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Study of the benefits and applications of passenger supersonic transport vehicles: Case Study of Starship-SpaceX

Document:

Appendix

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Chapter 1

Appendix A

In this section, all the extra information related to the State of Art will be shown.

1.1 Resume

Chart resume of the previous and actual prototypes with all the characteristics known about these models in order to compare the potential performance of each one.

Model	Objective	Speed	Altitude	Company	Year	Key concept	Status	Capacity	Type
Concorde	Point-to-point high-speed travel	Mach 2.04	18.29km	Aéropatiale +BAC	1976-2003	One of the firsts commercial supersonic models	Retired	90-128 passengers	Winged (HTHL)
Tu-144	Point-to-point high-speed travel	Mach 2.15	18.29km	Soviet	1977-1978	Winglets right behind the cockpit	Retired	140 passengers	Winged (HTHL)
VSS Unity - SpaceShipTwo	Space tourism	Mach 3	85.78km	Virgin Galactic	2016-present	Uses a twin-fuselage mother ship	In service	8 passengers	Winged (HTHL)
Supersonic 2.0	Point-to-point	Mach 3	Unknown	Virgin Galactic +Rolls-Royce	2020-present	Sustainable aviation fuel	In developmemt	9 to 19 passengers	Winged (HTHL)
Dream Chaser	LEO crewed and uncrewed missions, Space tourism	Unknown	LEO	SpaceDev	2006-present	Winged commercial spaceplane	In developmemt	7 passengers or around 5400kg	Winged (VTHL)
New Glenn	LEO crewed and uncrewed missions and beyond, Space tourism	Unknown	LEO, MEO, GEO	Blue Origin	2016-present	First stage fully reusable	In construction	Unknown	Unknown
New Shepard	LEO crewed and uncrewed missions, Space tourism	Mach 4	100km	Blue Origin	2015-present	Throttleable engine, fully reusable	In service	6 passengers	Rocket (VTVL)
SpaceLiner	Point-to-point high-speed travel	Mach 24 (50pax stage) / Mach 14 (booster)	80km	DLR	2006-present	Operate in a stratospheric way to avoid noise problems	In development	50 to 100 passengers	Unknown
X08 PEGASUS	Point-to-point high-speed travel	Unknown	110km	ANA HD - PD Aerospace	2017-present	Jet/Rocket combustion mode switchable engine	In testing	8 passengers	Winged (HTHL)
XB-1	Supersonic demostrator	Mach 2.2	Unknown	Boom Supersonic	2016-present	sustainable aviation fuel	In developmemt	1 pilot	Winged (HTLH)
Overture	Point-to-point high-speed travel	Mach 1.7	18.29km	Boom Supersonic	2016-present	emissions-neutral flying, sustainable aviation fuel	In developmemt	65 to 80 p assengers	Winged (HTLH)

Model	Objective	Speed	Altitude	Company	Year	Key concept	Status	Capacity	Type
Hytex	Point-to-point high-speed travel	Mach 5	Unknown	JAXA	2009-present	Hypersonic propulsion systems	In development	Unknown	Unknown
MR3	Point-to-point high-speed travel	Mach 8	30km	STRATOFLY	2020-present	Jet noise reduction, high-speed combustion, climate impact science, stratospheric flying	In testing	300 passengers	Unknown
Lynx	Suborbital flights	Mach 3	99.78km	XCOR Aerospace	2003-2017	Reusable rocket engines, composite-body vehicle	Cancelled	1 pilot, 1 passenger and/or 1 payload or small satellite	(HTHL)
X-37	LEO missions, experimental laboratory	Unknown	LEO	Boeing	1999-present	Reusable orbital experiment vehicle, solar energy	In service	Non	Unknown
Halcyon	Point-to-point high-speed travel	Mach 5	27.43km	Hermeus	2018-present	Engine development	In development	20 passengers	Unknown
Supersonic jet	Point-to-point high-speed travel	Mach 1.8	18.29km	Exosonic	2020-present	Low Boom, supersonic aircraft, sustanaibility	In development	71 passengers	Unknown
Tianxing 1 and 2	Suborbital tourism	Unknown	Unknown	Space Transportation	2018-present	Unknown	In testing	Unknown	Rocket (VTVL)

Table 1.1: Resume of the actual and previous high-speed models and their characteristics.

