



Response to the UK Government's Consultation Document to Determine the Location of a Proposed UK Spaceport

Prepared by the

Liverpool (John Lennon) Spaceport Feasibility Working Group

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Liverpool (John Lennon) Spaceport Working Group¹ Members

Alan Cross, Working Group Chair & Spokesperson (Liverpool, UK) is an active member of the 'British Interplanetary Society', as well as the 'Planetary Society' (Pasadena, USA). Alan **founded** the Working Group in early 2014 to explore the concept of expanding Liverpool (John Lennon) Airport into a mixed use air & spaceport.

Chris Atherton, CEO, Route to Space Ltd. (Liverpool, UK) is the founder of Route to Space Ltd., a start-up based in the North West of England which specialises in providing services & hardware for miniature (Nano, Pico & Femto) satellite developers. Since 2012, Route to Space Ltd. has assisted many clients; from Universities, Private Industry & Government departments, in launching miniature satellites & other research devices to the edge of the atmosphere utilising high altitude balloons. Route to Space Ltd. was recently shortlisted for Technology Strategy Board Launchpad II funding to develop a high altitude capsule to aid satellite developers to launch their miniature satellites on high altitude balloons. Chris has a BSc (Hons.) in Computer Network & Security & has previously been working in the IT industry for both start-ups & large international blue chip companies.

Abdul M. Ismail, CEO, Interplanetary Expeditions Ltd. (Liverpool, UK) has almost 20 years of experience in the design of advanced space propulsion concepts employing fluidised metal powder fuel & in parallel, over 12 years of experience brokering space technology to emerging space countries. He holds a HND in Mechanical, Aeronautical & Production Engineering, a BEng (Hons.) in Aerospace Engineering, an MSc in Space Studies & an MSc by Research. He retains professional connections to the Director of Research at the FAA's Office of Commercial Space Transportation, the Executive Director of Spaceport America, the CEO of the X-Prize, the CEO of Virgin Galactic, the Director of Business Development at Space-X as well as high level contacts at the world's space agencies including NASA, European Space Agency & the Japanese Aerospace Exploration Agency. He

¹ The Liverpool (John Lennon) Spaceport Feasibility Working Group is not in any way associated with the Peel Group who own Liverpool John Lennon Airport



is a Fellow of the British Interplanetary Society, an Associate Fellow of the American Institute of Aeronautics & Astronautics & currently serves on the Board of Trustees of the International Space University.

William Chambers, Director, EnviroSolution Ltd. (Liverpool, UK) is a Chartered Environmental Health Practitioner, with 16 years of experience in both the public & private sector. EnviroSolution Ltd. is a multi-disciplinary environmental & planning consultancy, providing consultancy work on a nationwide basis.

Steve Alley, Independent Development Adviser (Liverpool, UK) has 40 years of experience of planning & development issues, predominantly in the UK public sector, but latterly with a range of private clients.

Charles Diakou, Managing Director, Crown Travel (Liverpool, UK) has been working in travel for over 20 years from retail to corporate travel. He managed some of the world's largest travel corporate accounts then made the move to purchase his own agency in 2006. With a predominately luxury clientele he moved Crown Travel from being a local travel agent to corporate contracts with clients based in the UK (Liverpool & London), the United States (Los Angeles & Seattle) & South Africa.

James Longworth, Captain, Tally-Ho Aviation Ltd. (Edinburgh, UK) as well as founding 'Vibe Enterprises', a consultancy for large scale entertainment venues & the highly successful 'Leith Investments', which owns a number manufacturing & engineering companies, James has been operating throughout Europe as a commercial airline pilot for the last decade.



Response to Consultation Questions

CAA's High Level Recommendation

Q1. Do you agree with the CAA's high-level recommendation that, if a decision were taken to proceed, sub-orbital operations should preferably commence, either on a permanent or a temporary basis, from one (or more) of the following:

- an existing EASA-certificated aerodrome;
- an existing UK CAA-licensed aerodrome; &/or
- an existing UK military aerodrome, subject to approval from the MOD.

Agreed. Using existing facilities has clear economic benefits over developing a brand new site. With this in mind, it should be noted that the suborbital spacecraft & small satellite launchers that would likely operate from a UK spaceport invariably employ a two-stage system, the 1st being a commercially certified jet propelled 'mothership' & the 2nd stage being the rocket powered spacecraft. The sub-orbital (2nd stage) launch element need not necessarily take place within the aerodromes 'default' or 'traffic zoned' airspace. As the vast majority of the sub-orbital craft have two or more stages, with the 'mothership' (or 1st stage) capable of conforming to standard airworthiness for commercial aircraft, sub-orbital operations & flights of the 2nd stage could take place within restricted air traffic zones away from population centres. Descent & landing could take place from those restricted air zones, transitioning to a dynamically managed airspace to the aerodrome. With regards to the re-entry/approach of space planes, the initial frequency of operations (once every few weeks, eventually, every few days) could allow for most existing categories of airspace to be considered, as they already have existing precedents for high speed, unpowered approaches, in the form of emergency landings for commercial airliners². With some consideration, the legal framework for such landings could form the basis of spaceplane approach profiles. This then enhances the possibility of using the aerodrome for both

² SAFETY REGULATION GROUP, 2005. *Aircraft Emergencies (Considerations for air traffic controllers)*. CAP 745. Civil Aviation Authority.



'spaceport' & increased commercial traffic, which we believe will offer a better business case than focusing on a spaceport-only location. As a result of this, the majority of UK airports/airfields/aerodromes could launch these vehicles from their runways under the current regulations which currently cater for medium sized commercial jets.

Q2. Do you agree that in order to make maximum use of existing infrastructure, the location should preferably still be active but at a low level of aircraft movements & should have existing & appropriate ground infrastructure/facilities & service provision?

Agreed. Aerodromes with low-level traffic already possess the necessary infrastructure as well as experienced air traffic controllers. This would save on initial development & training costs. However aerodromes which have available adjacent land, not considered part of the aerodrome estate, which is able to be developed, as well as access to local or regional educational & aircraft manufacturing establishments (elaborated in the answer to Question 11) should also be considered.

Q3. Do you agree that greenfield sites should not be considered?

