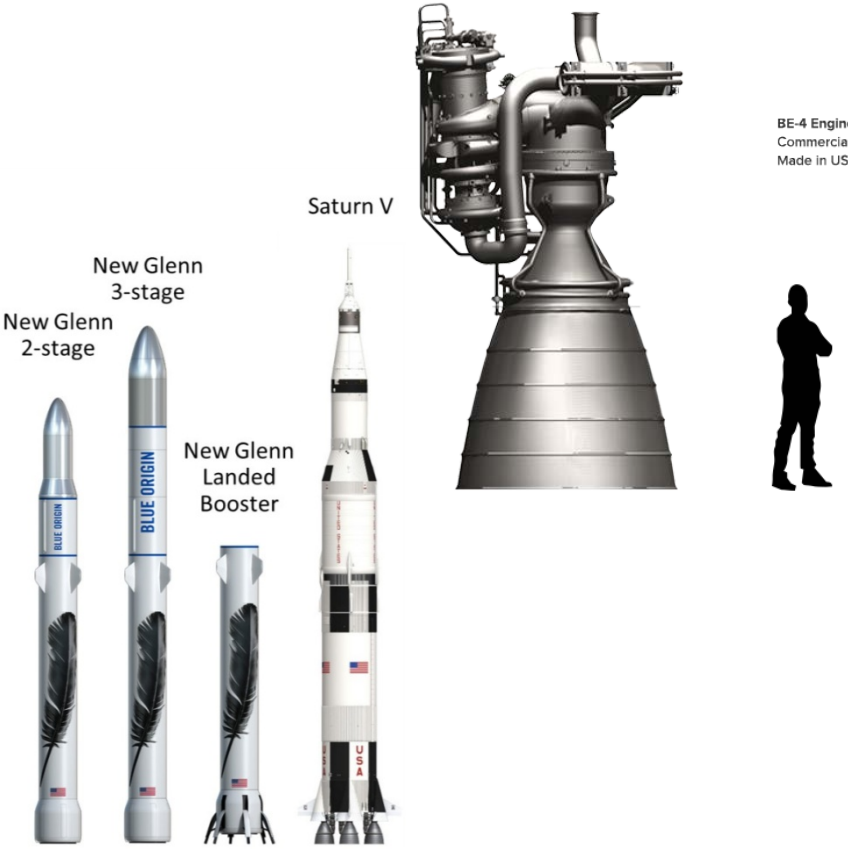
- Huge rocket
- Manned flights beyond LEO
- Flight before 2020

New Armstrong?

Rocket Engine development

- BE-3 – main engine for New Shepard
  - Throttling abilities for landings
- BE-4 – Staged Combustion engine for New Glenn

→ BE-4 is frontrunner for ULA Vulcan!



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Small Launchers

Small satellite market had exploded: nano/microsatellites – market for new small launchers?

