HEALTH & SAFETY LABORATORY

Spaceports: keeping people safe

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CONTENTS

ABOUT THIS DOCUMENT

How would we ensure that people are safe from spacecraft launch and spaceflight operations?

The government is developing the regulatory framework to allow commercial spaceflight operations to launch from the UK. The primary aim of this legislation is to make sure that commercial spaceflight operations do not pose an unacceptable risk of harming people near to where these operations are being carried out.

This document outlines some key existing health and safety legal requirements that may need to be implemented by a spaceport to minimise the risks to populations nearby from the storage and use of hazardous fuels.

This document also outlines a way that the risks to people near the launch and the spacecraft flight path could be assessed to make sure that a spaceport location is acceptable when considering public safety.

This document does not represent formal policy guidance in support of the Space Industry Act 2018. Rather, the information provided is based on studies undertaken to allow the government to understand possible ways to assure public safety.

INTRODUCTION

The introduction of the Space Industry Act 2018[1] by the government is to allow the development of a commercial launch industry from the UK. The UK already has a vibrant and rapidly growing space sector[2]. By developing the framework to allow launches from UK soil, the government is ensuring that the UK is at the forefront of the new commercial 'space age'.

A key aim of the Space Industry Act 2018 is to ensure that operators are safely managing all activities relating to launch operations in the UK in this future space age. The general public should not be exposed to any significant risks to health or life from spaceflight activities beyond that which they would normally be exposed in their daily lives.

The UK Space Agency (UKSA) and the Civil Aviation Authority (CAA) are taking the lead in drafting legislation to enable launches whilst protecting people who may be near potential spaceport locations or near possible spaceflight paths.

The UKSA and the CAA asked the Health and Safety Laboratory (HSL) to help them understand how they could ensure that risks to the public from spaceflight operations could be shown to be minimal.

HSL is the science, consultancy, and laboratory testing service of the Health and Safety Executive (HSE). HSL provides health and safety expert advice to government and industry in both the UK and internationally.

This document outlines some of the key points identified during these studies into assessing the risks to the general public in the area around a spaceport. This document is not formal guidance in support of the Space Industry Act 2018 and does not necessarily reflect UKSA, CAA, or HSE policy.

There are several distinct ways in which launch activities at a spaceport could pose a risk to the public. New regulation will seek to secure public safety and manage these risks.

The most obvious risk to people is from an incident at the launch, or during spacecraft overflight, or during the landing for a reusable spacecraft. This is where the spacecraft, or debris from the spacecraft, could fall onto the ground causing damage, or where debris explodes from a crash causing damage.

Other risks that might be less immediately obvious would be from the ground-based operations at the spaceport, in particular, risks relating to the storage and use of hazardous substances used as fuels in the spacecraft.

Many of the risks for spacecraft launch are well-known and there are decades of international experience with spaceflight activity. However, this is a rapidly developing industry, where there potentially could be new, unexpected hazards from innovation and new technologies. The UKSA and the CAA are working with HSL to establish how to provide assurance that space activities can be carried out safely considering future innovation as well as existing technologies.

[1] http://www.legislation.gov.uk/ukpga/2018/5/contents/enacted/data.htm
[2] https://www.gov.uk/government/publications/launchuk-prospectus

STRUCTURE OF THIS DOCUMENT

The ground-based spaceport activities that pose an off-spaceport risk mainly relate to the use of hazardous chemical substances as fuels. There are existing health and safety legal requirements that apply to the storage and use of substances that pose a flammable, explosive, or toxic hazard. The first part of this document outlines some of the pertinent legal requirements when dealing with hazardous substances and provides links to further information.

The second part of this document outlines methods for assessing the risks to individuals from launch and spaceflight. This allows a check to be made that launch activities could be carried out from a spaceport location without posing an unacceptable risk to people near to the spaceport or near to the spacecraft flight path.

EXISTING HEALTH AND SAFETY REQUIREMENTS

How do we ensure that people are kept safe from spaceport and spaceflight activities?

There are a number of established health and safety legal requirements that may need to be implemented by a spaceport before any operations could launch from the site. This would be dependent on the types of operation or activities being carried out at the spaceport. In particular, there would need to be an understanding of what types of substances were being used for fuel, whether these substances are hazardous, and if so, the quantities of these fuels being used and stored.

Some of the legal requirements that may need to be addressed by a spaceport are outlined below. In some cases, not all of these requirements will apply for a particular spaceport, and in other cases, there may be other legal requirements relating to health and safety that will need to be implemented. These will have to be considered on a case-by-case basis.

As spaceport operations are unlike other hazardous activities undertaken in the UK then care may be needed when applying existing health and safety requirements. Thought may need to be given to the specific combinations of hazards and the types of activity that will happen at a spaceport before implementing existing health and safety requirements.

GENERAL REQUIREMENTS

The Health and Safety at Work etc. Act 1974 (HSWA) is the Act of Parliament covering health and safety from work activities. A key principle of HSWA is that those who create risks are best placed to control those risks.

HSWA, therefore, sets out duties for employers to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all their employees. It is also the duty of employers to ensure, so far as is reasonably practicable, that people who are not employees are not exposed to health or safety risks from the work activities.

