Investor funded access to space from the UK? – The BIS Nanosat Launch Vehicle feasibility study

Final Report

(Part 1 only)

EXECUTIVE SUMMARY

Orbital access to space from the UK is feasible and could be investor funded

The British Interplanetary Society's Nanosat Launch Vehicle (BIS NLV) feasibility study has concluded that orbital access to space from the UK is feasible and could be investor funded. This could be implemented by a vertical-launch vehicle from the north of Scotland or, possibly, by air launch.

This conclusion results from the study's key questions and answers:

1. Would it be feasible to launch into orbit from the UK – if so how?

It would indeed be feasible to launch from the UK, by means of an SSO or polar orbit from Scotland.

2. What is the potential market?

Studies of current and potential future market dynamics using an Agent-Based Model suggest that the market has potential growth of between 8% and 22% per annum for the foreseeable future, and that a small satellite launcher can achieve a reasonable market share within this range. However, there is a significant strategic risk from competition with large launch vehicles offering discount ride-sharing.

3. How could access to space be most economically implemented for c.100 kg payloads?

The study has shown that the proposed small satellite launch vehicle is technically feasible and could either be ground or air launched. Overall, the lowest cost option was found to be a ground-launched 3-stage pressure-fed vehicle, but due to doubts over the technical feasibility of a pressure-fed first stage, a 3-stage pump-fed launcher was selected as the reference vehicle.

4. What might a realistic payload and revenue stream look like?

A 100 kg net flexible mixed payload configuration based on a flat mounting plate design that could accommodate various arrangements of CubeSats and microsats is optimum, with potential revenues of $4,160,000 to $4,875,000 per launch.

5. How do the economics come together and could a business case be closed?

An economic analysis suggests that both the ground and air launch reference vehicles could provide the kind of returns investors might require at a cost that would be acceptable to customers. Because of its lower overall costs though, the ground-launch option appears to be the less risky.

6. Could access to space from the UK be investor funded?

Space is increasingly seen as an interesting field of investment and the UK is blessed with a significant and enthusiastic investor base for starts up, supported by generous tax breaks for start-up investors. This suggests that access to space from the UK could be investor funded.

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1.1 FOREWORD

When this study began two years ago, the space scene in the UK was very different from today, not least because there is now an expectation that it will soon be possible to launch satellites from Britain.[1] Also, during the course of the study, other reports examining potentially viable launch services from the UK have appeared.[2, 3, 4]

However, it is still considered that this report complements rather than competes with other offerings, as it has several features that distinguish it from similar studies:

- The results are in the public domain, and not constrained by commercial considerations
- The majority of the report examines the economics and business case rather than concentrating on the technology
- It is technology unbiased, i.e. not tied to one particular hardware solution or launch method
- It assesses potential launch vehicles, not just on technical merit, but on whether they can support a business model that can launch payloads at prices customers are prepared to pay while also providing satisfactory returns to investors
- The results are presented in an investment rather than an engineering related way

Notes:
1. This document represents the views of the BIS NLV feasibility study group only, and is not to be construed or disseminated as being that of the British Interplanetary Society as a whole.
2. Acknowledgements – see page 43 of Part 2
3. References in the text are grouped as endnotes at the end of the main sections rather than the overall document.

1.2 INTRODUCTION

The study initially set out to answer the relatively simple question "How cheaply could access to space be for small space satellites?" [5] However, it quickly became apparent that the answer was "not cheap at all", and as the space scene in the UK was evolving rapidly , the study soon evolved to tackle the question "Investor funded access to space from the UK?", although with smaller satellites to LEO (Low Earth Orbit) still in mind.

The question might be simple, but the factors are complex, so as indicated by the executive summary on the front page, the study was broken down into a series of intermediate questions:

1. Would it be feasible to launch into orbit from the UK – if so how?

2. What is the potential market?

3. How could access to space be most economically implemented for c.100 kg payloads?

4. What might a realistic payload and revenue stream look like?

5. How do the economics come together and could a business case be closed?

6. Could access to space from the UK be investor funded?

This list does not mean that the questions were answered in order before moving on to the next, the study was very much an iterative process, the answers are interdependent, and the factors tended to be examined in parallel, with constant feedback between them.

