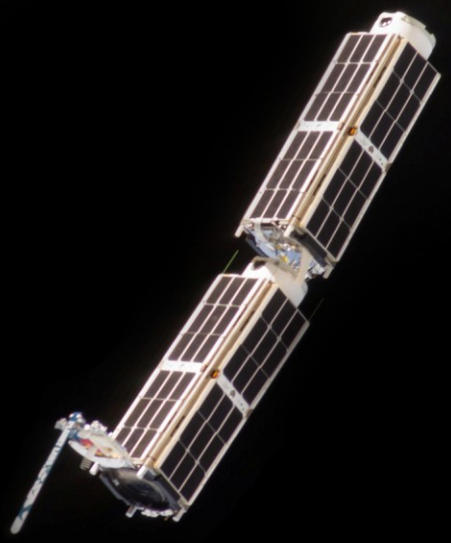
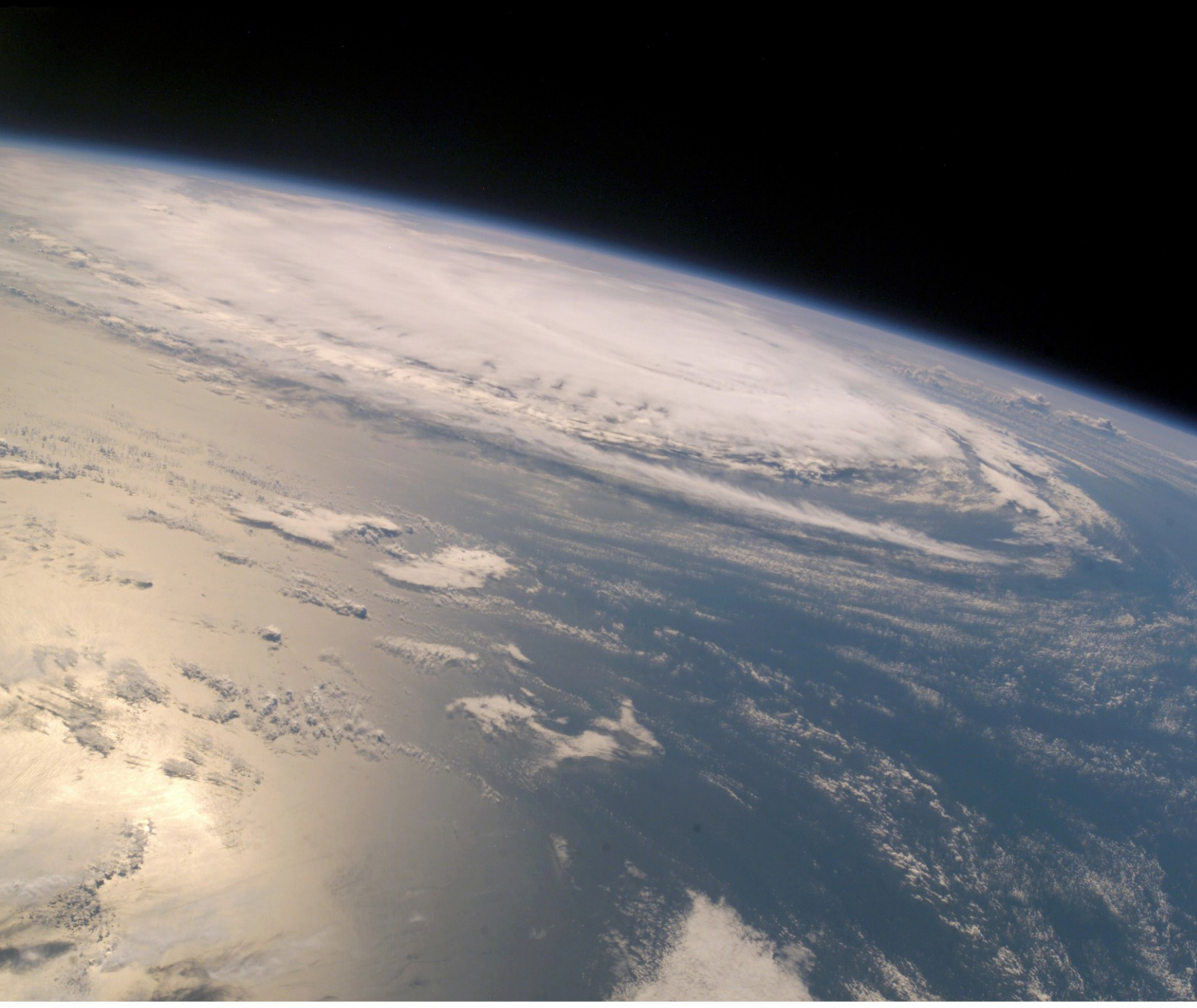
CURRENT SUPER-SMALL LAUNCH VEHICLE PROJECTS FOR MEETING MICRO-SATELLITE LAUNCH DEMAND