Agreed. There is a differentiation needed in that greenfield is land that is previously undeveloped, whereas in greenbelt, development is restricted by National Policy. A new airport built on a greenfield site would not be viable in the short term due to cost & time considerations factoring in the requirements for planning permission, the expense associated with a new build infrastructure, construction & developing transport links, marketing & other associated requirements necessary for a new location. These concerns, along with the limited number of flights envisaged, would not make financial sense. However expansion of an existing site will allow for increased commercial traffic & the associated benefits. If sites have suitable land adjacent, even if greenfield or greenbelt, they should be considered as long as planning concerns, including environmental & ecological factors, can be resolved & stakeholders are favourable. With particular respect to greenbelt



land, the Government's National Planning Policy Framework would require a 'very special circumstances' case to be made. These are complex arguments to muster, but the benefits of a spaceport scheme for the city & region make a compelling case & a potential successful submission possible. It could nonetheless be locally controversial. Given the economics & prioritisation (i.e. more logical uses), no new build sites are envisaged as providing a suitable location & hence should not be considered further. However land available for expansion adjacent to a current airfield including greenfield & greenbelt areas certainly should be considered.



CAA's Criteria

Q4. Do you agree with CAA's analysis identifying the criteria to be considered in identifying a permanent location for a UK spaceport? If not, please explain why.

In part disagree. While the criteria presented does address some of the fundamental considerations which are required for selecting the location of a spaceport, the Working Group believes that there is additional criteria which has not been included. It is also the view of the Working Group that the ways in which some of the criteria have been calculated are flawed.

Dealing first with the additional criteria; the Working Group believes that the report does not account for emergency landing facilities 'down range' from the sub-orbital launch area. Criteria weighting would be dependent on the quality, quantity & location of the emergency landing sites. The Working Group would suggest that the selected location have a minimum of three emergency landing sites, positioned nearby an open body of water from which sub-orbital flights are deemed to take place.

In terms of the other criteria; although the report accounts for population density, the way in which the density figures has been derived is believed to be flawed. This is because the figures do not appear to account for the siting of the spaceport facilities such as propellant (i.e. fuel plus oxidiser) storage relative to the areas of population density. For example, Liverpool John Lennon Airport (LPL) was suggested to have a population of ~20,000 nearby, however within a 1km radius of the proposed area the spaceport facilities would be based, there is currently a population of less than 100 people (not including public within the airport site itself). The report also does not take into account population densities along the proposed flight routes.

While the report accounts for the runway length to be 3,000m, the Working Group believes that this is the very minimum length required to allow for safe rejected take-offs as well as limiting the size of the 1st stage 'mothership' craft able to operate from a UK spaceport. It is suggested that the proposed site have the capacity to have its runway extended beyond the 3,000m quoted at some point in future. This is so as to avoid limiting the number & variety



of sub-orbital flight companies operating from the UK & thus reducing the risk of obsolescence.

The Working Group also believes that the suggestion of airspace complexity being a considered factor is noble; however as was pointed out in the report, UK airspace is already highly complex & congested. Using dynamically managed airspace as a way to manage the mixture of sub-orbital operations with existing traffic patterns would allow for larger areas of flight operations to be considered.

There is agreement within the Working Group that local meteorological conditions should be conducive to spaceflight operations at an airfield, however once above the weather this becomes less of a factor.

Q5. Do you think there are any other criteria that should also be taken into consideration? If so, please explain why.

Yes. Performing sun-synchronous launch operations is not considered to be economically adequate to sustain the viability of the spaceport, given worldwide competition; even though projected growth for nano & micro satellite development & launch is positive³. Extending the runway of an existing low density aerodrome regionally located near a centre, or centres, of high population density with associated high quality infrastructure would allow for increased commercial traffic to complement the spaceport during the initial periods of low sub-orbital activity or periods of inactivity; particularly for night-time flights when larger regional aerodromes are closed. Therefore the proposed location should have, as a high-weighted criterion, existing yet low-level commercial traffic which can be increased to enhance economic sustainability. It is likely that, in the coming decades, the economic viability of such a facility will be dependent on it being well connected to existing transport infrastructure. This is best measured by its proximity to a major population centre. As stated earlier, clarification is needed as to how 'population density' was measured & categorised by the CAA for their report.

³ BUCHEN, E. & DEPASQUALE, E., 2014. *2014 Nano / Microsatellite Market Assessment*. SpaceWorks Enterprises, Inc. (SEI).



Additional criterion should include a delivery partner or companies with proven track records of medium term goal identification & completion as it is essential that the finances & work to achieve this objective is available & strategically considered.

Q6. Do you agree that these are relevant criteria? What weight should be attached to them?

Table 1: Weighting Factors

Meaning	Assigned weight
Very high importance	5
High importance	4
Medium importance	3
Low importance	2
Very low importance	1
Not important	0

- **Essential operating criteria (3 out of 5):** Runway lengths should be capable of extension past 3,000m but most proposed locations can be extended. While segregated special use airspace is a must, the initial take-off & return glide could be standard airspace since only the 2nd stage would be considered experimental. Commencement of operation is time critical given that the projected start date is 2018 & thus the proposed sites with areas able to be easily & quickly expanded for minimal cost would be looked upon more favourably.
- **Safety factors (5 out of 5):** Away from densely populated areas (yes, but a number of the CAA recommended sites have populations adjacent to the aerodromes); safe storage of hazardous materials (agreed). Weighting is given the highest for obvious reasons.



- **Emergency Landing Sites (5 out of 5):** The larger the number of possible landing sites, the better but it is essential that the larger number of landing sites are located to the North, South, East & West of the ascent/descent flight profile; not just congregated in one area.

- **Meteorological conditions (4 out of 5):** Agreed but at the same time, 6 out of 8 locations are in Scotland where the weather is perhaps the most severe in terms of rainfall & crosswind. Weighting is important but a number of sub-criteria must be introduced outlining the average annual wind speed, average annual cloud cover, average rainfall & average flooding.

