Vertical Integration of Constellation Production

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August 19, 2019

LaPlace Summer Camp

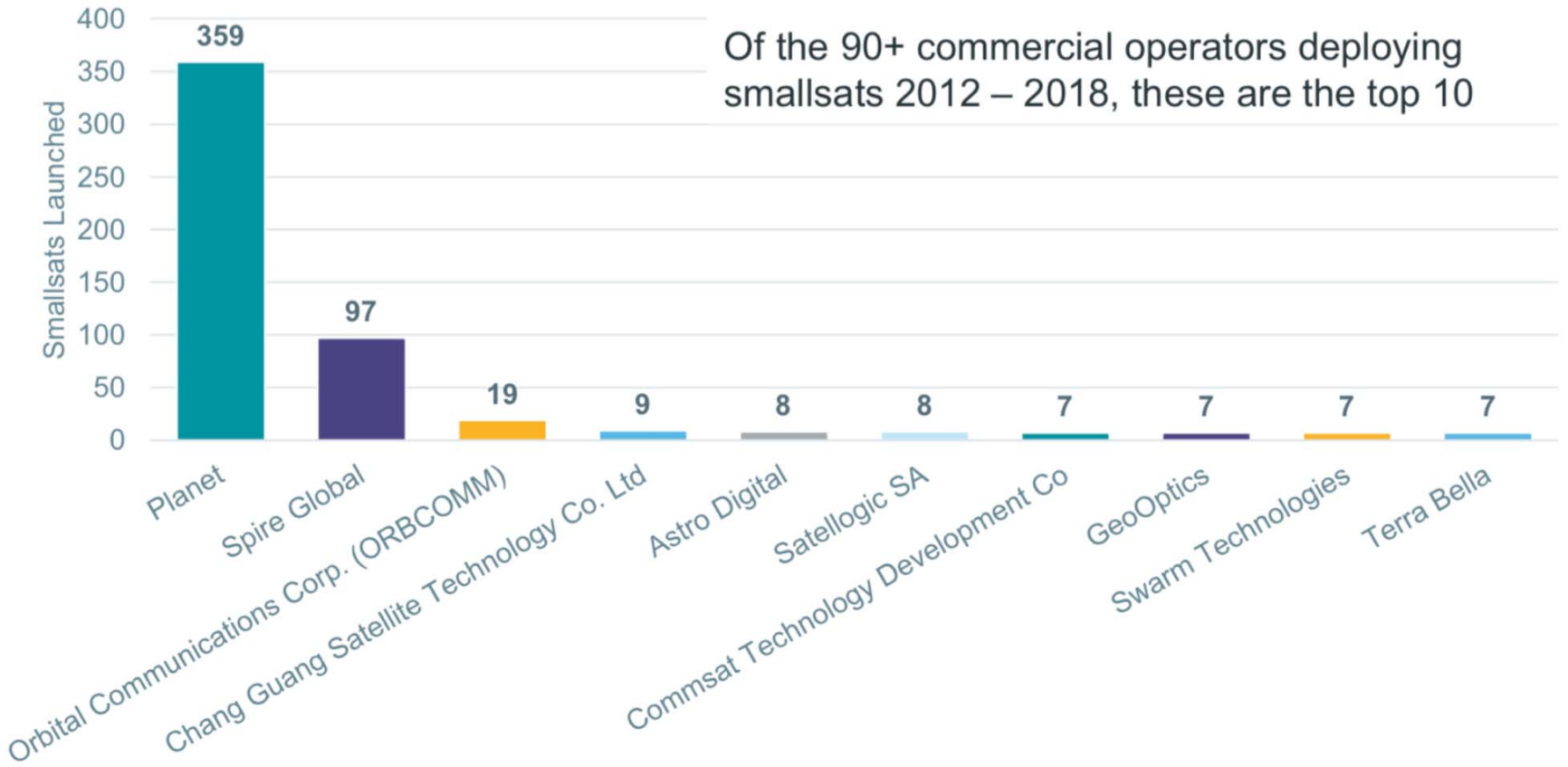
Current status of lean satellites

- Practical application via constellation started
  - Mass production era?
- CubeSat gets larger
  - Shifting to 3U, 6U
- Mission is shifting to “Tech-demo”, “Science” and “Practical (commercial) application” from “Education”

Constellation

Commercial Smallsats

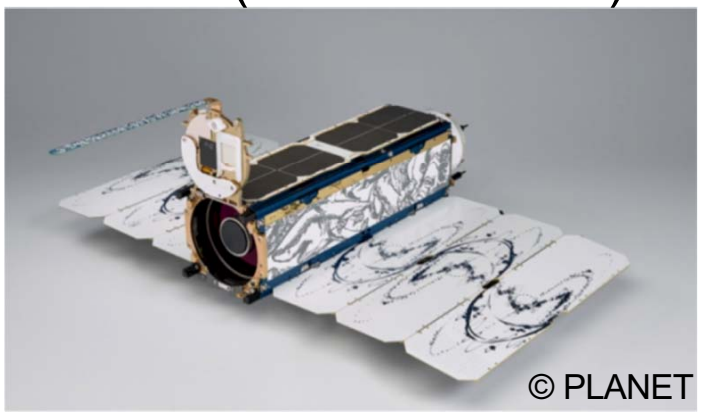
Commercial Operators Launching the Most Smallsats, 2012 - 2018



Notes: Planet has operated Terra Bella satellites since acquiring Terra Bella in 2017. Unlike the rest of the companies shown, ORBCOMM is a long-established operator, that first deployed satellites in the 1990s. In January 2018, Swarm Technologies launched 4 SpaceBee smallsats without authorization from the FCC.

Lean Satellite Constellation

Planet (>354 satellites)



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Earth observation

Spire (~100 satellites)

© Spire Global

Ship tracking, data collection, weather monitoring

SkySat (Terra Bella)

https://directory.eoportal.org/web/eoportal/satellite-missions/s/skysat

(Image credit: SSL)

60x60x95cm 120kg
18 satellites
Earth Observation
(2014~)

Mega constellation under construction

One Web
150kg 600 satellites

February 28, 2019

First 6 satellites

Image: Airbus

https://runwaygirlnetwork.com/2019/01/22/press-release-first-satellites-for-oneweb-shipped-to-launch-site/