COMMERCIAL SPACE TECHNOLOGIES LTD

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CURRENT SUPER-SMALL LAUNCH VEHICLE PROJECTS FOR MEETING MICRO-SATELLITE LAUNCH DEMAND

A REFERENCE IN CONFIDENCE TO
CST MEMBERS, ASSOCIATES
AND CUSTOMERS

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Contents

INTRODUCTION

This report serves dual purposes. Firstly, it is a continuation of numerous studies, which appeared more than ten years ago, and forecast a significant increase in 'super-small' satellites (including satellites with masses of less than 100 kg i.e. those attributed to micro-, nano- and pico-classes). These studies explained the coming expansion of this class of satellite development, with recent achievements in the global electronics industry, and noted that these achievements allowed these super-small satellites to be developed, for significantly less cost than previous satellites of similar purposes, but with greater sizes and masses. However, these studies also noted that, whilst the reduced costs for development / manufacturing of these satellites expanded their availability for relatively 'poor' users, such as educational institutions, small private companies and even amateur organisations, an accompanying problem arose that the launch costs did not decrease in conjunction with the reduction in cost of these small satellites. It became clear too, that piggy-back and multi-satellite cluster launches of these satellites, which were providing acceptable launch prices, would not satisfy a significant number of the satellites' owners, for specific reasons related to the features of these launches.

A detailed explanation of the current situation in this field, which became clear more recently, and has been reflected in presentations at various astronautical forums, and has confirmed very well the previous forecasts, is the first purpose of this report.

On the other hand, it is not enough to identify a problem and define its reasons and even conceptual ways to solve the problem, it is also necessary via technical means, to validate or invalidate these problem points. With an increasing trend in the number of super-small satellites to be launched, it had been identified that the best way to satisfy even the most demanding of these launch requests, would be to develop a sufficiently cheap super-small launch vehicle, which could provide dedicated, or in a worst case scenario, rideshare launches for these super-small satellites. Preliminary requirements and an approximate look at this type of launcher were defined at the same time (for instance in CST report [1]).

However, even after almost fifteen years, not one example of a small launcher, which could meet all the requirements for solving the problem, has appeared /1/. At the same time, a number of corresponding projects were proposed and even developed up to a level sufficient to demonstrate that these projects were infeasible, not from a technical perspective (there was no problem developing a launcher with very low payload capability), but from an economic perspective: the cost to launch and the price to the customer was significantly more than existing piggy-back and cluster launch options.

A significant number of super-small launch vehicles and systems have been under development more recently, initially to try and provide low launch prices. A review of these projects which are being developed, where physical hardware and testing has taken place and/or the concept and team behind it is viable, is the secondary purpose of this report. Since it is impossible to describe and assess all of these projects, in every detail relevant to technical features and to economic/organisational aspects, one of them is chosen as a reference example for this analysis, and for a following comparison with other projects. The Russian 'Taimyr' project is chosen for this role for two reasons: firstly, since it was already assessed by CST a year ago (as one of a number of projects by the same developer, see [2]), and secondly, CST has direct access to the developers.

This report therefore elucidates the current situation in the field of potential launchers to meet the demand for launching super-small satellites (of micro- and smaller classes), whilst describing the means by which they aim to meet this demand.