A spaceport, or spacecraft operator, will need to look after the health and safety of spaceport staff and spacecraft crews, and will also need to ensure that people near the spaceport or along the flight path are not harmed from the spaceport or spaceflight activities.

The Health and Safety at Work Act 1974 and the Management of Health and Safety at Work Regulations 1999 can be found at:

Health and Safety at Work etc. Act 1974
https://www.legislation.gov.uk/ukpga/1974/37/contents

The Management of Health and Safety at Work Regulations 1999
http://www.legislation.gov.uk/uksi/1999/3242/made

As low as reasonably practicable (ALARP)

The Health and Safety at Work etc. Act 1974 (HSWA) specifies that those that create risks should control those risks ***so far as is reasonably practicable*** (SFAIRP). The use of SFAIRP is to ensure that there can be a degree of common sense applied when ensuring people's health and safety. This is because the only way to have zero risk from an activity is not to do the activity.

HSE interprets that an employer has carried out their duties under HSWA if the employer can demonstrate that risks from their activities have been reduced ***as low as reasonably practicable*** (ALARP). This is described in a guidance document outlining HSE's decision-making process, 'Reducing Risks, Protecting People'.

Figure 1 illustrates a diagram from 'Reducing Risks, Protecting People' that demonstrates how HSE assesses the tolerability of risk (TOR).

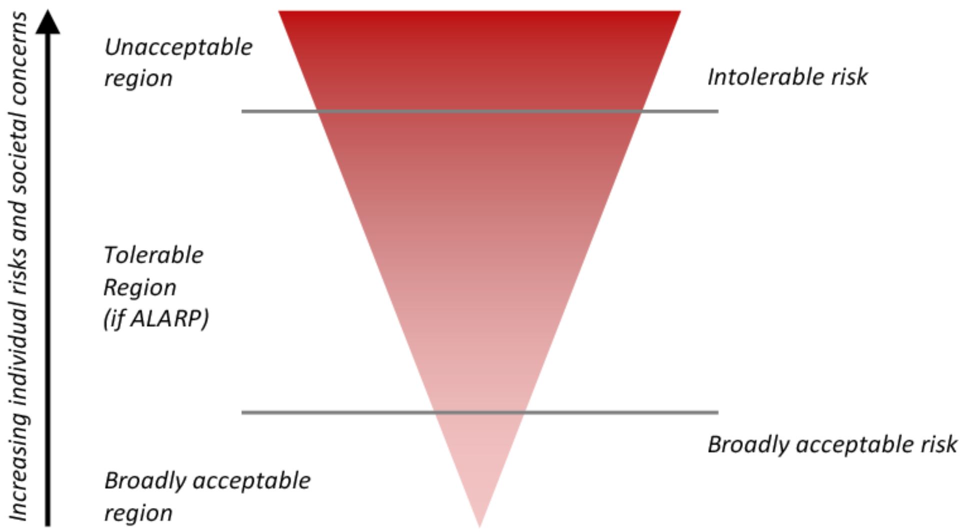

Figure 1 Assessing the tolerability of risk, from 'Reducing Risks, Protecting People'

Moving up the triangle in Figure 1 represents an increase in the risk of fatality to an individual or an increase in the level of societal concern for a risk. The diagram has three distinct zones moving up from the bottom of the triangle to the top:

- The ***Broadly acceptable region:*** The benefits from the activity can be considered to outweigh the risks from the activity. These risks do not generally alter the risks to which we are exposed day-to-day in our normal lives.
- The ***Tolerable region (if ALARP):*** The benefits from the activity are considered to be in balance with the risks through assessing that risks are ALARP. This does not mean that the risk is considered acceptable, but it does mean that we are willing to take the risk to receive the benefit. ALARP suggests that all reasonable measures have been carried out to control the risk by those that have created the risk.
- The ***Unacceptable region:*** The benefits from the activity do not outweigh the risks associated with the activity. There is no justification to continue with such an activity.

Those that create a risk that is *Tolerable (if ALARP)* need to justify that the risks are reduced ALARP. Less justification is required for a risk that is closer to the *Broadly acceptable region* on the triangle in Figure 1 than if a risk were higher on the triangle. If a *Tolerable (if ALARP)* risk is close to the *Unacceptable region* then those that have created the risk are expected to spend more time, effort and money to ensure that the risk is reduced ALARP than for a risk closer to the *Broadly acceptable region*.

Even risks that are in the *Broadly acceptable region* should be reduced ALARP. It is just that, as these risks are considered to be low, there is usually less that can easily be done to further reduce the risks.

Further information on ALARP can be found at:

Reducing Risks, Protecting People
http://www.hse.gov.uk/risk/theory/r2p2.htm

HSE's ALARP suite of guidance web page
http://www.hse.gov.uk/risk/expert.htm

HSE's ALARP "at a glance" web page
http://www.hse.gov.uk/risk/theory/alarpglance.htm

HEALTH AND SAFETY REGULATIONS

Table 1 shows the regulations that are owned and enforced by HSE or local authorities relating to health and safety. Depending on the work activities and operations undertaken, a spaceport or spaceplane operator may need to be compliant with a number of these regulations.