- **Environmental concerns (4 out of 5):** The addition of spaceplanes to an aerodrome with existing low-level commercial aircraft tends not to carry any additional nuisance concerns for the local population as they are accustomed to equivalent noise levels & other associated disruption. A weighting of 4 out of 5 identifies the concern over the environmental suitability, however all sites will be assessed under strict legislation & as such all site options will be given the same consideration. Any building or expansion of an airport will have environmental concerns however in the case of LPL, extension of the runway into the river would increase the wetland habitat for fauna in the medium to long term. Although the ecological & hydrological issues of altering the Mersey flow in its tidal reaches will require very careful consideration & mitigation. Additionally storage of propellant for space planes may affect the HSE enforced COMAH zoning around any airfield & this may impinge upon the suitability of some sites.

A runway extension to accommodate spaceport will allow heavier, larger commercial planes to use LPL too. This will benefit economically the city region, but may deleteriously affect local residents.

- **Economic issues (5 out of 5):** It is the opinion of the Working Group that the level of initial income from spaceflight alone will not be sufficient to maintain the aerodrome economically for a number of years after operations begin, before flights reach a level that is economically sustainable. On the other hand, income generated from commercial passengers arriving at LPL will contribute significantly towards the city & the region; which could assist in becoming



a major player & market leader in worldwide affairs. The economic benefits to the city region from heavy investment in infrastructure & technology are likely to be very large indeed. In time, spaceport-related expenditures may allow Liverpool to regain the prosperity it possessed as the UK's premier Atlantic sea-port. The suburbs of West London around Heathrow offer a potential parallel.

Ultimately, an economic cost-benefit study is required to examine the case for this proposal in this & other location.

Additional weighting factors

- **Advancement of science & innovation (5 out of 5):** Local & regional expertise should be considered as one of the principal motivating factors. While the CAA document acknowledges that the initial technology to be used at a UK spaceport will be from the US, investing in a UK spaceport should urge British companies & academic institutions to aspire to develop their own advanced concepts which would eventually compete with US technologies.
- **Growth of the space or aerospace sector including stimulating jobs in the wider supply chain or supporting existing space sector clusters (4 out of 5):** The location of existing aerospace companies & mandatory suppliers, e.g. chemicals required for propellant manufacture, would be considered very beneficial otherwise an entire localised infrastructure would have to be developed & qualified employees relocated to or near the location of the spaceport.
- **Synergy or support to existing economic usage of the spaceport location (5 out of 5):** This is absolutely essential. Most runways in the UK would have to be both lengthened & widened to accommodate the 1st stage of these two-stage-to-orbit spacecraft which will then afford a possibility of landing larger commercial aircraft such as Boeing (747, 767, 777) & Airbus (A330, A340 & A380) thus increasing commercial traffic to & from this destination. That is, if it is already an existing international destination which major carriers can justify flying to/from.



The location of the spaceport is paramount in considering the future development of the space industry. The location should be easily accessible from all areas of the UK as it is likely to develop into the focus for point-to-point travel between continents; after the initial spaceflights experience industry has been superseded. This necessitates a location with good transport links. As the main reason for point to point is reducing travelling time, the time taken to reach the spaceport will have to be considered.

- **Promotion of high level skills (4 out of 5):** Innovation is already a key tenet of the government's objective. While it may incentivise individuals to pursue high level skills there is already a surplus of engineering graduates leaving British academic institutions, annually.
- **Spin-off benefits such as tourism or other jobs related to spaceplane operations (3 out of 5):** Enhancing tourism to the spaceport will only be significant if there is something else to see in the region surrounding the spaceport & in most cases, large cities would afford an opportunity for increasing revenue from visitors & thus would have an advantage over more secluded areas. In summary, visitors from across the globe will bring enormous economic growth, employment & make the region more culturally aware.
- **Deliverability (5 out of 5):** This criterion is down primarily to a number of factors including the current owner (& their previous history of delivering projects) of the existing airport, the building around an already established aerodrome with low-commercial-traffic & proximity to road/rail infrastructure. A spaceport will possess a higher chance of deliverability if the aforementioned is already in place.

Q7. If more than one location closely met the essential operating criteria, safety, meteorological, environmental & economic criteria, do you agree that we should also consider factors around the contribution to local & national growth? If so, what weight should be given to these factors?

Locations of aerospace corporations surrounding the proposed spaceport could certainly assist with vital engineering know-how & will most likely spawn growth in the high-tech



aerospace sector both regionally & nationally. It would certainly help to have academic institutions offering aerospace engineering programs where spaceplane companies can benefit from interns, qualified graduates & technician engineers. Employment opportunities in the more deprived areas of the country would be welcomed.

In addition to aerospace corporations, it is likely that other industrial skills, such as heavy manufacturing, chemical processing/handling & skills connected with complex logistics will be essential to the operation of a spaceport. As the markets for private spaceflight grow, followed by the inevitable introduction of point-to-point suborbital travel, the hospitality sector will become an important factor in the commercial viability of the facility.

Each element, e.g. i) existing aerospace companies, ii) heavy manufacturing/chemical processing/handling, iii) academic institutions, iv) employment opportunities & v) hospitality should all be sub-categories & independently weighted.



A Coastal Location?

Q8. Do you agree with the CAA's analysis & strong recommendation that until there is a better understanding of sub-orbital spaceplane safety performance, spaceplane operations should only take place in areas of low population density & the resulting view that only a coastal location is suitable to protect the uninvolved general public?

In part disagree. Immediate access to a large expanse of open water is necessary for obvious safety reasons. Single stage to orbit craft would not be based in the UK as it requires an equatorial launch to reach orbit due to propellant requirements. The most common use of a UK spaceport would be for sub-orbital & high altitude, intercontinental travel. The 2nd stage sub-orbital element of a launch should take place away from populated areas; however the 1st stage can reach the required flight hours to achieve airworthiness certification, allowing it to operate within normal air traffic. The recovery/landing phase of the flight would occur after the experimental aspect of the flight had been fulfilled. In combination with a coastal aerodrome & a dynamically managed air corridor would allow flights to take off & land closer to populated areas than the report suggests.

With regards to population density, this is dependent on how it is measured. The UK spaceport is highly unlikely to be used a test facility for new spacecraft or its propulsion systems. Rather it will be a commercial facility, operating medium sized vehicles that have been developed, fully tested & certified elsewhere & whose experimental rocket powered mode will not be engaged until well away from any population centres. This drastically reduces the need for large exclusion zones. In fact, it is unlikely that any such zone over a kilometre in radius will be required.