To achieve these purposes, **Section 1** first explains the current demand for small launcher services within the global growth of the micro-satellite industry, highlighting the necessity for dedicated launch options with low prices, and notes the problems that are currently created by existing launch methods, including dedicated launches on converted ballistic missiles. Then the specific requirements, both technical and economic, for super-small launchers intended to meet the demand for launching micro-satellites on a commercial basis, are derived and defined in **Section 2,** with a definition of accessible limits for the values of corresponding parameters.

Twelve launch vehicle systems have been chosen for review in this report. These were chosen based on their ability to meet market demand in the near future. Of these twelve projects, eleven are described in **Section 3** with a brief description of the project, its conceptual features and proposed technical and economic figures. The projects represent proposed launchers of two basic concepts, common concept i.e. expendable vertical launch vehicles, and air launched, in which a launch vehicle is launched from a carrier aircraft (or another airborne vehicle). The projects also represent various types of launch vehicles to be used (for both mentioned concepts), with either solid- or liquid-propellant.

Section 4 is dedicated to the twelfth project, the Russian 'Taimyr' super-small liquid-propellant launch vehicle, derived from a common concept. **Paragraph 4.1** contains a brief description of the project, with references to a preceding report [2], but with changes and additions that had been included in the past year. **Paragraph 4.2** describes the current status of the project and its ongoing development, the start of construction (listing the works which have

been carried out for this process) and plans for its further development. Organisational aspects of the project and its funding status are described in **Paragraph 4.3,** including a description of the developer; the Lin Industrial LLC company, its management and personnel structure; its cooperation and business relationships, its interaction with Russian space relevant state bodies; available and proposed sources of funding, and forecasted figures for financial future.

A comparison of all the projects, from the perpsective of meeting the requirements defined in **Section 2**, is displayed in **Section 5**. Based on the results of this comparison, the definition of the 'Taimyr' project's competitiveness is carried out as a reference project, in order to highlight its chances of achieving its targeted economic efficiency.

A summary of the information in the report, and the results of its analysis, are presented in the **Conclusions**.

REFERENCED CST REPORTS

(indicated in square brackets in the text)

1. Super-small Launch Systems for Super-small Satellites, 2002.
2. A Second Attempt to Create a Russian Private Launch Vehicle: Developments of the 'Lin Industrial' Company, 2014.
3. A Survey of the Current Inventory of Small Launch Vehicles in Russia and the FSU and Its Development to 2020, Edition 10, Revision 1, 2012.
4. Super-small Launch Systems of Air-launch Concept: Features and Prospects (Analytical reference), 2013.
5. A Brief Report on Participation of CST Representatives in the 66-th International Astronautical Congress, 2015.
6. A Preliminary Assessment of Swiss Project of the SOAR Air-launch System, 2014.
7. A Choice of Carrier Aircraft for Air-launch Systems, Carrier Aircraft Options or Air-launch Systems, 2013.