Table 1 Regulations (Statutory Instruments) owned and enforced by HSE/local authorities

Name of Regulation
Generic requirements for good health and safety management
Classification, Labelling and Packaging of Chemicals (Amendments to Secondary Legislation) Regulations 2015
Dangerous Substances (Notification and Marking of Sites) Regulations 1990
Health and Safety (Consultation with Employees) Regulations 1996
Health and Safety (First- Aid) Regulations 1981
Health and Safety (Safety Signs and Signals) Regulations 1996
Health and Safety (Training for Employment) Regulations 1990
Health and Safety Information for Employees Regulations 1989
Management of Health and Safety at Work Regulations 1999
Notification of Cooling Towers and Evaporative Condensers Regulations 1992
Personal Protective Equipment at Work Regulations 1992
Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013
Safety Representatives and Safety Committees Regulations 1977
Workplace (Health, Safety and Welfare) Regulations 1992
Generic application to all work environments
Confined Spaces Regulations 1997
Control of Artificial Optical Radiation at Work Regulations 2010
Control of Electromagnetic Fields at Work Regulations 2016
Control of Noise at Work Regulations 2005
Control of Substances Hazardous to Health Regulations 2002 (as amended)
Control of Vibration at Work Regulations 2005
Dangerous Substances and Explosive Atmospheres Regulations 2002
Electricity at Work Regulations 1989
Health and Safety (Display Screen Equipment) Regulations 1992
Lifting Operations and Lifting Equipment Regulations 1998
Manual Handling Operations Regulations 1992
Pressure Systems Safety Regulations 2000
Provision and Use of Work Equipment Regulations 1998
Work at Height Regulations 2005
Work in Compressed Air Regulations 1996
Application to specific processes or complex activities
Acetylene Safety (England and Wales and Scotland) Regulations 2014
Construction (Design and Management) Regulations 2015
Control of Asbestos Regulations 2012
Control of Lead at Work Regulations 2002
Control of Major Accident Hazards Regulations 2015
Explosives Regulations 2014 (as amended)
Ionising Radiations Regulations 1999

Source: Adapted from HSE website http://www.hse.gov.uk/legislation/statinstruments.htm
More information on these regulations can be found by clicking on the web page link above.

REQUIREMENTS FOR DEALING WITH HAZARDOUS SUBSTANCES

For ground-based operations at a spaceport, the most significant hazards to workers and people near to the spaceport are likely to be from the use of the hazardous substances used as fuels in spacecraft.

There are a number of different existing health and safety regulations that may apply for dealing with the hazards and risks associated with such hazardous substances.

Many of the fuels already used for spacecraft are hazardous to human health by being flammable, explosive, or toxic. There are established regulations to minimise the risks of people being harmed by these types of substance.

An outline of some of the existing regulations that could apply to a spaceport is given in the following sections. The following listed regulations are not intended to form a complete list of requirements relating to hazardous substances. There may be other regulations that may apply to spaceport operations. Each spaceport will have to be assessed on a case-by-case basis depending on the operations being carried out at the spaceport.

As mentioned earlier, care may be required when looking at applying existing health and safety requirements to spaceport activities. Spaceports may have a range of different types of hazards that requires some extra thought. Also, the existing regulations were not developed with spaceports in mind; this means that some spaceport operations will not fall under existing health and safety regulations. These aspects will have to be dealt with on a case-by-case basis, as it will be dependent on the types of fuels used and on the types of operation that will be carried out from the spaceport.

The Control of Major Accident Hazards (COMAH) Regulations 2015

The Control of Major Accident Hazards (COMAH) Regulations 2015 describes the legal framework to ensure that companies that use or store quantities of dangerous substances above specified thresholds take all measures necessary to prevent major accidents and limit the consequences for human health and the environment.

A major accident could involve a release of toxic material, a fire, or an explosion involving one or more dangerous substances causing serious harm to workers, nearby populations and the environment.

Many of the fuels and propellants used in existing spacecraft and satellites classify as dangerous substances under the COMAH Regulations. If these substances are stored above specified quantities, then the spaceport or the spaceport's fuel storage depot would be defined by the Regulations as a COMAH establishment.

Further information and guidance on COMAH can be found at:

Control of Major Accident Hazards (COMAH) Regulations 2015
http://www.legislation.gov.uk/uksi/2015/483/contents/made

HSE's COMAH home web page
http://www.hse.gov.uk/comah/

A guide to the Control of Major Accident Hazards Regulations (COMAH) 2015
http://www.hse.gov.uk/pubns/books/l111.htm

Land Use Planning (LUP) and Hazardous Substance Consent (HSC)

There are regulations to consider the impact of certain sites involving the storage, use, or transporting of quantities of hazardous substances on nearby populations and for proposed developments (e.g. new construction developments such as housing, or developments of existing buildings, etc.) near to such sites. There are different regulations for England, Scotland, and Wales.

Sites that want to store or use quantities of hazardous substances above specified thresholds must obtain Hazardous Substance Consent (HSC) from the Hazardous Substances Authority. There is a legal requirement for the Hazardous Substances Authority to obtain HSE's advice on whether consent should be given to store the quantities of substances requested. HSE considers the hazards and risks that people nearby could be exposed to from the hazardous substances when providing advice.