StarLink
227kg 12,000 satellites

May 24, 2019

First 60 satellites

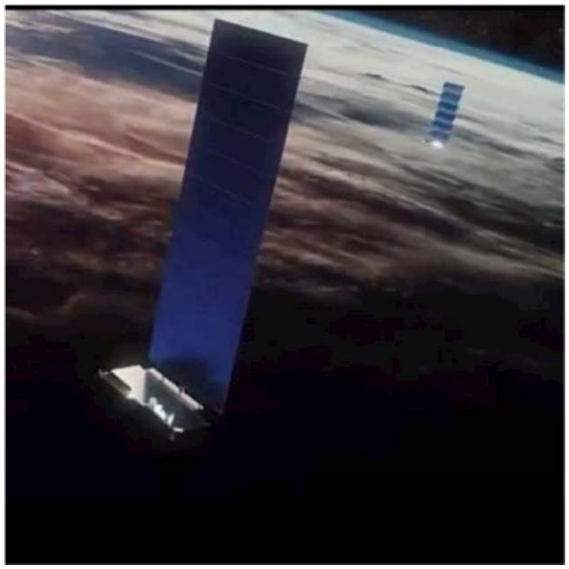
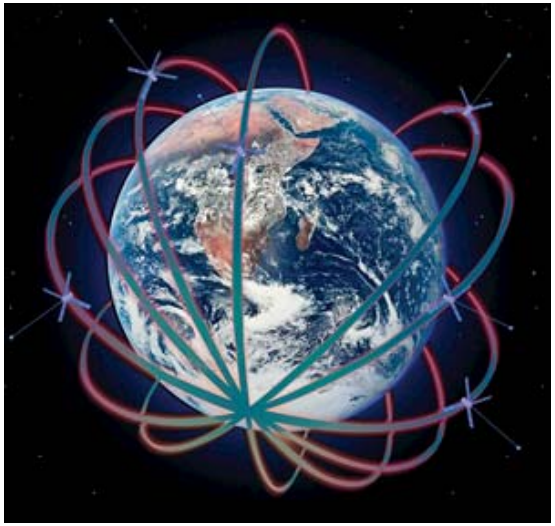


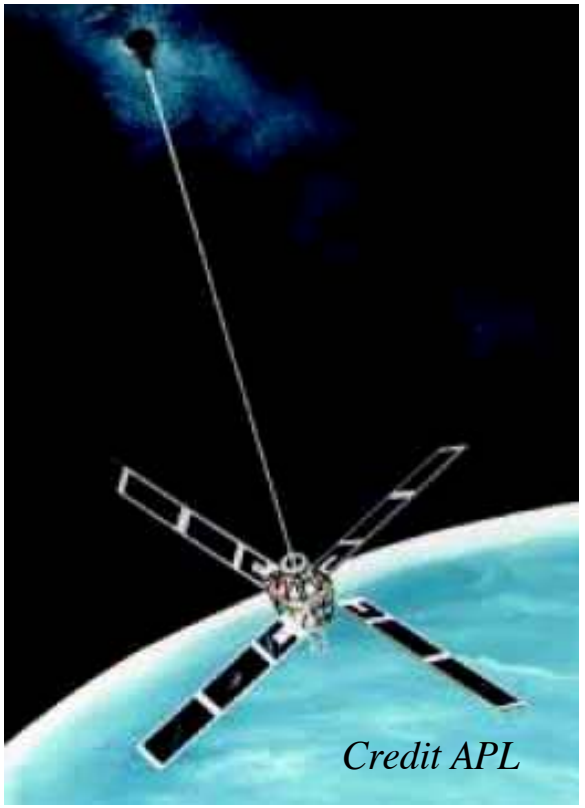
Image: SpaceX

https://twitter.com/elonmusk/status/1132024717936713733

Constellation

- TRANSIT (1960s)
  - 46 Satellites from 1959 to 1988
  - Position determination of US Naval Ship (nuclear submarines)
  - 55kg each
  - 1100km altitude





http://www.aero.org/publications/crosslink/spring2010/08.html *http://en.wikipedia.org/wiki/Transit_(satellite)*

Constellation

- GPS (Global Positioning System)
  - 24 satellites, 6 orbital plane at 55º inclination
  - Orbital period half a day
  - The first launched in 1978
  - See the animation of orbital motions of GPS at
  - http://en.wikipedia.org/wiki/File:ConstellationGPS.gif
- GLONASS(GLObal Navigation Satellite System)
  - 24 satellites, 3 orbital plane at 65º inclination