As noted in the foreword, one of the distinguishing features of the study is that it is open-minded on examining the basic questions about commercially viable access to space from the UK for small satellites. For instance, unlike some other studies that have resulted in final reports, it does not assume a particular technical solution in the form of an existing launch vehicle.

It is, of course, extremely tempting to start with an existing technical solution, as it simplifies a complex task by removing one of the major variables. So with this significant variable still in place, the study soon developed a process that allowed "what if" approaches to possible solutions to be evaluated and compared.

In particular, the study concentrated on validating economic ways of reaching LEO. Novel methods of launch were initially considered, but quickly found to bear excessive R&D risks at current technology readiness levels. As a basis for cost estimates based on a parts-count model, a range of launch vehicle designs have been compared using both a top-down model based on historical data, and a bottom-up model optimising a range of design parameters.

On the regulatory side, the fast-changing situation in the UK and further afield has been examined, together with associated insurance, launch site and trajectory issues, and it is recognised that these factors are the most difficult to cost, as there is little historical experience to base estimates on.

1.2.1 Why "Nanosat" Launch Vehicle?

Because of the study's origins, "Nanosat" was originally used in the title, but the study now also includes the launch of larger microsatellites. However as the term Nano/Microsatellite used by some is a little clumsy, the original name has been retained.

	Mass (kg)	CubeSat "U" range (1.33 kg/U)	Examples
Mini	500-100	376 – 75 U	
Micro	100-10	75 – 7.5 U	Sputnik 1 (83 kg) [1957] Prospero (66 kg) [1971]
Nano	10-1	7.5 – 0.8 U	STRaND-1 (3.5 kg 3U) SSTL CubeSat (smartphone in space) Typical CubeSats
Pico	1-0.1	0.8U and less	Small CubeSat
Femto	100 g – 10 g	-	KickSat Sprites

Figure 1.2.1 – Common small satellite classifications as used in this study

1.2.2 Why not greater than 100 kg?

At various places in this report, reference is made to a payload mass of nominally 100 kg. It could be asked, as larger payloads tend to cost less per kg to reach orbit, why not use a larger value? The answer is:
(i) The scope of the study was to determine the smallest viable launch vehicle
(ii) Mixed payloads > c.100 kg would require an unrealistic share of the annual global space satellite market.[6]
(iii) The study investigated payloads less than 100 kg (20 and 50 kg were looked at), but found that the cost per kg of launching becomes higher than the market could bear.
This is not to say that launching single satellite payloads (i.e. with low deployment hardware overhead) of perhaps 130 kg shouldn't be allowed for, but the market above 150 kg has not been addressed by this study.[7]

1.2.3 What next?

As noted in Section 2.7, it is intended that this final report will be followed by events and publicity, starting with an evening lecture at the BIS HQ on 17th May 2018,[8] articles in BIS magazines and online, and promotion at forthcoming conferences such as RISpace 2018.

Those involved have agreed [9] to follow this initial two year month study by a twelve month "Phase 2", which will include activities such as:

- Deeper top down and bottom up technical work as required, which might include seeking funding for some aspects
- Validation of the economic model leading to a draft pitch to investors
- Consideration of the future structure of the study – spin off from the BIS, form a trust/company?
- A deeper look at the logistics chain required (r&d, manufacturing, payload integration, access to launch site, launch site layout)

For further information, or to join Phase 2 of the study, please contact the project leader:

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1.3 KEY FINDINGS

This section corresponds to the 'Key Findings' of the main sections (2.1 to 2.7) of this report. It expands on the points made in the executive summary on the front page, but for more detailed analysis of the pros, cons, assumptions and caveats see the main sections of the report referred to.

Overall

The British Interplanetary Society's Nanosat Launch Vehicle (BIS NLV) feasibility study has found that orbital access to space from the UK is feasible and could be investor funded. This could be implemented by a vertical-launch vehicle from the north of Scotland or, possibly, by air launch.