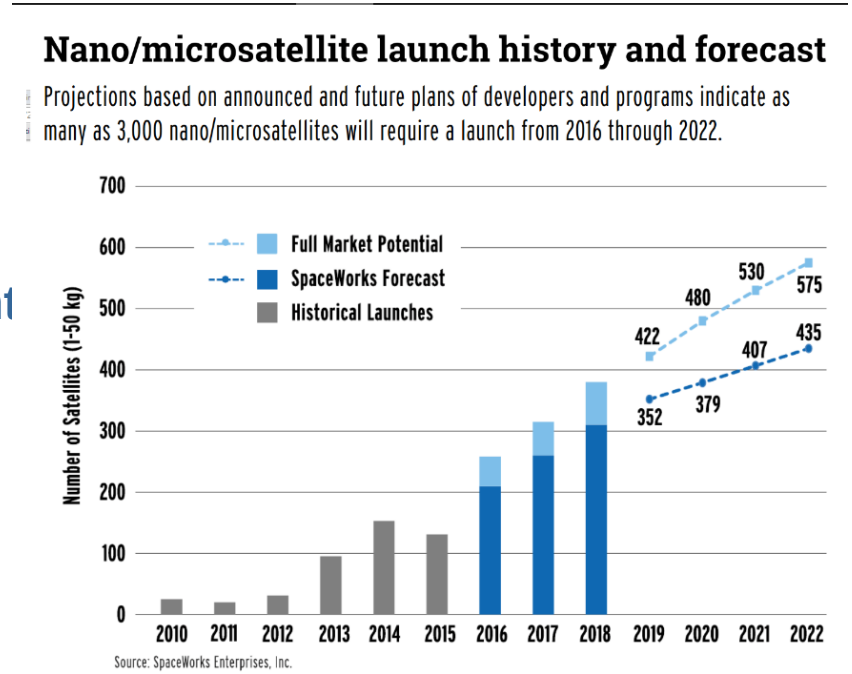
Several small launchers in development

- Rocket Labs Electron (NZ)
- Virgin Galactic Launcher 1 (US)

All with target “low cost access to space”

Many satellites but not high total weight

Many likely to be launched on conventional launchers



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Manned Launches – In Development

Very active!

Space Tourism – sub orbital

- Virgin Galactic
- Blue Origin

Commercial missions (ISS)

- SpaceX Dragon Capsule
- Boeing Starliner

Exploration

- NASA Space Launch System, SLS
- SpaceX Interplanetary Transport System, ITS
- Blue Origin New Armstrong

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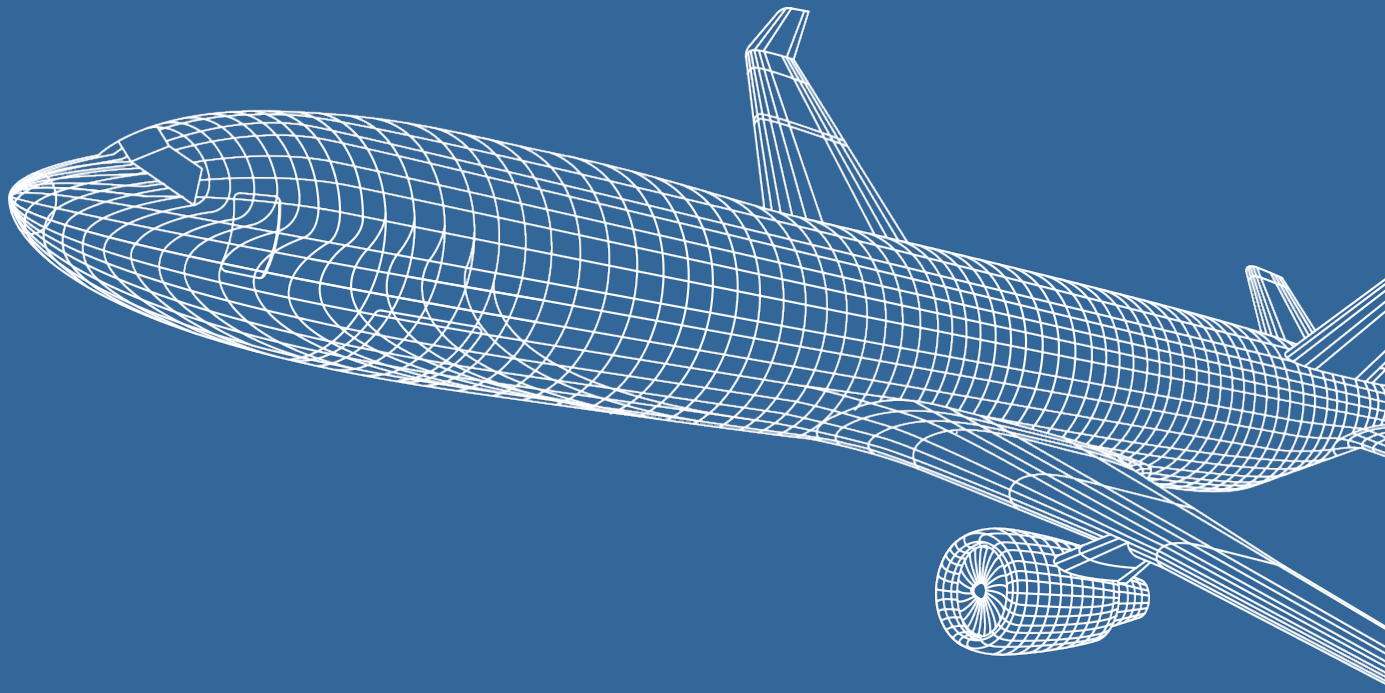

Thank you

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