IRIDIUM

Service started in Jan. 1998

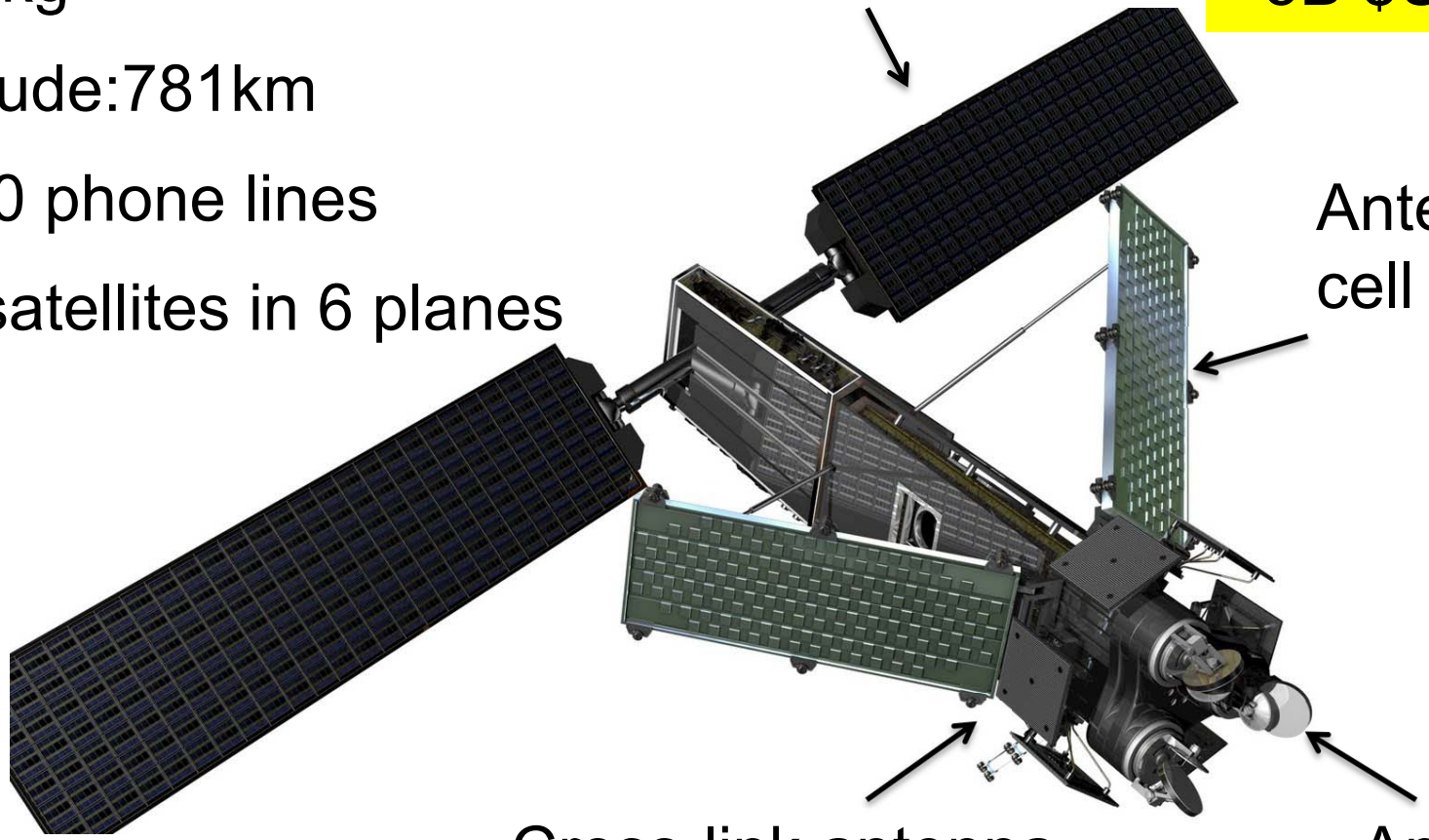
680kg

Altitude:781km

1100 phone lines

66 satellites in 6 planes

4.3 days/satellite
>5B $USD



http://svescapevelocity.blogspot.com/2009/12/iridium-communications-satellite-et.html

First-generation LEO constellation

Example : OrbComm

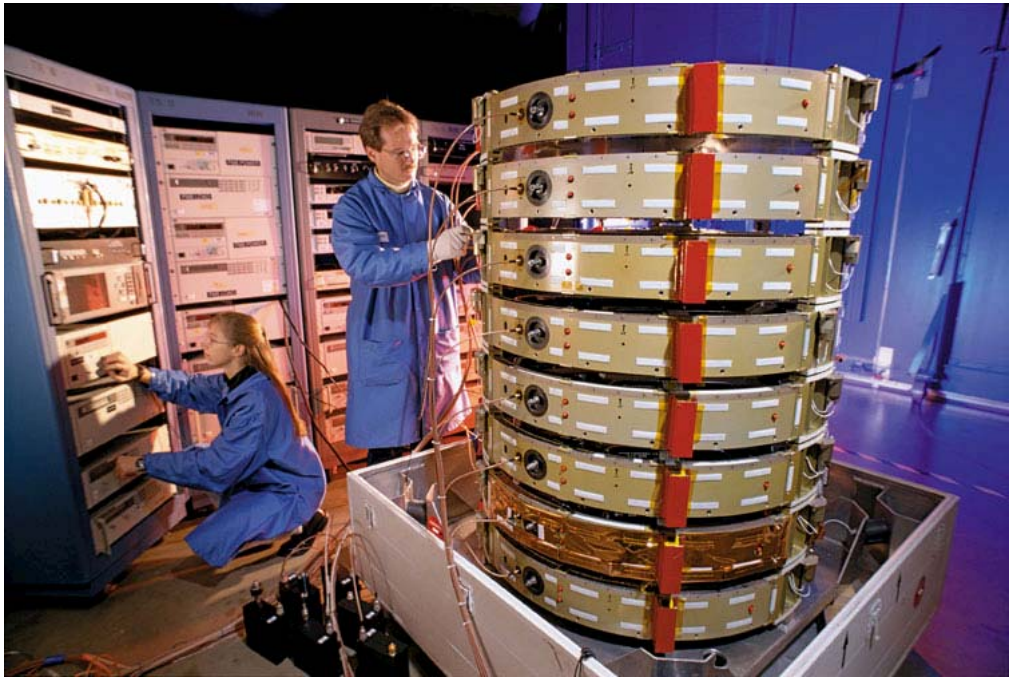
- Mass 46kg,
- 1m diameter, 16.5cm thick, 0.21m^3
- 150W (BOL) (GaAs solar cell)
- 35 Satellites in 740 to 825km
- 6 orbital planes
- 5 life years
- FM1, FM2 Launched in April 1995
- Others launched from late 1997 to late 1999
- Bankrupt in 2000

http://www.satnews.com/cgi-bin/display_image.cgi?1908629056

OrbComm

- ５個同時に組み立て、試験をする
- 1ヶ月に5個の製造ペース
- 1機５億円弱

- Batch production and test of 5 satellites
- 5 satellite per month
- Less-than 5 million $ each



http://www.orbital.com

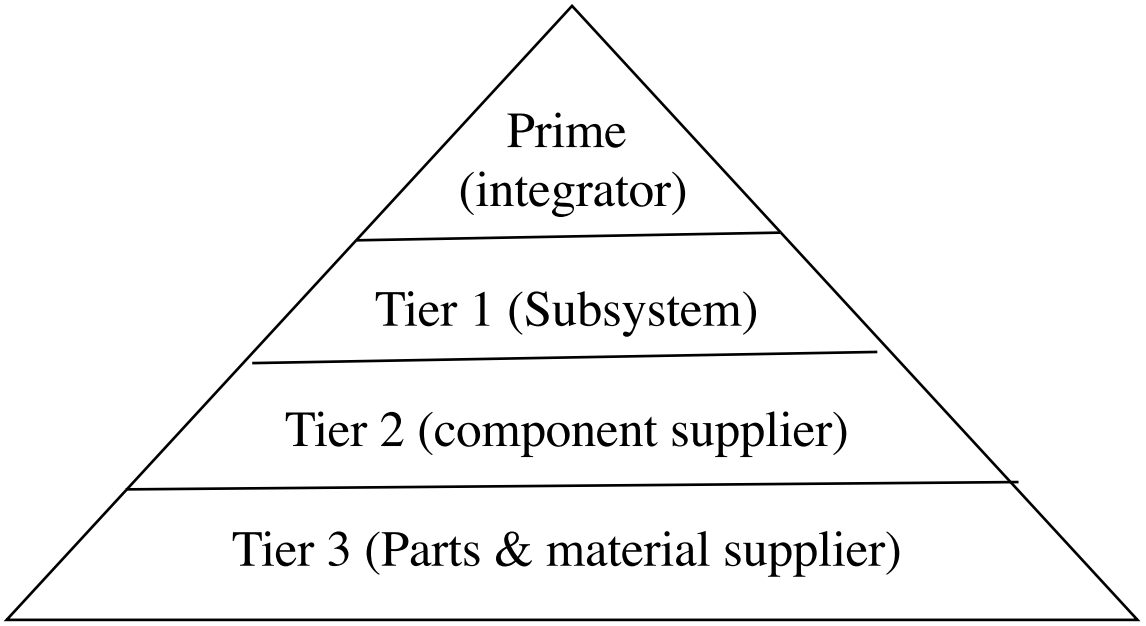
Difference between now and then

- Use of COTS (Commercial-Off-The-Shelf) parts and components
  - Drastic cost reduction
- Adaption of lean satellite philosophy
  - Risk-taking
- Need to achieve
  - Low-cost & Fast-delivery & Reliability