Storage of propellant will need to be considered with discussion with the Health & Safety Executive (HSE) over their requirements for COMAH (control of major accident hazard) zoning, i.e. in the event of an incident what areas will be affected & how that will affect the suitability of locations, availability & transport of the propellant to the site.

In addition to a coastal location, enhancing safety can come in the form of as many emergency landing sites as possible in case the upper atmospheric wind shears blow the craft off-course; remembering that during descent, the craft will not be powered & will glide.



CAA's Shortlist of Potentially Feasible Locations

Q9. What are your views on the CAA's shortlist of eight potential sites?

Annex A (Table 2 to Table 9) outline the pros & cons of the CAA's eight potential sites, see pp20 – 21. Every one of the shortlisted sites do not meet the standards required for sub-orbital operation when additional factors such as runway length, down range emergency landing sites, closer proximity to regional population densities are included.

While there are certainly benefits to the CAA sites, the cons outweigh the pros & all options were eliminated.

Additional information can be found in Annex C (Trade-Off Analysis) which includes a weighted decision matrix on the CAA's proposed sites & LPL Spaceport.

Q10. Are there any locations on the CAA's shortlist which you consider should be disregarded? If yes, please give your reasoning.

Any CAA shortlist aerodromes with less than three emergency landing sites surrounding the ascent or descent glide within restricted air zones should be automatically eliminated from further consideration. That means the following should not be considered further;

- Campbeltown airport
- Kinloss barracks
- RAF Leuchars
- RAF Lossiemouth
- Stornoway airport
- Newquay Cornwall airport



Glasgow Prestwick airport is considered to be too busy for a low-traffic airport & the Firth of Clyde is too narrow with insufficient stretch of water between a sub-orbital hop when launched in a South-Westerly direction.

This left Llanbedr as the only option worthwhile considering but even then, Llanbedr airfield is far too remote to be considered viable. The infrastructure (transport, maintenance etc.) that would be needed to be built would likely dwarf the cost of readying the runway for spaceplane operations. Also, it is highly unlikely that a dedicated spaceport facility will be economically viable, when compared to a joint facility offering conventional commercial flight & suborbital launches.

Q11. Are there any additional locations that you consider should be on the CAA's short list? If yes, please explain why.

The Liverpool Spaceport Working Group advocates Liverpool John Lennon Airport (LPL) as the preferred option for the following reasons.

The pros & cons are listed in Table 10, p22, but to summarise, its existing aerodrome already caters for average commercial traffic, primarily European flights (albeit a 757-200 has operated from LPL to New York in the past). By using dynamically managed flight areas, traffic can be restricted around the sub-orbital flight on its recovery sequence. The general public would also be avoided as LPL airport operates on a peninsula within the River Mersey meaning the majority of the population is contained to one side, with development space adjacent to the unpopulated, river side of the airport which is currently farmland. Although the population of Liverpool & Manchester are large, the populations are concentrated in two separate areas, with a relatively sparse population density between both cities. This is also the area that existing air traffic utilising LPL operate over. While within the Liverpool region, the river Mersey is 6km wide at its widest with the Irish Sea directly to its North West.

Manchester airport is nearing capacity & extending LPL will allow larger aircraft to utilise the airport; not to compete with Manchester but to complement the North West – especially during night-time arrivals & departures (which already take place with Easyjet & Ryanair); when Manchester airport is closed. This enhances synergy & the economics of the spaceport by generating revenue from additional commercial traffic.



Liverpool is geographically central to the rest of the UK & is only 2 hours 7 minutes by train to Central London. The spaceplanes would take-off from LPL & head South West & then launch in a Northerly direction which then affords five possible emergency landing sites; Dublin airport, RAF Valley/Mona, George Best Belfast airport, Isle of Man airport & Blackpool airport.

Liverpool has surrounding high-technology, petrochemical & aerospace industries with Airbus located in Broughton, North Wales on the Chester/Cheshire border as well as at Poynton, East Cheshire; BAE in Wharton near Preston & STFC at Daresbury in addition to ESSAR Stanlow & numerous academic institutions offering aerospace engineering degrees; located in Liverpool, Chester & Manchester.

Annex A: Pros & Cons of CAA Sites

Table 2: Pros & Cons of Campbeltown Airport

	Site	Region	Pros	Cons
1.	Campbeltown airport	Scotland	→ Isolated location	→ Hours from any major city → Only 1 possible emergency landing site (Islay airport) → Very little public transport → Weather poor, year round

Table 3: Pros & Cons of Glasgow Prestwick Airport

	Site	Region	Pros	Cons
2.	Glasgow Prestwick airport	Scotland	→ Commercial airport → Very good connectivity with international air & local/national public transport → University of Glasgow (School of Engineering) and University of Strathclyde (Faculty of Engineering) → Clydespace, a cubesat developer is based in Glasgow → 3 possible emergency landing sites (RAF West Freugh, Campbeltown airport & George Best Belfast City airport)	→ Firth of Clyde too narrow to launch to sub-orbit; Isle of Arran on one side; mainland on the other with N. Ireland to the South West → Limited restricted airspace nearby → 35 miles from Glasgow → Almost 15,000 people live on the airport's doorstep → Weather poor, year round

Table 4: Pros & Cons of Kinloss Barracks

	Site	Region	Pros	Cons
3.	Kinloss barracks	Scotland	→ Clear launch path towards the North Sea	→ Distant from any major city → Only 2 possible emergency landing sites (Dornoch airport & RAF Lossiemouth) → Population of ~1,900 on the doorstep of the airport → Weather poor, year round

Table 5: Pros & Cons of RAF Leuchars

	Site	Region	Pros	Cons
4.	RAF Leuchars	Scotland	→ Close to Dundee & a couple of hour's drive from Edinburgh → Clear launch path towards the North Sea	→ Only 1 possible emergency landing site (Dundee airport) → Population of ~3,000 adjacent to the airbase → Weather poor, year round