Chapter 2

Appendix B

In this section, all the additional information recapitulated from the Case Study section will be located in this section.

2.1 Detailed history of Starship/Super Heavy

SpaceX's Starship is an orbital class rocket that will be the first fully reusable launcher and the most powerful vehicle launch in the world, capable of performing missions to all types of orbits, as this system is designed to provide service both in Earth orbits and in missions to the Moon and Mars. Its payload capacity, which categorizes it as super heavy, allows it to be capable of carrying up to 100 metric tons of weight, which can be equivalent to satellites, cargo, and crew.

This is possible thanks to its composition consisting of a two-stage vehicle, the name of which has been modified during the creation of its different prototypes and existing models, which are currently called Super Heavy Rocket (booster) for the first stage and Starship (spacecraft), which has the same name as the complete rocket, for the second stage. The series of prototypes built were designated in 2019 by the nomenclature BN (serial booster) for the first stage and SN (serial number) for the second stage. Later, in 2021, changed the nomenclature to *Ship* for the first stage, and *Booster* for the second stage.

2.1.1 Starship evolution: since the first prototype till the actual model

The idea behind the Starship system has been in constant evolution for years, going through different stages with different names until it reached the concept it is known today. This last product underdevelopment for around four years has gone through a dozen generations of smaller prototypes with various configurations.

1. **Mars Colonial Transporter (MCT)**
   Its development began in 2012 when the desire to develop a fully reusable rocket system with substantially greater capabilities than the Falcon 9 led to the creation of the Mars Colonial Transporter/Mass Cargo

Transport (MCT) idea, which was abandoned a few years later in 2016 as the system was intended to be able to go beyond Mars, and it is for this reason that the name of this idea was changed to Interplanetary Transport System (ITS).

2. **Interplanetary Transport System (ITS)**

3. **Big Falcon Rocket (BFR)**
   Later, in 2017, the design evolved into the new launch vehicle named Big Falcon Rocket (BFR) which consisted of an initial two-stage design composed of 6 Raptor engines and a delta wing and split flaps that was intended to achieve the objectives of payload mass, landing capabilities and reliability. However, in 2018, it was redesigned with three rear fins and two forward fins to serve the new lunar project named #dearMoon that was announced that same year.

4. **Starship / Super Heavy**
   Finally, in 2019, the two major parts were renamed Starship (second stage) and Super Heavy (booster), starting with this the actual Starship's active test program. This same year also a remarkable change in the design of the aircraft was announced, as the previous structural material used in its construction, which was composed of carbon fiber, was modified for a lighter and more economical one that corresponded to stainless steel, in addition to the ease of manufacture and its strength of stainless steel at cryogenic temperatures.

   - **Starhopper:**
     The first prototype test vehicle was coupled to a single Raptor engine and performed several hop tests, lifting up 150 meters in the last test before its retirement on August 2019.

   - **Mk prototypes**

   - **SN (*serial number*) prototypes:**
     SpaceX has manufactured several SN prototypes throughout the years, the first ones, between SN1 and SN6, performed low-altitude flights but most of them resulted unsuccessfully as some collapsed during the pressure stress test (SN1 and SN3), and others like SN4 exploded due to its fifth engine firing. In August 2020, the SN5 model became the first flight-capable Starship when performed a 150 meters high flight and landed prosperous, as well as the SN6, notwithstanding, later the engine fired in another attempt.

     High-altitude test flights without the booster were performed for the models between SN8 and SN15. In December 2020, SN8 flew several miles high but its engines shut down and performed a distinctive 'skydiver' belly flop maneuver that put the rocket in a horizontal position resulting in an explosive crash on the landing pad. The next model, SN9, also crash-landed in an explosion in February 2021, when flew to an altitude of about six miles. The two following prototypes launches attempted around March 2021, also not went as expected: the SN10 attempt successfully launched and landed but exploded later due to a fuel leak, and the SN11 vehicle froze after the engines had reignited for landing caused by a small methane leak leading to another failure. Finally, in May 2021, the SN15 model successfully touched down softly on the landing area even though some issues happened after the landing such as loss of tank pressure or a small fire in the engine [1].