Vertical integration vs Horizontal integration

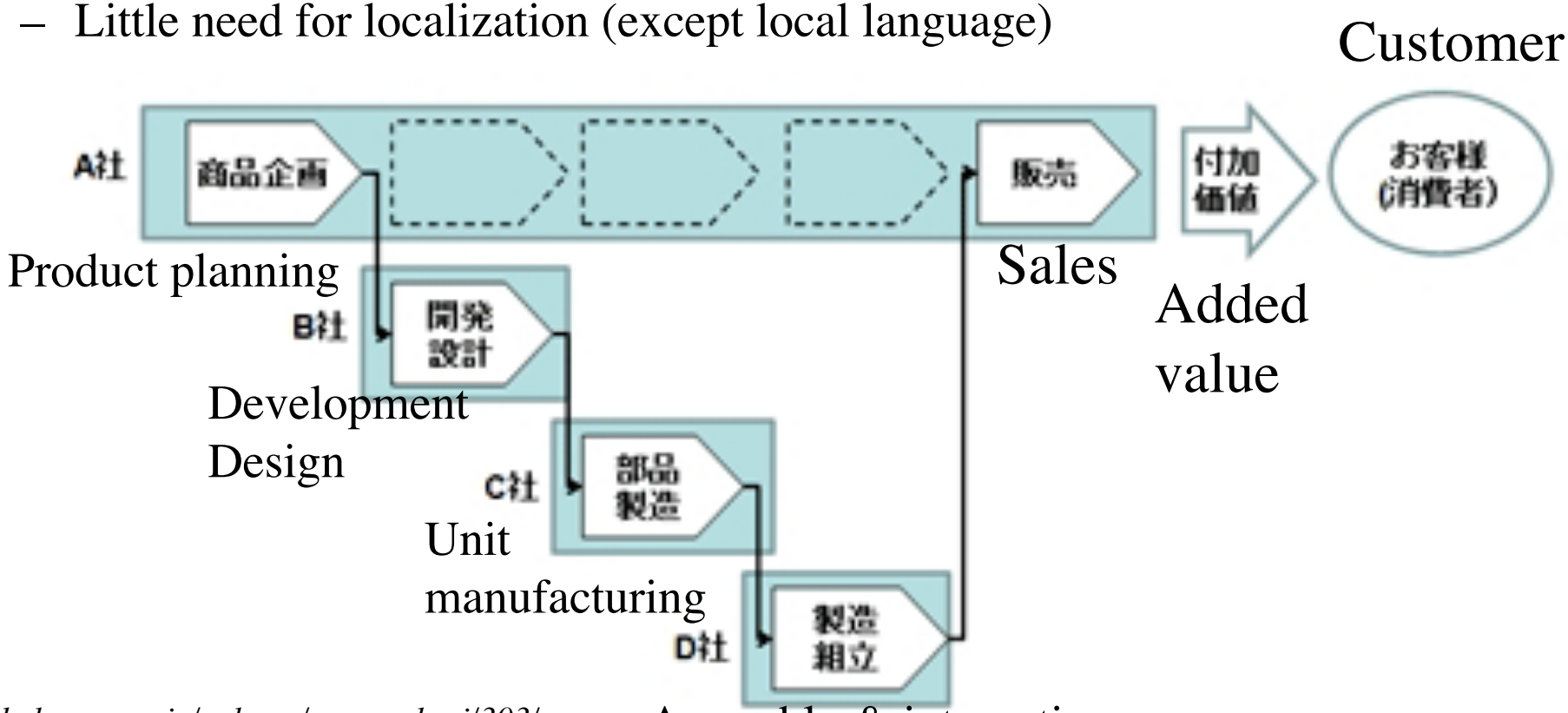
Horizontal or Vertical?

- Vertical structure
  - Success of Toyota in 1980 and 90s
  - Achieving lean enterprise throughout *Keiretsu* (hierarchy)
  - Just-in-Time production from the top (Toyota) to the bottom (parts supplier)
  - Physical proximity of the suppliers, the market, etc
  - Automobile requires delicate integration of mechanical parts



Horizontal or Vertical?

- Horizontal structure
  - Success of Dell in 2000s
  - Procuring parts/units/subsystem worldwide with the lowest price
  - Assembly at countries with cheap labor
  - IT network to handles the procurement
  - Modular products. Needs to define only interface
  - Little need for localization (except local language)



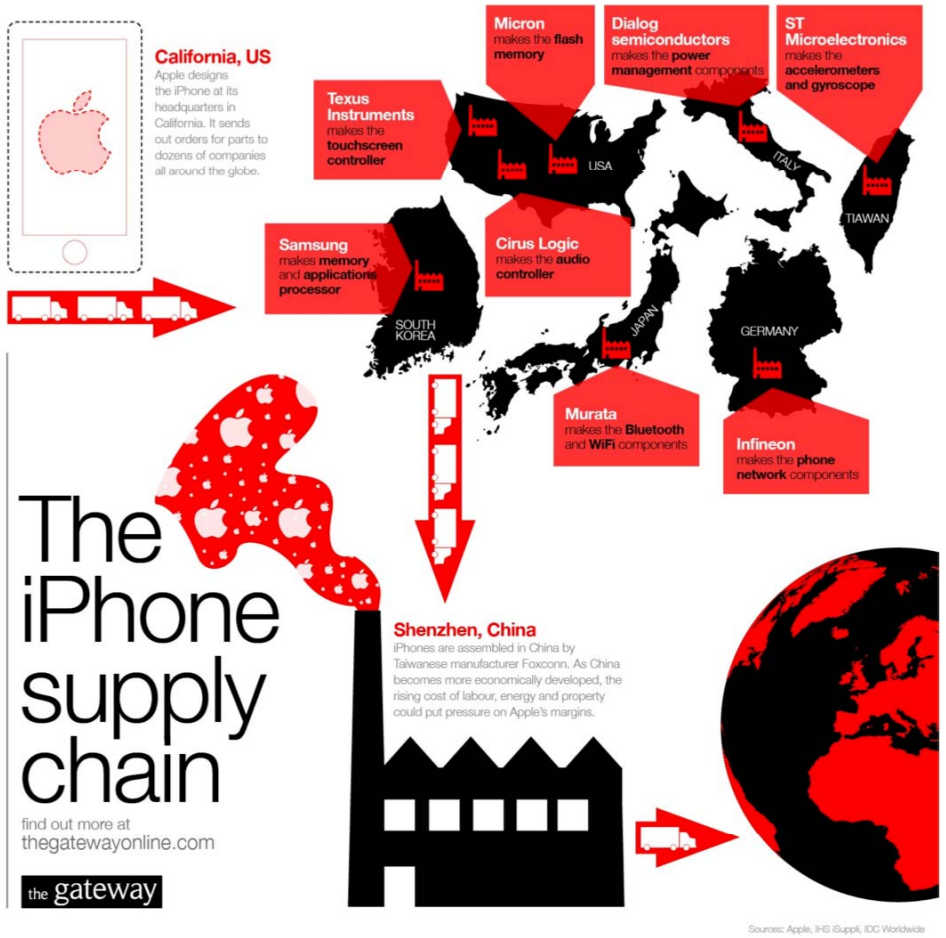
http://www.kobelcosys.co.jp/column/monozukuri/303/

Horizontal or Vertical?