1. Would it be feasible to launch into orbit from the UK – if so how?

- In principle it would be possible to launch into SSO or polar orbits from the UK.
- Practical ascent trajectories to SSO could be achieved even when using dogleg manoeuvres to avoid overflying populated areas.
- It appears that dogleg launch trajectories could meet applicable safety requirements as far as avoiding the Faroe Islands is concerned; but "The Moine" potential launch site has a major safety issue to address because the "West of Shetland" oilfields lie in the centre of the launch corridor to the east of the Faroes.
- The "cost" or penalty of using dogleg ascent trajectories is not significant for the BIS NLV reference vehicle.
- The UK is actively putting into place the necessary legal and regulatory framework.

(For details see section 2.1 of Part 2.)

2. What is the potential market?

(i) Smaller launch vehicles become progressively more expensive to operate per unit of payload because costs do not scale down linearly with the payload. A 100 kg payload launch vehicle is close to the smallest that can be realistically achieved with existing technology.

(ii) A modest schedule of six launches per year, assuming a 100 kg payload vehicle, appears feasible for a UK-based small launcher under current market conditions.

(iii) ABM modelling strongly suggests that recent growth in small satellite launch is driven by a backlog being cleared as launch services improve, rather than underlying growth of the client base. This could mean that the number of clients seeking launch could drop quite suddenly once this backlog has been served.

(iv) An optimised ABM forecast suggests annual market growth of 15%-17%, lower than most forecasts suggest. Extreme forecasts suggest growth rates of 8%-22% are feasible within this analysis.

(v) Low growth may actually benefit small launch providers as such an environment suggests clients are not being served by existing launch providers to a significant extent – i.e. there is a large gap in the market to fill.

(vi) In a high growth market particularly (but not exclusively), "Big Launch" rideshare is a major strategic risk. They can reduce prices more easily, and can streamline their service offerings to increase their appeal. This would put pressure on a small launcher's business case, especially if multiple small launchers enter the market.

(vii) In 2017 the actual number of nano/microsatellites (1-50 kg) launched was reported to be just over 300.

(For details see section 2.2 of Part 2.)

3. How could access to space be most economically implemented for c.100 kg payloads?

The study has shown that the proposed small satellite launch vehicle is technically feasible and could either be ground or air launched. Overall, the lowest cost option is the ground-launched 3-stage pressure-fed vehicle (option 7) with a total score of 885. There is, however, doubt as to whether this option is technically feasible. Of the ground-launched concepts, the 3-stage pump-fed reference vehicle (option 1) has the second lowest cost overall (1124), and the 2-stage pump-fed variant (option 2) has the lowest development cost (402). The air launched options generally have a lower cost than the corresponding ground launched vehicles, but these parts scores exclude the cost of the carrier aircraft or glider. Once aircraft costs are taken into consideration, assumed at £10 million for the glider development and tow aircraft modification, the total development cost of all of the air-launched concepts would be higher than their ground-launched equivalents.

(For details see section 2.3 of Part 2.)

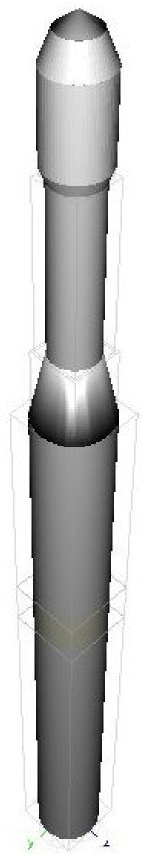

Figure 1.3.1 – a visualization of BIS NLV 3-stage pump-fed reference vehicle (option 1).

Note – The design of this vehicle has not been optimised, it is basically the "top-down" outcome of the mathematical modelling process that has taken place to produce the most economical access to space.

4. What might a realistic payload and revenue stream look like?

A 100 kg payload option would be optimum, in particular the flexible mixed payload configuration based on a flat mounting plate design that could accommodate various arrangements of CubeSats and microsats, as shown in Figures 2.4.1 and 2.4.2.

To optimise the useful payload and revenue a flexible mixed payload configuration based on a flat mounting plate design that could accommodate various arrangements of CubeSats and microsats is the most efficient because it avoids a carrier for the "primary" microsats.