- **S (*ship*) prototypes**

2.1.2 Production updates

The most recent production status from May 2023 is the following one:

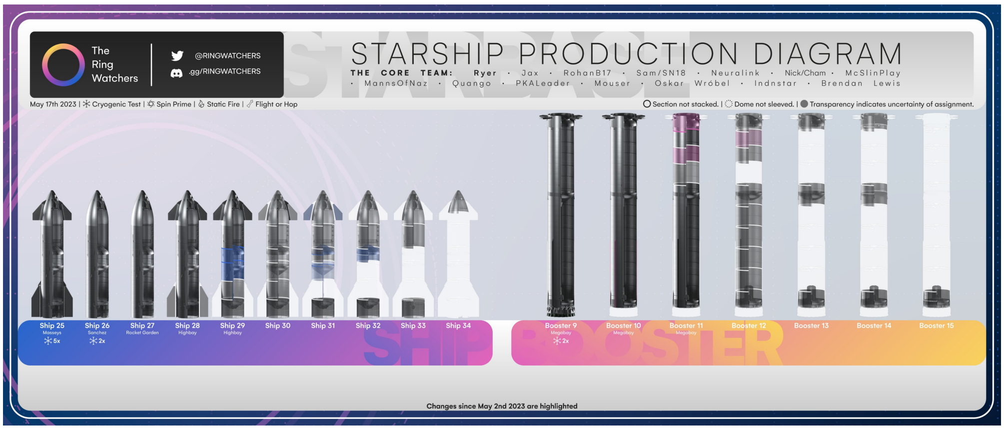

Figure 2.1: Actual prototype parts in production, last update made in May 2023. Extracted from *The Ring Watchers*.

2.2 Ownership

OWNERSHIP, DIRECTORS AND OFFICERS

1. ENTITY OWNERSHIP

Information relating to Space Exploration Holdings, LLC and the members who own of record and/or vote 10% or more of the membership interests of Space Exploration Holdings, LLC is as follows:

Space Exploration Holdings, LLC

State of Organization:	Delaware
Principal Place of Business:	1 Rocket Road, Hawthorne, CA 90250
Primary Business Activities:	Provider of satellite broadband services.
Principal Shareholders:	Space Exploration Holdings, LLC is a direct wholly owned subsidiary of Space Exploration Technologies Corp. ("SpaceX"), a privately held Delaware corporation located at 1 Rocket Road, Hawthorne, CA 90250.

Space Exploration Technologies Corp.

State of Organization:	Delaware
Principal Place of Business:	1 Rocket Road, Hawthorne, CA 90250
Primary Business Activities:	Provider of launch services to government and commercial satellite customers.
Principal Shareholders:	SpaceX is a privately held company in which the sole shareholder who is the beneficial owner of a 10% or greater interest is Elon Musk, as trustee of a private trust. Mr. Musk's trust currently owns 42.3% of the outstanding stock of SpaceX and has voting control of 78.2% of the outstanding stock of SpaceX. Mr. Musk, a U.S. citizen, can be contacted at the following address: 1 Rocket Road, Hawthorne, CA 90250.

Figure 2.2: Excerpt from SpaceX's recent FCC fling in July 2022. Extracted from [2].

2.3 Funding rounds

Depending on the reason and maturity stage of the startup, these funding rounds are established with an end goal in mind and can therefore be categorized into these types [3]:

1. Pre-Seed: The first round of investments in which the concept is at an early stage and is still in the testing and feasibility verification phase. It mainly involves the investment of the founder(s) and maybe also the ones from an interested angel investor.

   In the SpaceX case, in its initial period from 2002 to 2012 the company operated with an amount of money of 1B dollars that came from 700M of government grants and 300M from private funding, including $100M from the CEO of the company, Elon Musk.

2. Seed round: A riskier stage where the idea starts to take form so the funds are utilized for further research, product development, hiring critical personnel, and product-market fit testing [**wallstreeetmojo**]. It involves most commonly angel investors and venture capitalists.

3. Series A round: In this stage, the startup has solid proof of the concept and needs additional funding to reach greater heights. Typically, angel investors and venture capitalists are also involved, and might also include private equity firms; earlier and new investors that believe in the potential of that idea.