- Vertical & Horizontal structure
  - Success of iPhone in 2010s
  - Procuring parts/units/subsystem worldwide
  - Rigorous control of supplier
  - Highly integrated product

http://jpkc.suibe.edu.cn/SYWLX/default.php?mod=bestcourse&do=detail&tid=73

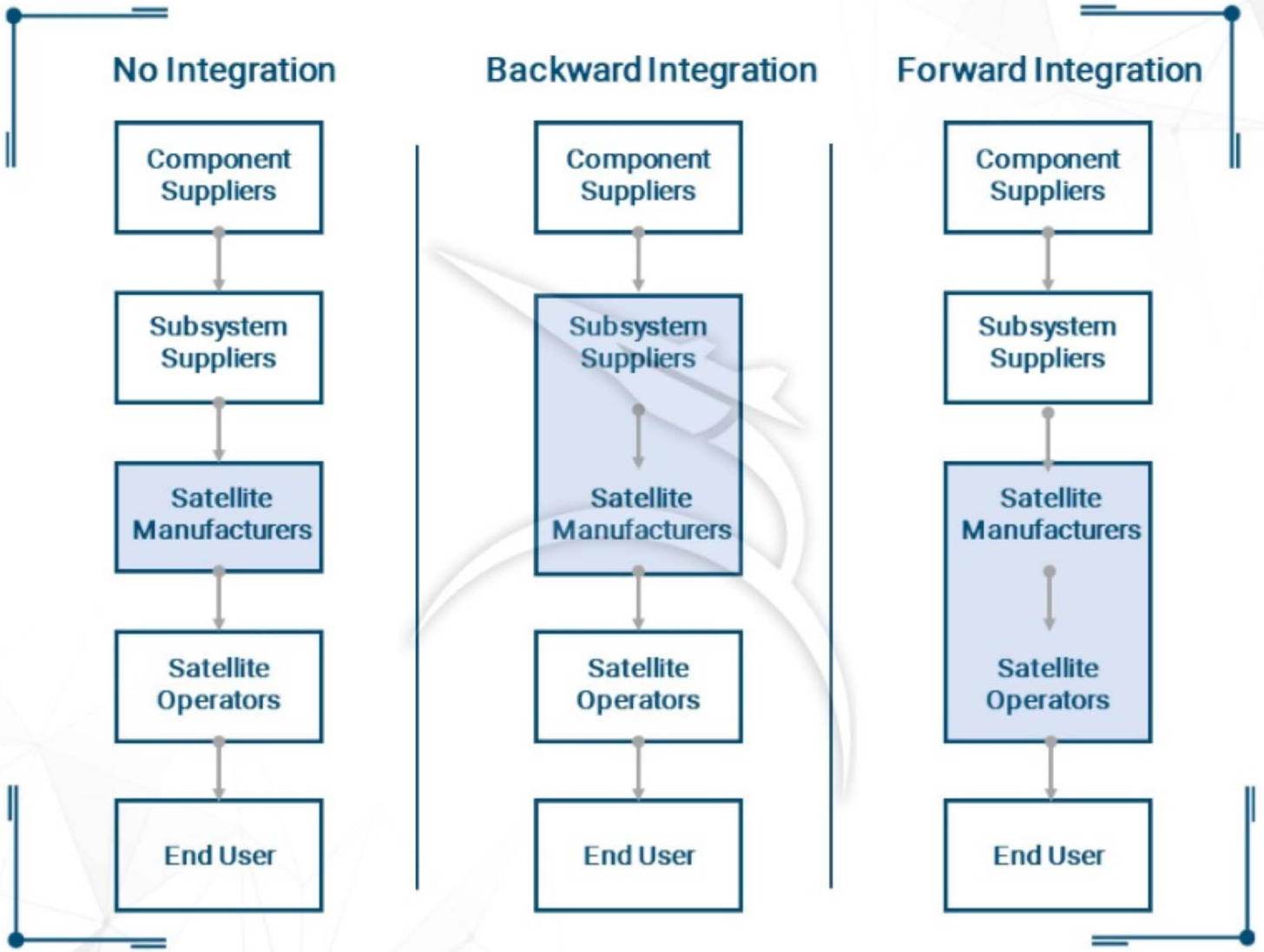
http://visual.ly/iphone-supply-chain



Question

- Is traditional satellite development & production scheme vertical, horizontal or vertical & horizontal?