As part of the Land Use Planning (LUP) process, there is a legal requirement for a Local Planning Authority to obtain HSE's advice regarding the safety of future populations from planning applications near to chemical sites or pipelines that could pose a significant hazard to the population.

As discussed earlier, many of the fuels and propellants used by spacecraft and satellites are considered to be dangerous substances under the COMAH Regulations. The threshold quantities used for HSC are the same as those used to determine whether a site is a COMAH establishment.

Further information and guidance on LUP and HSC can be found at:

The Planning (Hazardous Substances) Regulations 2015
http://www.legislation.gov.uk/uksi/2015/627/contents/made

The Town and Country Planning (Hazardous Substances) (Scotland) Regulations 2015
http://www.legislation.gov.uk/ssi/2015/181/contents/made

The Planning (Hazardous Substances) (Wales) Regulations 2015
http://www.legislation.gov.uk/wsi/2015/1597/contents/made

HSE's Land Use Planning home web page
http://www.hse.gov.uk/landuseplanning/

HSE's Hazardous Substance Consent web page
http://www.hse.gov.uk/landuseplanning/hazardoussubstances.htm

The Explosives Regulations 2014

The Explosives Regulations 2014 defines the health and safety legal framework relating to explosives. The Regulations describe the permissioning regime for the manufacture and storage of explosives.

As some rockets and propellants used as spacecraft fuels are classified as explosives, then a spaceport or spacecraft operator may need to obtain licences to store, manufacture and use such substances. The hazards from not controlling the risks from the use and storage of explosives could cause harm to nearby populations as well as workers at the spaceport.

In this case, the word 'explosive' has a distinct definition. Many rocket propellant substances that can cause an explosion are not defined as an explosive and, therefore, are not within the scope of the Explosives Regulations 2014. See the further information for more details.

Further information and guidance on the Explosives Regulations can be found at:

The Explosives Regulations 2014
http://www.legislation.gov.uk/uksi/2014/1638/made

HSE's explosives home web page
http://www.hse.gov.uk/explosives/index.htm

HSE Guidance on Regulations – Safety provisions
http://www.hse.gov.uk/pubns/books/l150.htm

HSE Guidance on Regulations – Security provisions
http://www.hse.gov.uk/pubns/books/l151.htm

The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002

The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002 describe the legal framework to ensure employers control the risks to safety from fire, explosions and substances corrosive to metals.

DSEAR requires employers to protect people from these risks to their safety in the workplace, and to members of the public who may be put at risk by the work activity.

The application of these regulations with respect to spaceport and spaceflight operations will be to ensure that the fuels used for the spacecraft are stored and used safely and will be needed to protect spaceport workers and others nearby who may be at risk from these hazards (for example, passengers at the spaceport).

In this case, the word 'explosive' is not used in the same way as for the Explosives Regulations 2014 (see previous section). In such a case, DSEAR is to make sure people are safe where there could be flammable gases or vapours (the explosive atmospheres). See the further information for more details.

Further information and guidance on DSEAR can be found at:

Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002
http://www.legislation.gov.uk/uksi/2002/2776/contents/made

HSE's Fire and Explosion home web page
http://www.hse.gov.uk/fireandexplosion/index.htm

The Control of Substances Hazardous to Health (COSHH) Regulations 2002

The Control of Substances Hazardous to Health (COSHH) Regulations 2002 outlines the legal framework to ensure that employers either prevent or reduce their workers' exposure to substances that are hazardous to health. This is for everyday exposure to harmful substances rather than exposure following an accident.

As discussed earlier, many of the fuels and propellants used in spacecraft and satellites are dangerous substances that are harmful to human health. The implementation of COSHH would be needed by a spaceport and spacecraft operators to protect workers that might come in contact with these dangerous substances as part of their day-to-day jobs.

Further guidance on COSHH can be found at:

The Control of Substances Hazardous to Health (COSHH) Regulations 2002
http://www.legislation.gov.uk/uksi/2002/2677/contents/made

HSE's COSHH home web page
http://www.hse.gov.uk/coshh/index.htm

ASSESSING LAUNCH RISKS TO THE PUBLIC

There is a risk that there could be an incident during the launch or during the flight of the spacecraft to space. In such an incident, there could be debris that falls to the surface causing damage and injury through impact.

There could be explosive debris, or the spacecraft could explode, causing injury or structural damage that leads to injury from the explosion 'blast wave'. There could be fires from the debris impacts or from the fuels burning following an incident. There could also be a release of toxic material that could cause harm to those exposed.

These are all examples of 'worst case' outcomes during a launch or spacecraft flight. The government is putting the framework in place to allow commercial space launches from the UK. This framework will require operators of the spacecraft and the spaceports to manage safety to minimise the risks from these types of incidents.

From space launches around the world, however, it is clear that launching into space is still a risky business. It is not an easy thing to do and there are a lot of things that can go wrong.

HSL has developed a way of assessing the risks to individuals at locations near to a spaceport or near to the spacecraft flight path. Using this method helps ensure that the location of a spaceport and operations at the spaceport do not pose an unacceptable risk to people in the vicinity.