4. Series B round: This stage is achieved when the startup has proven that can scale up its idea by dedicating user bases and steady streams of revenue. Then, the investors would help by employing advanced market reach activities, increasing market share, and forming operational teams [4].

5. Series C round or more: At this point, the startup is looking for strategic acquisitions for several reasons like eliminating competition or increasing geographic reach. Involves more demanding investors but because of the success of the startup at this stage, the company will be involved with the largest venture capital companies in several funding rounds established.

6. Initial Public Offering (IPO): This is the final process that is applied when a startup is totally established and its business has grown enough. Then, the private company decides to raise funds from the public by selling its shares in the stock market where any investor can contribute. Nevertheless, many companies do not complete an IPO and proceed to grow further by having more series that will entail more money.

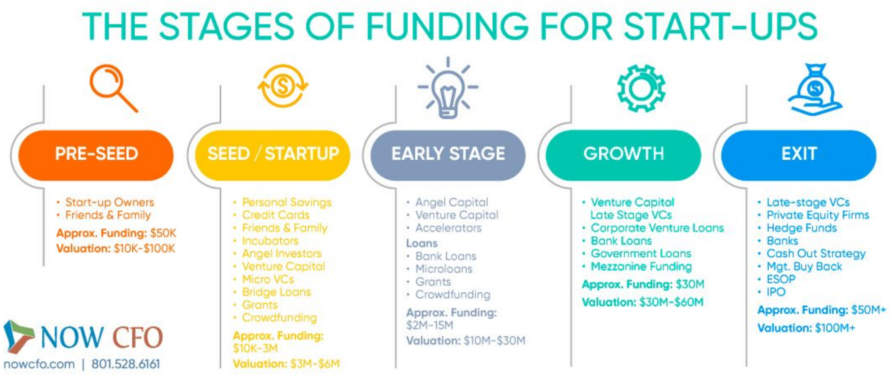

Figure 2.3: Stages of funding rounds till a startup becomes public. Extracted from [5].

2.4 Market segmentation: types and benefits

The different market segmentation types can be classified into five groups:

- Demographic Segmentation: breaking the market into customer demographics such as age, income, gender, race, education, or occupation.
- Firmographic Segmentation: breaking the market into organization aspects such as the number of employees, number of customers, number of offices, or annual revenues.
- Geographic Segmentation: assuming that people of the same geographical area have similar needs.
- Behavioral Segmentation: relies on market data, consumer actions, and decision-making patterns of customers.
- Psychographic Segmentation: strives to classify consumers based on their lifestyle, personality, opinions, and interests

To implement market segmentation allows the company to have the following advantages [6]:

- Increased resource efficiency
- Stronger brand image
- Greater potential for brand loyalty
- Stronger market differentiation
- Better targeted digital advertising

2.5 SpaceX's financial status: 2023 Revenue Projection

SpaceX 2023 Revenue Estimate			
Launch	**#**	**Per (MMs)**	**Total (MMs)**
Starlink	30	$0	$0
Falcon 9 (Standard Commercial)	30	$60	$1,800
Falcon 9 (Transporter)	4	$40	$160
Falcon 9 (Crewed Seats)	20	$60	$1,200
Falcon 9 (CRS - ISS Missions)	4	$145	$580
Falcon 9 (Government)	9	$100	$900
Falcon Heavy	5	$125	$625
Launch Revenue			*$5,265*
Starlink	**# (Ks)**	**Per/Per Mo**	**Total (MMs)**
Hardware (Additions)			
Residential & RV	1,280	$600	$768
Business	320	$2,500	$800
Maritime	1	$5,000	$5
Aviation	0.75	$150,000	$113
Subscriptions			
Residential & RV	2,133	$110	$1,998
Business	467	$500	$1,692
Maritime	1	$5,000	$32
Aviation	0.75	$18,500	$54
Starlink Revenue			*$5,462*
Other			
HLS Contract (Recognized)			*$750*
Transport & Tracking Layer (Recognized)			*$75*
Other Revenue			*$825*
Total Revenue			**$11,552**

Figure 2.4: Estimation of SpaceX 2023 Revenues not based on any internal data or proprietary information. Extracted from [7].

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