Vertical integration in satellite industry

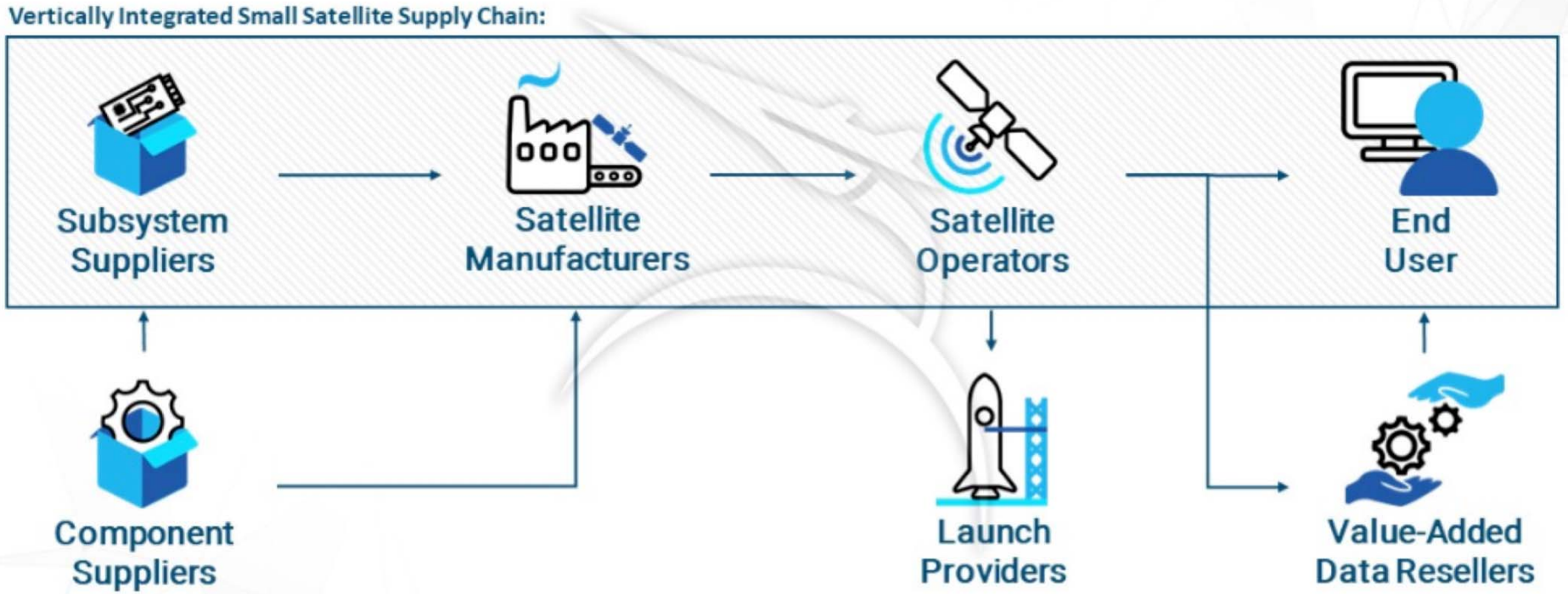


Source: SpaceWorks, “A Different Approach: Vertical Integration in Satellite Manufacturing”
https://www.spaceworks.aero/a-different-approach-vertical-integration-in-satellite-manufacturing/

Vertical integration in satellite industry

From "New Kids on the Block, How New Start-Up Space Companies Have Influenced the U.S. Supply Chain" Bryce Space and Technology, June 2017

Vertical integration in satellite industry



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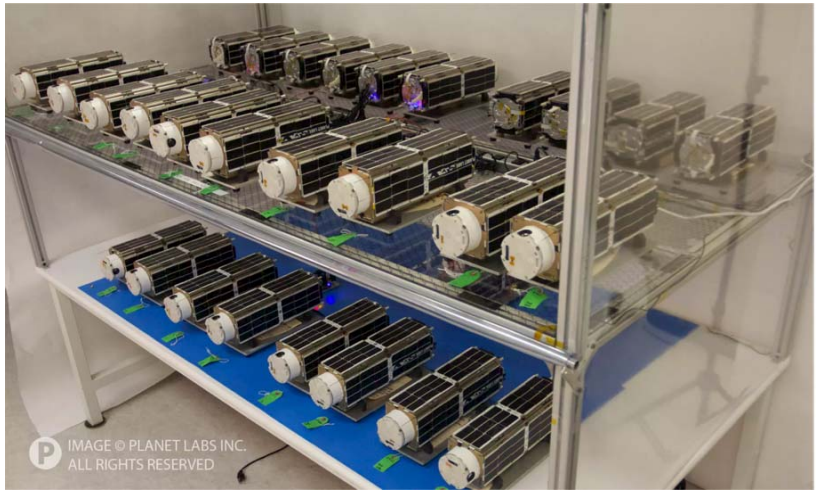
Basically, it does everything from component/subsystem manufacturing to end-user service (example: Spire and Planet)

Vertical integration

- It is interesting to see Planet and Spire, the two major constellation builders both chose vertical integration. Why?

Planet (>354 satellites)



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Spire (~100 satellites)

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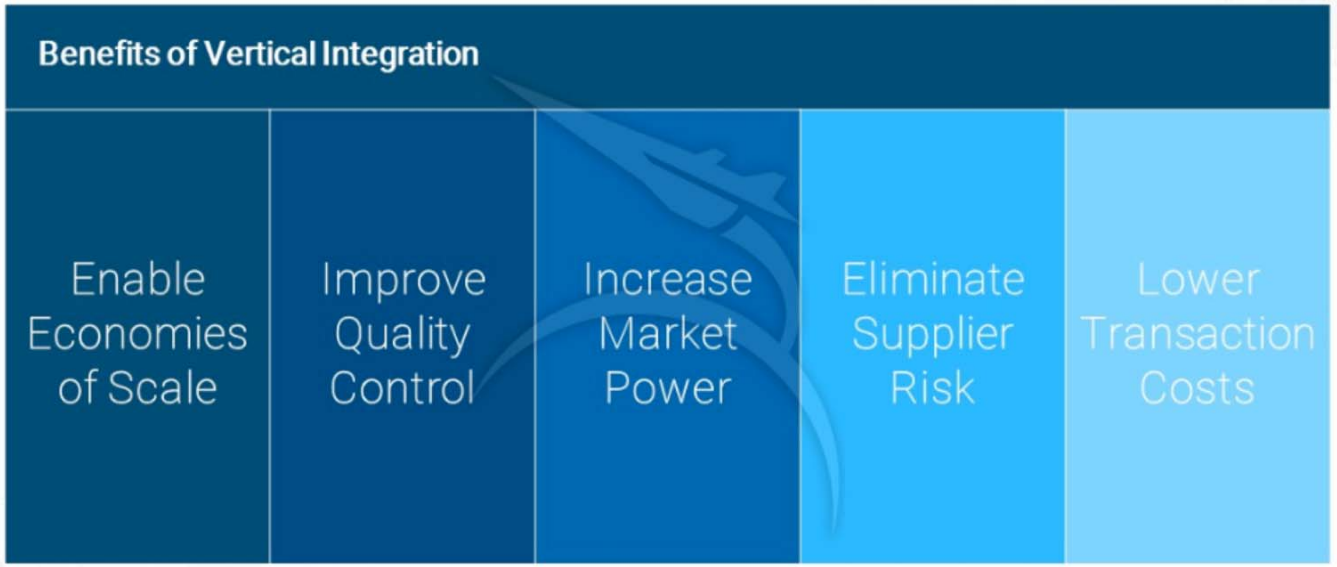
Benefit of Vertical Integration