The regulations used in the USA for commercial space transportation were used as the starting point to develop methods to assess the public safety from UK launches. Identifying what could be used from the US approach was considered a sensible approach as the USA has a long-established track record in carrying out spacecraft launches.

The Federal Aviation Administration Office of Commercial Space Transportation (FAA AST), the regulator for commercial space operations in the USA (AST is an abbreviation for 'Associate Administrator for Commercial Space Transportation'), publish detailed descriptions of the methods and criteria used to grant US launch licences. This means that there is a wealth of information available based on years of launch experience.

ASSESSING COMMERCIAL LAUNCH RISKS IN THE USA

Commercial spaceflight in the USA is regulated by the FAA AST. The methods used by the FAA AST to issue spaceport licences and operator licences are outlined in the 'Code of Federal Regulations Title 14 – Aeronautics and Space, Chapter III: Commercial Space Transportation' (14 CFR, Chapter III).

The FAA AST uses collective risk to work out whether a licence should be given to a spaceport or spacecraft operator. The collective risk is represented as the number of casualties that could be expected per mission (Ec). This is compared against a limit of expected casualties for a mission set by the FAA AST.

If the calculated expected number of casualties per mission (the collective risk) for a spaceport is lower than the limit, then the FAA AST will give the spaceport a licence. Otherwise, the FAA AST will not give the spaceport a licence, but will ask for more detailed calculations to be carried out.

A more detailed calculation will generally give the FAA AST the information needed to make a final decision. This will either be that the extra detail shows that the collective risk is below the limit so that a licence can be given, or that the risk is too great and the operation cannot go ahead.

There are two methods outlined in 14 CFR, Chapter III to calculate the collective risk to determine different licences that can be issued by the FAA AST:

- 'Part 417 – Launch Safety'
  This method is used to calculate the expected number of casualties per mission for launches that will be carried out by a spacecraft operator at a spaceport.

  This method requires detailed information about the type of spacecraft used in the mission, including exact information about the flight paths that will be taken as the spacecraft travels to space.

- 'Part 420 – Licence to operate a launch site'
  This method is used to calculate the expected number of casualties per mission for a spaceport location, taking into consideration the types of launches that could occur from the spaceport. This method is not as detailed as the method described in Part 417.

  This method does not require the details of the spacecraft. Instead, this method makes assumptions on the possible flight corridor for the spacecraft and types of failure that could harm people on the surface if there were difficulties during a launch.

Both methods work out areas where people could be harmed from an accident during a launch and then multiply the probability of an accident happening with the number of people within those areas. This gives the expected number of casualties (Ec) for the mission.

The FAA AST specifies individual risk limits per mission as well as the collective risk limits.

A US operator has to obtain a launch licence from the FAA AST no matter where in the world a launch takes place. This means that any US operators that want to launch from the UK would need to obtain a launch licence from the FAA AST based on the expected casualties calculated using the methods described in 14 CFR, Chapter III.

Further information on the methods used by the FAA AST to licence commercial launch operations and launch sites in the USA can be found at:

Code of Federal Regulations Title 14 – Aeronautics and Space, Chapter III: Commercial Space Transportation (14 CFR, Chapter III)
https://www.law.cornell.edu/cfr/text/14/chapter-III

Part 417 – Launch Safety, 14 CFR, Chapter III
https://www.law.cornell.edu/cfr/text/14/part-417

Part 420 – Licence to operate a launch site, 14 CFR, Chapter III
https://www.law.cornell.edu/cfr/text/14/part-420

FAA AST Flight Safety Analysis Handbook, 2011
https://www.faa.gov/about/office_org/headquarters_offices/ast/media/Flight_Safety_Analysis_Handbook_final_9_2011v1.pdf

Changing the Collective Risk Limits for Launches and Reentries and Clarifying the Risk Limit Used To Establish Hazard Areas for Ships and Aircraft, 2016
https://www.federalregister.gov/documents/2016/07/20/2016-17083/changing-the-collective-risk-limits-for-launches-and-reentries-and-clarifying-the-risk-limit-used-to

ASSESSING RISKS IN THE UK

The UK has an established health and safety regulatory system. Health and safety is regulated by the Health and Safety Executive (HSE) in Great Britain and by the Health and Safety Executive for Northern Ireland (HSENI) in Northern Ireland. As discussed earlier, there are existing health and safety requirements that a spaceport or spacecraft operator needs to implement to be compliant with the law for ground-based operations.

Having this established health and safety regulatory system means that there are measures of risk already used within the UK to regulate high hazard industries and activities. HSL undertook a review of measures of risk used by the UK government to identify how these could be applied to spaceport activities.

Individual risk is a commonly used measure of risk where a 'baseline' of risk can be established that allows the risks from different activities and industries to be compared. The individual risk per year gives the likelihood that a hypothetical person at a given location would be harmed by a hazardous event over a year. A hypothetical person here means anyone present at that location throughout the year, it does not mean that a single person is at that location all of the time.

Two key areas of risk-based regulation within government were identified that use location-based assessment of risks. In both of these cases, zones of different levels of risk can be viewed on a map of the location surrounding the hazard. Both of the examples identified use the individual risk per year to a specific level of harm to a person.

Individual Risk

One way of defining individual risk is that, if there is an individual risk of death of 1 in a million per year from a hazard, on average, one person would die every million years from exposure to the hazard if this hazard were present for a very long time.