Table 6: Pros & Cons of RAF Lossiemouth

	Site	Region	Pros	Cons
5.	RAF Lossiemouth	Scotland	→ Clear launch path towards the North Sea	→ Only 2 possible emergency landing sites (Dornoch airport & RAF Kinloss) → Take-off or landing at one direction will be over adjacent town → Population of ~6,800 located next to the airbase

Table 7: Pros & Cons of Stornoway Airport

	Site	Region	Pros	Cons
6.	Stornoway airport	Scotland	→ Isolated location	→ Zero possible emergency landing sites North of Scotland → Literally hours away from any major city → Weather poor, year round

Table 8: Pros & Cons of Llanbedr Airport

	Site	Region	Pros	Cons
7.	Llanbedr airport	Wales	→ Clear launch path, only if flying South & then bank West over the Irish sea → 5 emergency landing sites (RAF Valley/RAF Mona, Blackpool airport, Isle of Man airport, George Best Belfast City airport & Dublin airport) over the Irish sea	→ "Spaceport only" location → Poor economic justification → Very poor connection to rest of the country → Above average rainfall. Site also sits within a flood zone (flood zone 3)⁴. → The spaceplane would have to fly over the peninsula if flying North → Only 1 possible emergency landing site to the South (Aberporth airport)

Table 9: Pros & Cons of Newquay Airport

	Site	Region	Pros	Cons
8.	Newquay Cornwall airport	England	→ Excellent launch sites between the Irish & Celtic Seas	→ Zero possible emergency landing sites West of England → Slightly in-land with built up areas under flight path → Not very well connected to public transport → Hours away from any major city

⁴ THE ENVIRONMENT AGENCY, 14th August, 2014-last update, Flood Maps for Planning (Rivers & Sea): <http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683.0&y=355134.0&scale=1&layerGroups=default&ep=map&textonly=off&lang=e&topic=floodmap#x=257898&y=326335&lg=1,&scale=8> [5th October, 2014].



Annex B: Pros & Cons of LPL Spaceport

Table 10: Pros & Cons of Liverpool John Lennon Airport

	Site	Region	Pros	Cons
9.	Liverpool John Lennon Airport	England	<ul style="list-style-type: none"> → Recognised by The Rough Guide as being the world's third most recommended city to visit in the world → Good connections with international (particularly European) flights → Very good connectivity with public transport → Only 2 hours 7 minutes to London by train → ~4 hours to Glasgow by car & train → ~1 hour 30 minutes to Birmingham, by car & train → 45 minutes by car to Manchester → Meteorologically best site → Geographically central to the UK → 5 emergency landing sites (RAF Valley/RAF Mona, Blackpool airport, Isle of Man airport, George Best Belfast City airport & Dublin airport) over the Irish sea → Airport will not rely 100% on spaceflight recommends commercial traffic to support it (see Section 2.15 of CAA document) → Surrounding aerospace industries (Airbus/Broughton & Poynton, BAE/Wharton & STFC/Daresbury) → Academic institutions <ul style="list-style-type: none"> ○ University of Liverpool (Aerospace Engineering) ○ Liverpool JMU (Mechanical Engineering) ○ University of Chester (Faculty of Science & Engineering) ○ University of Manchester (School of Mechanical, Aerospace & Civil Engineering) 	<ul style="list-style-type: none"> → Speke has a population of ~20,500 but is not directly adjacent to the airport → Has to be extended from both sides to equal 3,000m → Take-off & landings would take place over Runcorn & Hale to the East & the Wirral peninsula to the west → Hydrological & environmental effects of extending runway into river would need to be carefully explored



Annex C: Trade-Off Analysis



Table 11: Weighted Decision Matrix

		Alternatives																	
		Campbeltown		Glasgow		Kinloss		RAF Leuchars		RAF Lossiemouth		Stornoway		Llanbedr		Newquay		Liverpool	
Category Criteria	Criterion Weight	Criterion Score	Criterion Weighted	Criterion Score	Criterion Weighted	Criterion Score	Criterion Weighted	Criterion Score	Criterion Weighted	Criterion Score	Criterion Weighted	Criterion Score	Criterion Weighted	Criterion Score	Criterion Weighted	Criterion Score	Criterion Weighted	Criterion Score	Criterion Weighted
Essential operating criteria	3	5	15	1	3	3	9	4	12	4	12	1	3	3	9	4	12	3	9
Safety factor	5	4	20	2	10	3	15	5	25	3	15	5	25	5	25	4	20	2	10
Emergency landing sites	5	1	5	3	15	2	10	1	5	2	10	0	0	5	25	0	0	5	25
Meteorological conditions	4	3	12	3	12	3	12	3	12	3	12	2	8	4	16	5	20	4	16
Environmental concerns	4	4	16	2	8	3	12	5	20	3	12	5	20	5	20	4	16	3	12
Economic issues	5	0	0	4	20	2	10	4	20	2	10	0	0	0	0	2	10	5	25
Advancement of science & innovation	5	1	5	4	20	2	10	5	25	2	10	1	5	0	0	1	5	5	25
Stimulation of jobs	4	1	4	5	20	2	8	3	12	2	8	1	4	1	4	1	4	5	20
Existing economic usage	5	0	0	4	20	1	5	2	10	1	5	0	0	0	0	2	10	4	20
Promotion of high level skills	4	5	20	5	20	5	20	5	20	5	20	5	20	5	20	5	20	5	20
Spin-off / tourism	2	2	4	4	8	2	4	3	6	2	4	1	2	1	2	3	6	5	10
Deliverability	5	1	5	5	25	2	10	2	10	2	10	1	5	1	5	3	15	5	25
Sub-total	51	27	106	42	181	30	125	42	177	31	128	22	92	30	126	34	138	51	217
Total score			2.08		3.55		2.45		3.47		2.51		1.80		2.47		2.71		4.25



Justification for Criteria Scoring

Table 12: Scoring Factor

Meaning	Scores
Fully satisfies	5
Substantially satisfies	4
Nearly satisfies	3
Partially satisfies	2
Nominally satisfies	1
Does not satisfy	0