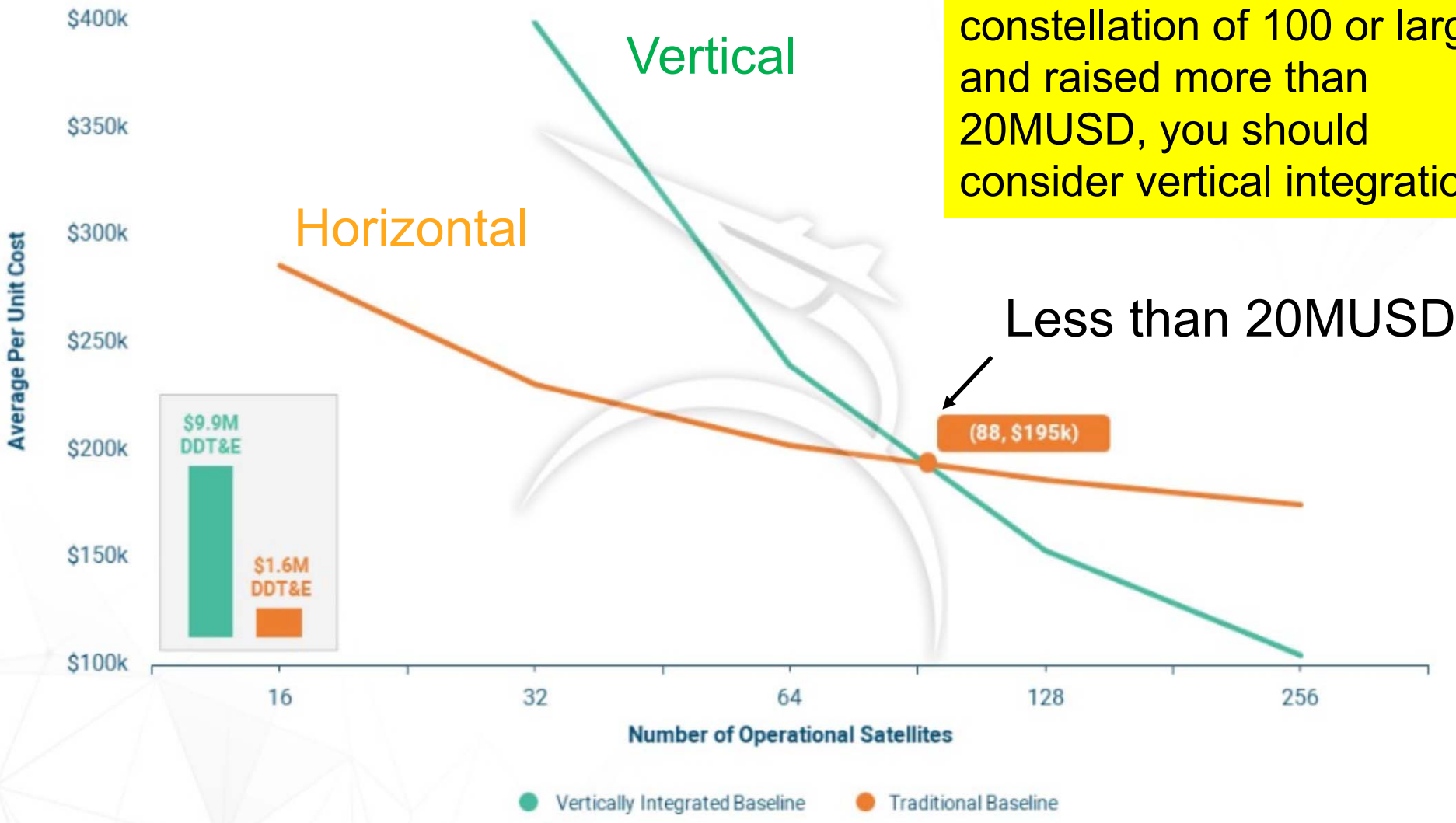


Source: SpaceWorks, “A Different Approach: Vertical Integration in Satellite Manufacturing” https://www.spaceworks.aero/a-different-approach-vertical-integration-in-satellite-manufacturing/

What is disadvantage of vertical integration?

Vertical or Horizontal? (CubeSat)

If you plan to build a constellation of 100 or larger and raised more than 20MUSD, you should consider vertical integration

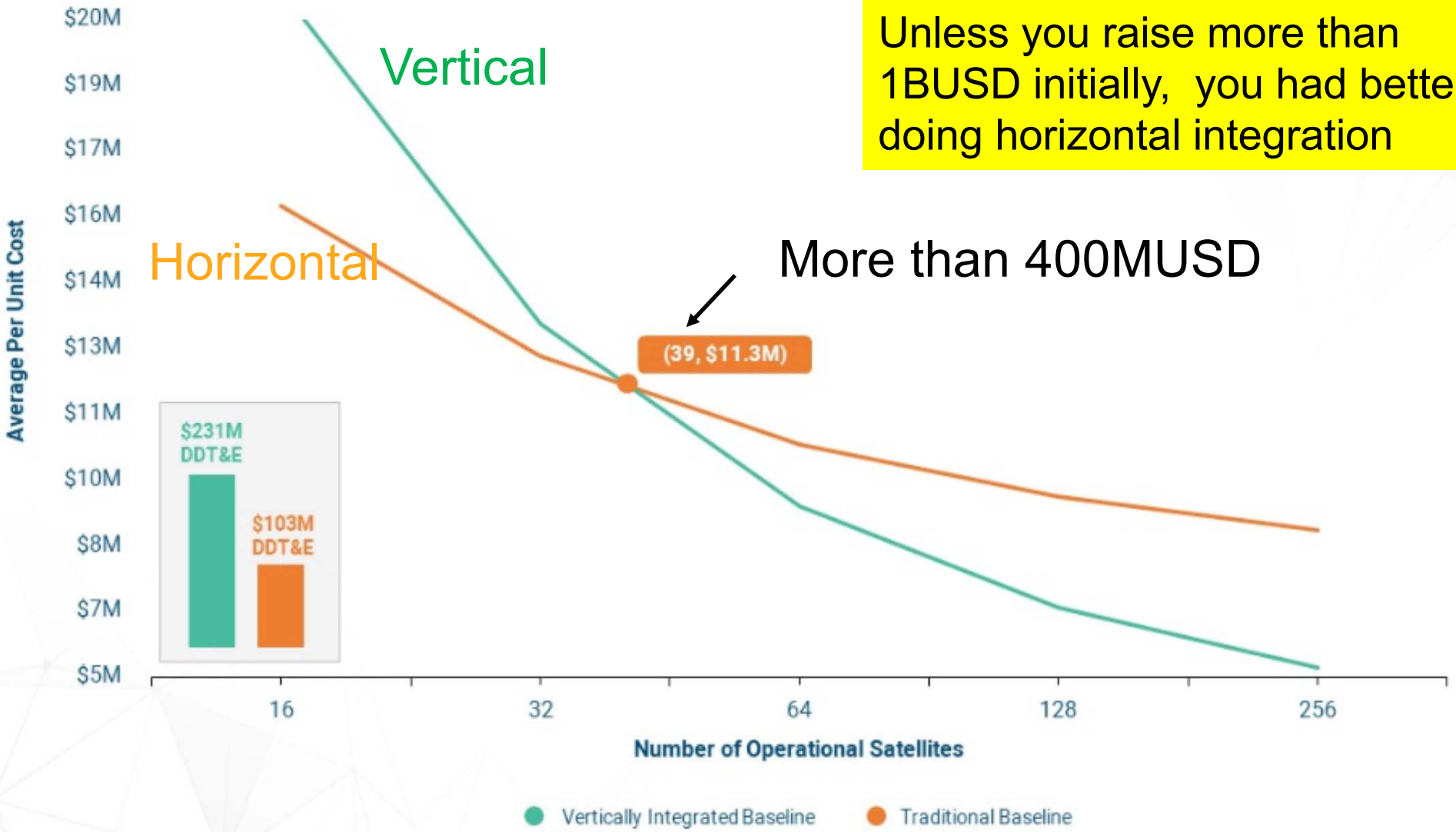


Source: SpaceWorks, “A Different Approach: Vertical Integration in Satellite Manufacturing”
https://www.spaceworks.aero/a-different-approach-vertical-integration-in-satellite-manufacturing/