A 100 kg net payload may seem modest, but even six launches a year might require 60 small satellite customers, a significant percentage of the potential global market, and the logistics of even that quantity could be difficult to manage.

(For details see section 2.4 of Part 2.)

5. How do the economics come together and could a business case be closed?

An economic analysis which looked at the distribution of returns under simulated demand scenarios, suggests that both the ground and air launch reference vehicles could be viable in the sense that the project has the potential to provide sufficient returns for its investors, over a 10 year horizon at payload cost of £40(c.$57)k/kg, that market analysis suggests would be acceptable to customers. Because of its lower overall cost however, the ground launch option appears to be the less risky, although this is dependent on the availability of a suitable vertical launch space port and sufficient launch windows. From an operational perspective, air launch may prove to be less risky due to greater flexibility in terms of spaceport location and weather.

	Ground launch (initial investment £30m)			Air launch (initial investment £40m)		
Growth in demand	**high**	**intermediate**	**low**	**high**	**intermediate**	**low**
Fee = £40(c.$57)k/kg	Very robust (avg.5.0 launches p.a.)	Very robust (avg.5.0 launches p.a.)	Robust (avg.5.0 launches p.a.)	Robust (avg.5.3 launches p.a.)	Weak? (avg.5.3 launches p.a.)	Weak (avg.5.3 launches p.a.)
Fee = £30(c.$43)k/kg	Robust (avg.5.9 launches p.a.)	Weak? (avg.5.9 launches p.a.)	Weak (avg.5.9 launches p.a.)	Robust (avg.7.0 launches p.a.)	Not viable	Not viable

Table 1.3.1 Tabulated depiction of the business case conclusion

(For details see section 2.5 of Part 2.)

6. Could access to space from the UK be investor funded?

The evidence of investments in other small launcher projects is that launch vehicles are seen as an interesting opportunity for investors, particularly those who are active investors in “big data” enterprises. The UK is blessed with a combination of an enthusiastic angel and crowdfunding investor base supported by generous tax breaks for start-up investors. Furthermore a project to build a UK launch vehicle allied with the development of UK space ports is likely to have a strong public profile that will help entice investors and may even encourage some form of assistance from the government. In principle there is a substantial investor base that could prove interested in a project such as the BISNLV and which suggests that access to space from the UK could be investor funded.

(For details see section 2.6 of Part 2.)

1.3.1 Risks and assumptions

The risks and assumptions on which the key findings are based are explained in Section 2 of this report. In particular, the market growth scenario risks are explained in sub-section 2.2.4, the development and production cost assumptions in the final two paragraphs of sub-section 2.3.3, and the economics and business case aspects of the fee per kg to orbit in sub-section 2.5.6.

References (Sections 1.1 to 1.3 only, websites last accessed March 2018)

[1] For instance the UK Space Agency’s, *Initial Call for grant proposals,* 9 February 2017, and subsequent activity. (See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/597449/Call_for_grant_proposals.pdf.)

[2] Riley, D. *et al* (2017). SCEPTRE Final Report, Deimos Space UK Ltd., Harwell, Oxford, UK, report SCEPTRE-DMU-FR issue 1.1, 17/02/2017.

[3] CST Ltd. (2017), *Importing Small Chinese Launchers for UK Operations*, Commercial Space Technologies Ltd., Hanwell, London. Edition 1, 27/3/17. (No author attributed.)

[4] Cremashi, F., Wiegand, A., Burkhardt, H. (2017), *Cost effective design of a nano-launcher with ASTOS*, proceedings of the 11th IAA Symposium on Small Sats for Earth Observation, Berlin, Germany, 24-28 April 2017.

[5] Brand, R.H. (2016), *The BIS NLV feasibility study – scope & definition*, BIS NLV Feasibility Study document RHB-2016-02, issue 1, 21/05/16.

[6] See Table 2.4.2 for the annual numbers of satellites that even a 100 kg payload would require.

[7] On the basis that to be of value, a business strategy must exclude things.

[8] https://www.bis-space.com/2018/03/01/20283/orbital-access-to-space-from-the-uk.

[9] Phase 2 - for instance see *BIS NLV working day 7 - full report,* issue 2 20/1/2018, page 2.