- **Essential operating criteria:** Glasgow Prestwick Airport – although 2,665m in length – cannot be extended easily because it has two A-roads & rail on either side of the main runway & thus received the lowest score (but one of the A-roads could be made into a tunnel – at expense). Stornoway received the next lowest score. Not only is it less than 2,500m, extending it would result in cutting off the main road or extending into the sea. LPL, Llanbedr & RAF Kinloss received the next lowest scoring because they are less than 2,500m but can be extended. Newquay, RAF Lossiemouth, RAF Leuchars received high ratings because they are currently between 2,500m & 3,000m & can be extended. Campbeltown received the highest rating since it already qualifies for the CAA's +3,000m requirement.
- **Safety factors:** Proximity to population density is not the only criteria but the location of the flight-path & whether or not the uninvolved public are located on either side or under a flight-path. Glasgow & LPL received the lowest score. While there is a high population density close to LPL, aircraft always take-off diagonally & away from this area; but aircraft have to descend over a large number of villages & towns. Glasgow, on the other hand has a large population adjacent to the aerodrome. Kinloss, RAF Lossiemouth. Campbeltown & Newquay have slightly lower population densities within proximity of the aerodromes whereas RAF Leuchars, Stornoway & Llanbedr scored the highest, for obvious reasons.



- **Emergency landing sites:** This criterion was surprisingly omitted from the CAA's criteria list but it is important that the quantity of the emergency landing sites are not located in one area but around the sub-orbital ascent/descent flight profile of the 2nd stage. Stornoway & Newquay do not even qualify as they have zero emergency landing sites. Campbeltown & RAF Leuchars only have one possible emergency landing site. Kinloss & RAF Lossiemouth have two emergency landing sites but they are both on one side. Glasgow has three possible emergency landing sites & the two which received the highest score, Llanbedr & LPL have five emergency landing sites.
- **Meteorological conditions:** The weather in the Scotland tends to be more overcast & experience stronger winds than the rest of the UK & thus received mid-scores. Llanbedr receives slightly less severe weather than Scotland & thus scored slightly higher. According to the met office data dated 1981 – 2010, the Merseyside area has much less rain, cloud, ground frost, lower average wind speed than any of the other suggested sites⁵. Liverpool with the South East of England scored the highest in this case.
- **Environmental concerns:** Extension of runways poses environmental & planning issues for all sites in the short term however locations in less inhabited areas will ensure fewer concerns regarding noise nuisance, although conversely background noise levels will be lower & so the comparative noise levels will be higher in sparsely populated areas. In the case of LPL, extension of the runway into the river would increase the wetland habitat for fauna in the medium to long term, offsetting concerns over the loss of RAMSAR wetland areas utilised for an extension.
- **Economic issues:** Campbeltown, Stornoway & Llanbedr are not well connected to the rest of the UK & will require major investment plus to focus on a 'spaceport only' location would render the site economically unsustainable. Therefore these three were considered not to satisfy this criterion. Newquay, Kinloss & RAF Lossiemouth are relatively distant from a major city whereas RAF Leuchars is a few hours' drive from Edinburgh. Glasgow & LPL are very well connected & the latter in particular is a low-intensity aerodrome but have the

⁵THE MET OFFICE, UK Mapped Climate Averages. <http://www.metoffice.gov.uk/climate/uk/averages/ukmapavge.html> [September 30th, 2014].



potential to cater for more commercial flights with runway extensions thus affording the opportunity to accept larger carriers. However, Glasgow Prestwick is not as close geographically as LPL is from the population centre, so the economic advantage of the former would not be as great as it would be for Liverpool & the Northwest given the population density.

- **Advancement of science & innovation:** The closest engineering college to Llanbedr is at Bangor & Rhos-on-Sea & although the University of Aberystwyth is relatively close, it does not have an engineering department, thus was given a zero score. Campbeltown (Argyle College), Stornoway (Lews Castle College) & Newquay (Cornwall College) offer technician engineering diplomas & albeit not higher education, they were granted very low scores. Kinloss & RAF Lossiemouth partially satisfies because there are no academic institutions at these locations but the University of the Highlands & Islands is nearby. Glasgow Prestwick has both University of Glasgow & University of Strathclyde nearby thus was rated very highly. The highest rating goes to RAF Leuchars & LPL. The former has St. Andrews, University of Dundee, University of Edinburgh & Sterling & the latter has University of Liverpool, Liverpool John Moores University, University of Chester & the University of Manchester are within its vicinity.
- **Growth of the space or aerospace sector including stimulating jobs in the wider supply chain or supporting existing space sector clusters:** Campbeltown, Stornoway, Llanbedr & Newquay were all given a very low rating. It is more than likely that some aviation companies will be located at the airport which is why a score of zero was not given. Kinloss & RAF Lossiemouth & were given a relatively low rating. Although there is no aerospace industry in these regions, it is possible that skilled aerospace (military) engineering contractors will be located here. In addition to possible military contractors, RAF Leuchars has STAR-Dundee thus was given a slightly higher score. LPL has, within travelling distance, Airbus Defence & Space (at Broughton & Poynton), Thales BAE Systems (Wharton) as well as STFC Daresbury & was given the highest score alongside Glasgow which has a number of advanced engineering companies including Marshall Slingsby Advanced Composites, BAE Systems, Thales Land Joint Systems located in or around the city.