Vertical or Horizontal? (~300kg)

Development cost of each component is expensive

Unless you raise more than 1BUSD initially, you had better doing horizontal integration



Source: SpaceWorks, “A Different Approach: Vertical Integration in Satellite Manufacturing”
https://www.spaceworks.aero/a-different-approach-vertical-integration-in-satellite-manufacturing/

Rationales for vertical integration (Spire's case)

- Rapid cycles of satellite design improvements
  - Iteration with suppliers takes too much time
- Rapid response to available launch opportunity
  - Cannot wait for long-lead items
- Horizontal integration is too slow
- Outcome
  - Cost saving
  - On-time delivery of satellites
  - More reliable
- Drawback
  - Initial investment for in-house components development

Key: Securing talents

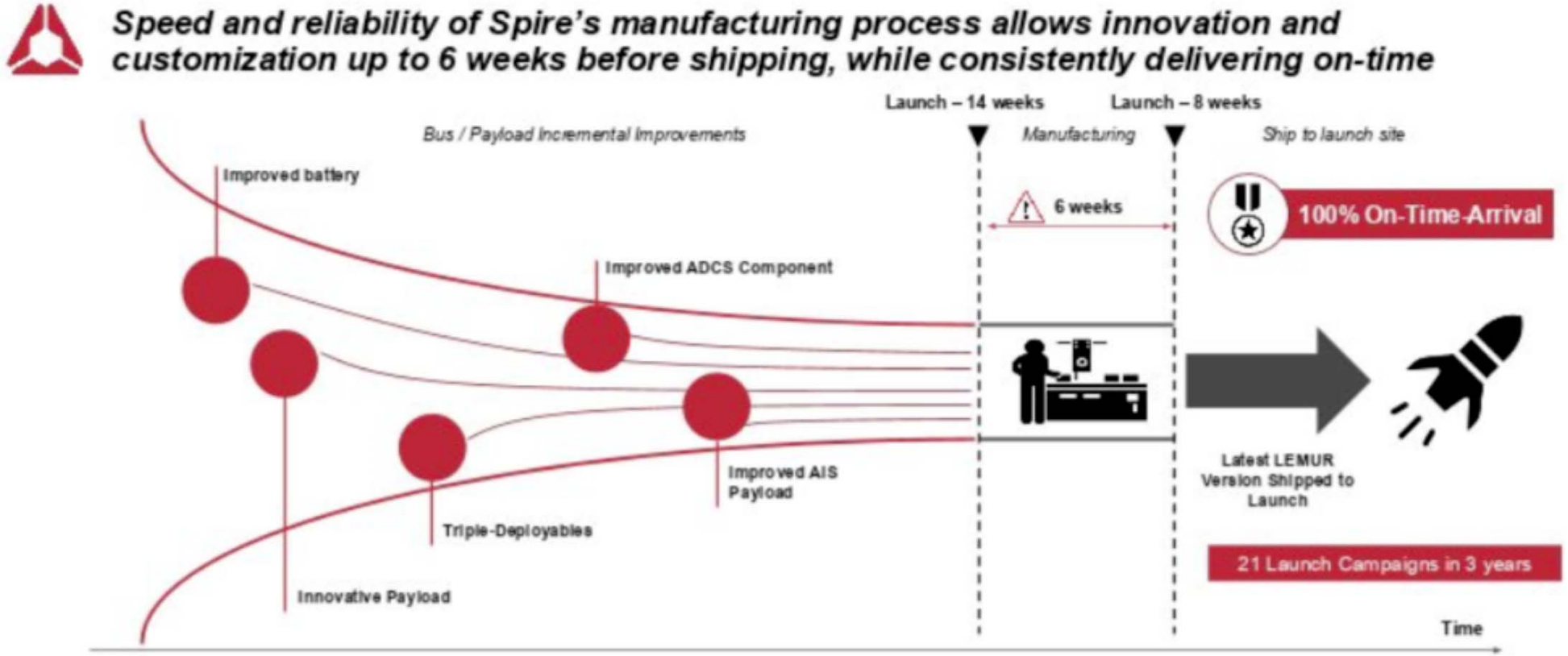
Hardware Vertical Integration - Supplier v Spire Cost Savings

Hardware Description	GBP Saving
Attitude Determination and Control System	43%
Deployable Solar Arrays	38%
Electrical Power System	57%
Battery	63%
UHF/VHF deployable antennas	72%

Daniel Bryce, Jeroen Cappaert, "Smallsat Manufacturing, The Spire "Constant NPI" Model", Small Satellite Conference, 2019

Rationales for vertical integration (Spire's case)

- They can now build 8 satellites in 16 days



Daniel Bryce, Jeroen Cappaert, "Smallsat Manufacturing, The Spire "Constant NPI" Model", Small Satellite Conference, 2019

Vertical integration in Kyutech satellite projects?

	In-house	Outsourced items
Structure	Proven	
EPS	Proven	
OBC	Proven	
COM	In progress	Tx/Rx
Backplane	Proven	
Solar Array	Proven	Solar cells
Battery	Proven	
Attitude determination	In progress	Sun sensor Earth sensor Star tracker
Attitude control actuator	In progress	RW MTQ
Propulsion	No	
AOCS software	In progress	

Rationale for vertical integration for our case

- Pros
  - Avoid proprietary issues
    - Can transfer technologies to BIRDS countries
  - Rapid development
  - Reliability
  - Cost saving
  - Standardized bus
    - Wider possibilities of joint satellite project by adapting various payloads
- Cons
  - Cost to maintain design and manufacturing knowledge
- Key
  - Constant satellite development, manufacturing and operation to make the design and manufacturing knowledge updated and continuous improvement
  - Transfer the knowledge to a commercial company?
    - Need special agreement for non-commercial usage

Plagiarism (無断盗用)

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