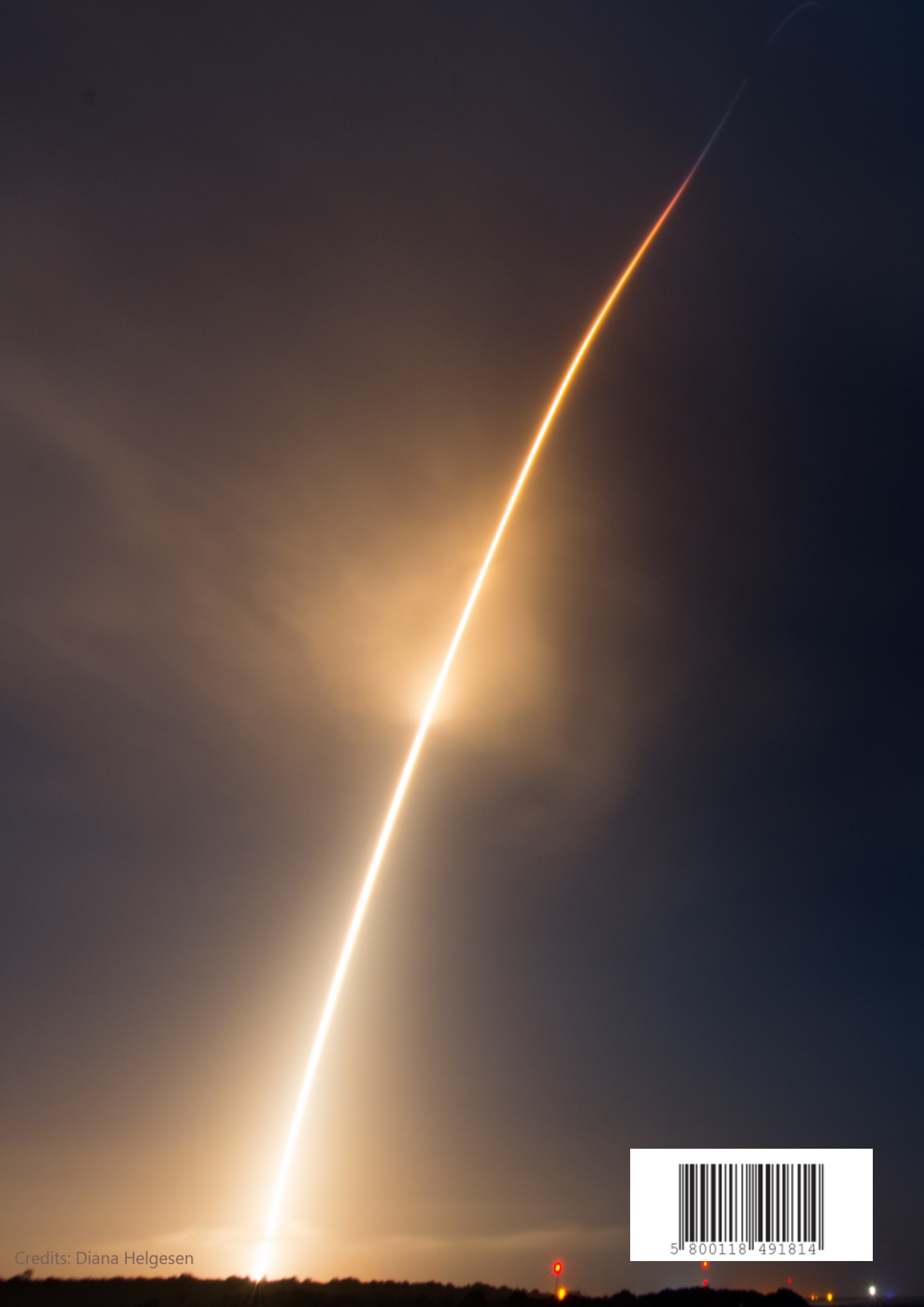
EXTERNAL REFERENCES

(indicated in slant brackets in the text)

1. World Launcher Review, Seradata & CST, 2015.
2. Technical Effects of NASA's CubeSat Launch Initiative, IAC-15.B4.5.3 paper of IAC-2015, 2015.
3. Spaceflight, November 10, 2015.
4. SpaceNews.com, November 5, 2015.
5. NASA Spaceflight.com, November 5, 2015.
6. Seradata Space Intelligence, June 12, 2014.
7. Seradata Space Intelligence, November 24, 2014.
8. Firefly– a New Generation of Low Cost, Small Launch Vehicles Designed to Serve the Rapidly Growing Small Satellite Market, A. Bradford, IAC-15.B4.5.12 paper of IAC-2015, 2015.
9. Space.com, September 10, 2015.
10. Via Satellite, April 6, 2015.
11. www.planetary.org, October 14, 2015.
12. www.americaspace.com, June 16, 2015.
13. Parabolic Arc, July 22, 2015.
14. Bloostar: A Balloon-assisted Lightweight Launcher to Orbit Microsatellites, IAC-15.D2.7.8 paper of IAC-2015, 2015.
15. Sverkhlegkaya Raketa 'Taimyr' ('Taimyr' Super-small Launcher), *in Russian*, Lin Industrial LLC, 2015.
16. Room, the Space Journal, # 3 (5), 2015.
17. isicad.ru, September 1, 2015.
18. http://www.kommersant.ru/doc/2841635, October 27, 2015.

19. Firmma, August 31, 2015.

20. Global Launcher Market Survey – Where Are We, and Where Are We Going?, D.Lim, BIS-RS-2015-56 paper of Reinventing Space Conference, 2015.



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