An alternative way of describing individual risk is, if there is an individual risk of death of 1 in a million per year from a hazard, then a hypothetical person exposed to that hazard for a year would have a 1 in a million (that is, 0.0001%) probability of dying in that year from exposure to the hazard.

The first example of the use of individual risk to protect public safety identified is the use of Public Safety Zones (PSZ) by the Department for Transport (DfT). Public Safety Zones are established for larger civil airfields in the UK. The PSZ consist of zones of individual risk of fatality calculated for take-off and landing at the airfield runways. The PSZ are used to restrict development in the zones to minimise the populations that could be exposed to an aircraft crashing on take-off or landing.

As there will be considerable fewer spacecraft launches than aircraft flights, then this is not to suggest that the PSZ approach will be used for spaceports. This is merely to illustrate an area where the government already uses the concept of individual risk zones to control public exposure to high hazard activities.

The second example identified is the Land-Use Planning (LUP) zones used by HSE when advising on proposed developments near major hazard chemical sites. Zones of individual risk of receiving a *dangerous dose* are used by HSE to provide advice to local planning authorities (LPA). HSE advises the LPA on whether the calculated risk suggests that people in a proposed development would be exposed to an unacceptable level of risk from the chemical site operations. This method takes into account the impact of an accident on vulnerable populations (for example, older people, children, those with restricted mobility, and so on).

This is another example where the government uses individual risk zones to help try to ensure public safety from hazardous activities. As discussed earlier, if a spaceport stores hazardous chemicals above specified quantities, then Land Use Planning zones will be calculated for the spaceport site.

Further information can be found at:

Health and Safety Executive (HSE)
http://www.hse.gov.uk/aboutus/insidehse.htm

Health and Safety Executive for Northern Ireland (HSENI)
https://www.hseni.gov.uk/content/about-hseni

HSE's 'Reducing Risks, Protecting People' document
http://www.hse.gov.uk/risk/theory/r2p2.htm

Department for Transport's Public Safety Zones
https://www.gov.uk/government/publications/control-of-development-in-airport-public-safety-zones

HSE's Land Use Planning home web page
http://www.hse.gov.uk/landuseplanning/

ASSESSING COMMERCIAL LAUNCH RISKS IN THE UK

The FAA AST methodology is used to licence commercial spaceports and launch activities in the USA. Theoretically, this methodology could be used to assess the risks for commercial spaceports and launches in the UK. The US methodology, however, generates single numbers for the collective risk (expected casualties per mission) to compare against the target limits. The population is a significant input to this calculation. This raises several issues for using this US method in the UK.

- The UK is a highly populated small country. The USA has large areas of land with little, or no, population where commercial spaceports can be located. This allows the collective risks calculated for these spaceports to meet the limits required by the FAA AST to allow space launches. The UK does not have these large areas of unpopulated territory available.

- The UK does not use collective risk when assessing public safety for other industries or activities. This would make it difficult to understand how the risks generated from a spaceport compared to the risks from aircraft take-off and landing at larger airports, or from, say, a chemical site or a nuclear site.

- The use of a single value does not allow an understanding of where there may be areas of high risk from the launches. Understanding locations where there would be a significant risk of harm to a person allows identification of interventions to avoid exposing people to these risks.

- To allow certain space operations to develop, the FAA AST has occasionally issued waivers to some operators even though the expected number of casualties calculated for the mission is not below the limit. This can work because of the low population density around the US spaceports. This would not be an option that could be used in the UK.

- The FAA AST does provide a method to convert from collective risk (expected casualties per mission) to individual risk (likelihood of becoming a casualty per mission), but this is, in effect, a surrogate for individual risk rather than being a comprehensive calculation of individual risk. This conversion process would not provide the detailed identification of locations of high risk that would be necessary for the UK to assess and manage risks to people as done for other industries and activities.

- The US method does not have any means to assess the impact on vulnerable populations (for example, older people, children, those with restricted mobility, and so on). Vulnerable populations may be more at risk from a hazardous event through either being less resistant to harm, or through a reduced ability to escape if there were an accident.

Airfield Public Safety Zones (PSZ) and Land Use Planning (LUP) zones around chemical sites are already used to protect the public from activities in the UK which have hazards that have a low chance of occurring but could injure or kill a high number of people (a low likelihood, high consequence hazard). A similar approach to protect the public from spaceport activities would allow an understanding of where there could be high risks and how to ensure that the public are not exposed to unacceptable risks from these activities.

The FAA AST methods are described in detail in documentation online. Many of the processes described in the FAA AST Part 417 regulations that are used to calculate the collective risk are similar to those that are required to calculate the individual risk of fatality. Given that the USA has a long history of space transportation, then it seems a sensible starting point to identify which parts of the US methodology could be used to help calculate the individual risk per year of a person being harmed.

ASSESSING THE INDIVIDUAL RISK FOR UK LAUNCHES

Any methodology for calculating the individual risk needs to:

- Identify the hazardous failure scenarios for the spacecraft flight. These are accident scenarios that lead to debris impacts, explosive effects, and releases of a toxic substance.
- Calculate the frequencies of the hazardous failure scenarios occurring.
- Simulate what physically happens during an accident using mathematical models. The mathematical models allow the areas where people could be harmed from the different hazards to be identified.
- Calculate the probability of a person at a location being harmed following an accident.
- Calculate the individual risk of fatality per year for all locations where people could be harmed.