- **Synergy or support to existing economic usage of the spaceport location:** All but one aerodrome will need its runway extended which puts all locations on equal footing. The longer & wider runways will afford an opportunity for larger commercial aircraft such as Boeing (747, 767 & 777) & Airbus (A330, A340 & A380) to land & take-off from these sites. Even if there is existing location transportation & road infrastructure was improved, there is no real commercial requirement for airline operators to fly in & out of locations like Campbeltown, Kinloss, RAF Lossiemouth, Stornoway, Llanbedr & Newquay so it is doubtful major carriers will see the benefit of flying to & from these locations. As a result, they were all awarded zero. Almost 10 million people flew to & from Edinburgh which implies that there is potential for RAF Leuchars to perhaps handle some of that commercial traffic, should an increase be required & thus an average score was awarded. Over 7 million people flew in & out of Glasgow but the problem with this location are that two A-roads & railway are positioned at either end of the runway so it may be difficult to extend the runway. That being said, a tunnel could be built under a possible runway extension to ensure the A-road and rail line is not disconnected. Over 20 million passengers flew in & out of Manchester which is nearing capacity & it is unlikely additional runways can be added. Manchester does not operate at night whereas LPL, which hosted over 4 million passengers, does operate night flights & with a runway extension could introduce night flights for Middle Eastern, Asian & American airlines – not to compete with Manchester but complement air traffic to & from the North West of England. That being said, the runway will have to be lengthened at both ends to cater for the 3000m mark. Since both Glasgow & LPL require careful planning in addition to runway extension, they were awarded high, but not very high, scores.
- **Promotion of high level skills:** This criterion isn't dependent on any location & thus all sites were given the same score.
- **Spin-off benefits such as tourism or other jobs related to spaceplane operations:** Stornoway & Llanbedr are beautiful & serene which may be appealing; but not so much as larger cities which thrive on tourism. Locations with interconnections with other nearby cities will be more appealing to national & international travellers. As a result, the aforementioned were given a relatively low score. Kinloss & RAF Lossiemouth are close to Inverness so was graded slightly higher, as was Newquay which benefits from tourism albeit



primarily during the summer months. RAF Leuchars is located between two major Scottish cities, Edinburgh & Dundee, & both Perth & Sterling are nearby so was given a relatively high score. Glasgow was given the same score, for the very same reasons. LPL was given the highest score because the city centre is less than 10 miles from the airport. Chester & Manchester is within an hour's drive & London is just over two hours by train. The city is effectively central to the United Kingdom. Just as importantly, Liverpool recognised by The Rough Guide as being the world's third most recommended city to visit in the 2014⁶.

- **Deliverability:** Llanbedr, Campbeltown, Stornoway, Kinloss, RAF Lossiemouth & RAF Leuchars are too secluded & will require substantial investment so were given the lowest scores. Newquay operates some commercial flights so has limited infrastructure. Both Glasgow & LPL operate relatively low-intensity commercial aerodromes & have excellent road & rail links to & from its destination so received the highest rating. In addition LPL is owned by Peel Holdings, an independent company with a history of delivering large projects including developments such as the Trafford Centre & MediaCityUK & redevelopments including the Manchester Ship Canal, Liverpool Superport & the Atlantic Gateway. Airports ownership includes; City Airport Manchester; Robin Hood Airport, Doncaster Sheffield & Durham Tees Valley Airport, Darlington. They are also an investor in renewable energy with the UK's largest onshore wind farm Scout Moor Wind Farm; docks; with Manchester Docks, the Port of Liverpool & Clydeport; & Retail Parks; Lowry Outlet Mall, Salford Quays; Gloucester Quays, Gloucester; & including sites in Blackburn & Stockport. They also have stakes in The Pinewood Studios Group – 71.1% (largest shareholder); UK Coal – 28.3% (largest shareholder); Intu Properties plc – 20% (largest shareholder) & Land Securities – 4%.

⁶ THE ROUGH GUIDES, Top Ten Cities. <http://www.roughguides.com/best-places/2014/top-10-cities/> [5th October, 2014]

Annex D: LPL Spaceport Overview

Position

Geographically central to the United Kingdom, LPL is ideally located in an East-West configuration, facing a 5,000m stretch of the Mersey Estuary's tidal mud flats, with limited buildings & population on the adjacent Wirral peninsula under the existing flight paths.

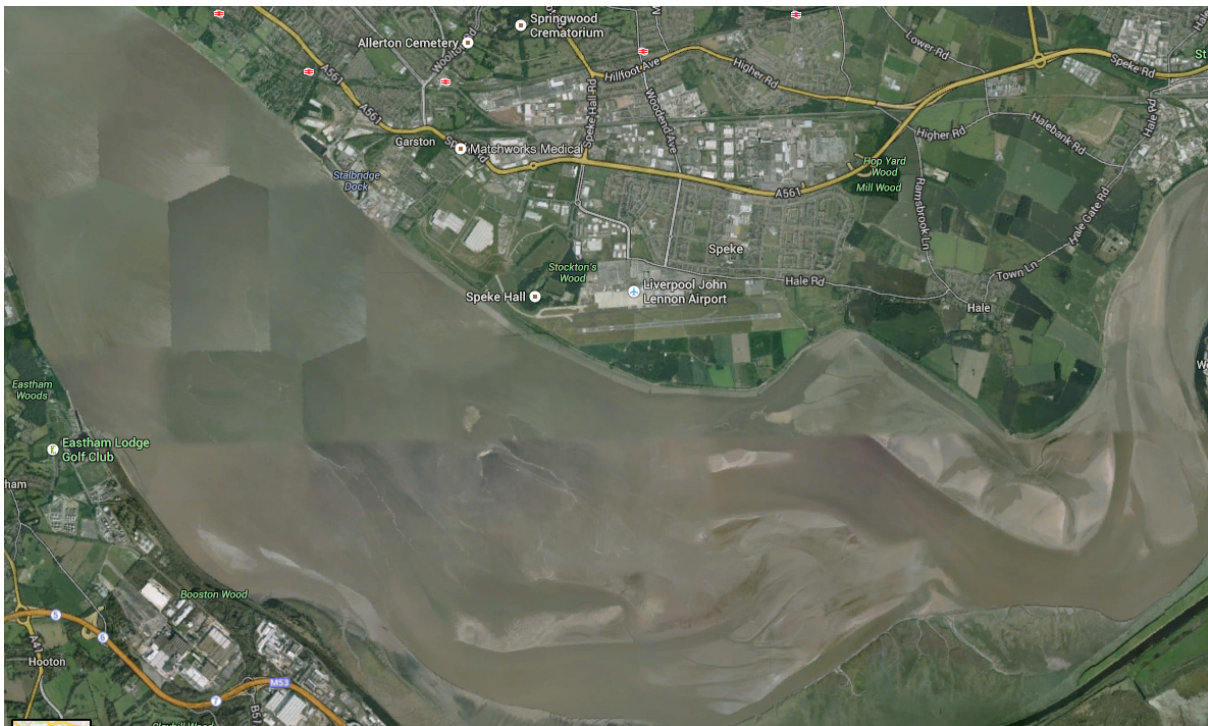


Figure 1: Position of LPL in relation to surrounding population & infrastructure

Concerning the industry & skills base necessary for such a venture, within the Liverpool City Region, there exists heavy industry & technical expertise needed to establish & operate a spaceport - from heavy manufacturing at Cammell Laird, Jaguar Land Rover & Vauxhall, to the chemical handling at Eastham & the handling skills of the 'post-Panamax' docks. This is without considering the entire North West & North of England. Also, the transport infrastructure in the area is well established for use by heavy industry & passenger transport



including rail (both passenger & freight), air (John Lennon, Manchester International & the Airbus site in North Wales), water (the Liverpool Docks, Manchester Ship Canal & Liverpool2) & of course the road infrastructure, all of which allows the rapid transportation of people, parts & payloads of any shape or size to & from the site at Liverpool John Lennon.