This general approach can be applied to any type of launch within the scope of the Space Industry Act 2018. The differences for different types of launch will generally be the variation in the types of hazardous failure that could occur.

Figure 2 shows a high level outline of the steps required to calculate the collective risk (expected number of casualties per mission) using the method detailed in the FAA AST Part 417 regulations. The steps required to calculate the individual risk (likelihood of fatality per year) are also shown. Some of the steps needed to calculate the two different measures of risk are the same.

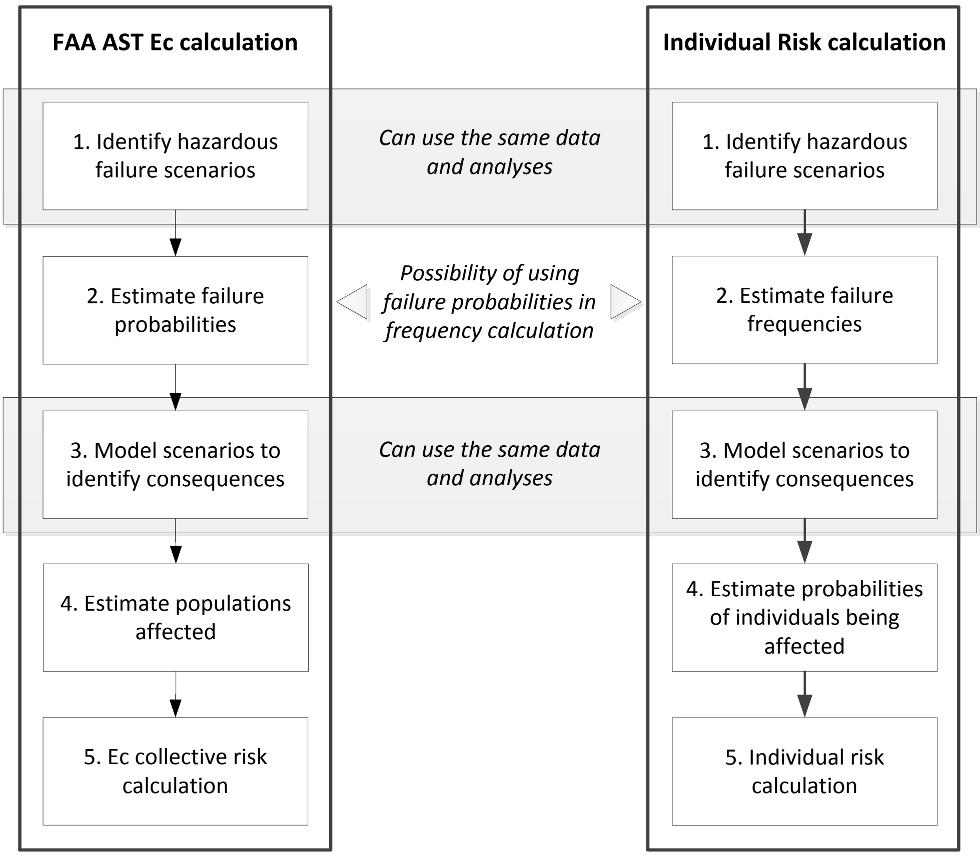

Figure 2 Consistencies of approach between the FAA AST collective risk (Ec) calculation and an individual risk calculation for spacecraft operations

Working out the hazard scenarios if there is a failure

The first part of the risk assessment is to work out what could go wrong that could lead to people being harmed. This involves identifying the hazards from a spacecraft launch.

The obvious hazards from a spacecraft launch are that the spacecraft crashes, or explodes, or breaks up during flight. This could harm people through:

- The impact of the spacecraft or spacecraft debris falling to the ground.
- Fires from the crash or from the flammable fuels on the spacecraft.
- An explosion from the propellants used, either from a crash or from explosive debris.
- A release of a toxic chemical as some fuels used in spacecraft are toxic to humans.

These are the hazard outcomes. What is needed is an understanding of what can go wrong in the first place that can lead to these outcomes. Identifying a list of hazardous scenarios allows an understanding of the events that could occur if things were to go significantly wrong during a launch.

The US FAA AST provides examples of failure scenarios that should be included in a collective risk (Ec) calculation. This includes events such as

- On-trajectory failure: failure of the spacecraft along the expected flight path.
- Malfunction turn failure: failure after the spacecraft moves away from the expected flight path.
- Diabolical turn failure: also known as a random attitude failure, it is a complete loss of directional control. Unlikely to occur in real life but allows assessment of a 'worst-case' scenario.

In the FAA AST events, one of the potential reasons for the destruction of a spacecraft is a command destruct event. This is where the flight control of the spacecraft deliberately destroys the spacecraft to limit the impact from a loss of control. Obviously, plans would need to be considered and implemented for the crew to escape prior to any self-destruct of a manned spacecraft.