Runway

The runway at LPL is 2,285m. In 2007, Peel Holdings, the airports current owners, commissioned a study into runway extension, resulting in a proposed inland extension of 150m coupled with a doubling of its current width, resulting in a 2,435m * 92m runway.

In order to meet our own minimum requirement for spaceport operations of at least 3,000m, an extension of 565m of runway would be required. This could easily be achieved with an extension in the Mersey Estuary, which, if designed conscientiously, could expand & enrich the RAMSAR designated wetlands of the River Mersey.

Expansion of the existing airport

Immediately south of LPL is an area of farm land known as 'Oglet'. Expanding into & dedicating this area to spaceport operations, separate from the airports existing facilities, would dramatically reduce any danger to the uninvolved public (see Figure 2, p32).

Such an expansion would be a similar undertaking to Peel Holding's 'Liverpool2' post-Panamax dock facility, located several miles downriver from LPL, which is estimated to cost £300M.

Airspace, launch & approach

Whilst the airspace of the North West is relatively complex, the CAA has already identified Llanbedr Airfield as a potential Spaceport site due to the controlled airspace around Snowdonia & the Welsh coast. Any air launch vehicle from LPL could directly access this airspace in a matter of minutes, thus negating concerns for the uninvolved public around LPL itself.

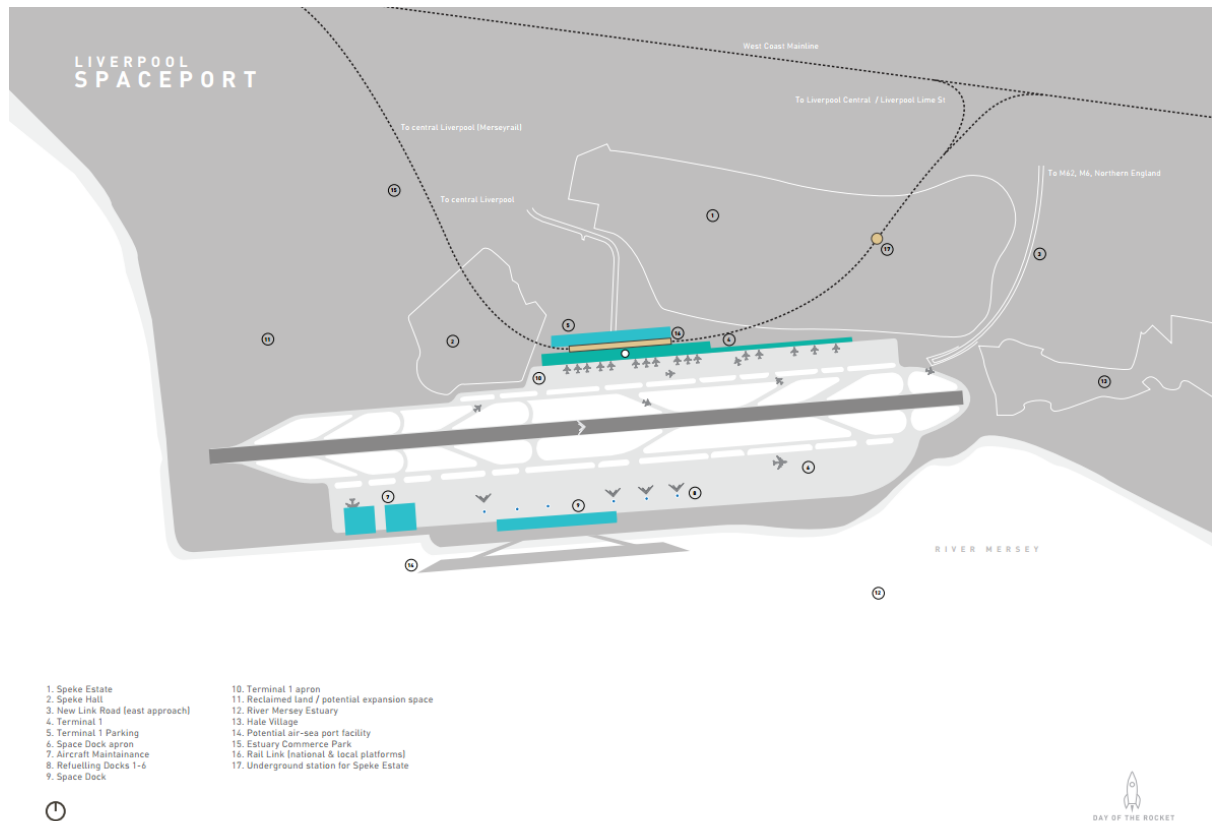


Figure 2: A possible configuration for an expanded LPL, highlighting a runway extension via a peninsula/reclaimed land & spaceport facilities at 'Oglet'

With regards to spaceplane landings at LPL, these aircraft descend at much a steeper rate than regular aircraft & so have a greatly reduced area over which they approach. LPL has the advantage of approach vectors from the west that would see spaceplanes initially descend & decelerate over the Irish Sea & Dee Estuary before gliding, unfuelled, over the sparsely populated centre of the Wirral peninsula before final approach across the Mersey Estuary. Whilst approaches from the East may be rarer, the corridor here could take approaching vehicles over the rural areas South of Manchester & Warrington before following the River Mersey, North of Runcorn & directly into LPL John Lennon. Landing from either direction could easily be performed so as to pass over a minimal amount of population or infrastructure.



Annex E: Contact Information

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