The identification of hazards, therefore, needs to be done on a case-by-case basis. No two types of spacecraft are likely to be identical, although there may be similarities that allow some crossover when identifying possible failures.

The identification of hazards needs to involve the spacecraft operators. Operators will have the information about their spacecraft to identify the foreseeable hazards from operations and will know the best ways to deal with them. The hazardous scenarios identified in the FAA AST guidance, however, can be used as a starting point to identify hazards for a particular spacecraft.

It is likely that a comprehensive hazard identification process will involve a number of different methods and involve experts in several fields.

As mentioned earlier, a US operator will need to carry out a collective risk (Ec) calculation to obtain a licence from the FAA AST no matter where in the world a launch takes place. Any US operated spacecraft launching from the UK will have already identified hazard scenarios. This same list of hazard scenarios can be used for the individual risk calculation.

This is not to say, however, that only US spacecraft or only those using the US methods should be allowed to launch from the UK. As long as a spacecraft operator identifies a list of reasonably foreseeable hazard scenarios for a launch then this should allow the individual risk to be calculated.

Working out the failure probabilities and failure frequencies of the hazard scenarios

The risk of a person being harmed from a hazardous event during a spacecraft launch needs to be calculated. To assess this chance of being harmed then the probability or likelihood of a hazardous event happening needs to be calculated.

A commonly used method is to analyse the history of an operation or an event to calculate the likelihood of a failure.

The number of failures relative to the number of times that an operation has occurred can give an indication of the likelihood of failure. For example, a spacecraft that carried out 1,000 missions has had 1 failure. A simple calculation would be that there is a 1 in a 1,000 chance of failure per mission.

To convert this to a failure frequency per year then this can be multiplied by the number of missions per year. For example, 6 missions per year multiplied by a 1 in a 1,000 chance of failure per mission gives a failure frequency of 6 in a 1,000 chance of a failure per year.

Detailed flight histories, however, may not yet be available for many modern spacecraft that might operate in the UK. Where possible, flight histories for similar spacecraft or for a range of similar spacecraft might allow some identification of failure probabilities or frequencies. Otherwise, alternative methods may also need to be used.

The FAA AST collective risk methods use failure probabilities; an individual risk calculation ideally needs failure frequencies. The probabilities, however, can be used to calculate the failure frequencies in some cases. For example, an overall failure probability per mission could be converted to a failure frequency per year by multiplying by the number of missions per year as in the simple example given above.

The FAA AST describes two approaches to calculating failure probabilities: a ‘top-down’ approach and a ‘bottom-up’ approach.

The top-down approach can be used to derive failure probabilities for the whole vehicle, or for different phases of the flight. The method identified in the FAA AST guidance calculates the probabilities of success or failure for a succession of launches of a vehicle. This can be used to determine an overall failure probability for the launch (or phase of flight).

The bottom-up approach requires a more detailed analysis of the possible failures that could occur for the spacecraft. This approach calculates the failure probabilities of basic components of the spacecraft. The process works upward through the various subsystems until probabilities can be defined for the whole spacecraft. Risk assessment techniques such as Fault Tree Analysis, Event Tree Analysis, and so on, are identified as possible ways to calculate the basic component failures to help provide the probabilities and frequencies associated with potential spacecraft failures[3].

This is not to say that these are the only methods available, some statistical techniques are identified as a possible alternative approach by the FAA AST. Other approaches could also be used where multiple simulations of launches are carried out to work out how often someone could be harmed. Any approach used should be explained and justified.

It is recommended that data be recorded for all types of space activity once spaceports start operating in the UK. This data should be used to update the risk assessments and the methods used over time. It could be that the data developed during the testing and initial operation of spacecraft will provide enough information to calculate suitable failure probabilities and frequencies.

[3] *Risk management: Risk assessment techniques,* British Standards Institution BS EN 31010:2010

Working out how the consequences of a hazard scenario can affect people

Mathematical models are used to simulate the physical effects of an accident to calculate how a person could be harmed. For a spacecraft launch, mathematical models can be used to calculate:

- How the debris can 'disperse' following break-up of the spacecraft, including effects of the initial momentum on debris scatter, the altitude at break-up, the wind speed, wind direction and other weather impacts on the debris dispersion, and so on.
- The impact force of debris on the ground that could lead to harm, bounce and skidding of debris on impact, the effects on a person being out in the open or being indoors, and so on.
- The effects of an explosion on a person from explosive debris, including blast effects leading to injury and fatality, explosion effects for people out in the open and for those sheltering in buildings, the impact from fragments of debris following an explosion, and so on.
- The effects of a toxic vapour cloud from a release of debris containing toxic chemicals, harmful levels of toxic exposure, the effects of being indoors or outdoors, and so on.

The use of these types of model allow for 'casualty areas', areas on the ground where people would be harmed by an accident, to be calculated.

The FAA AST describes models for most of these effects. HSL reviewed the models described in the FAA AST guidance and found that all of the models identified could be used to simulate these hazard consequences and the impact of these accidents on people on the ground.

The FAA AST methodology requires operators to provide debris lists, which give the size, shape and mass of the debris fragments that would be produced by each failure scenario. Debris lists can change significantly during the duration of a flight as fuel is used up, or as stages are jettisoned.

The production of a debris list requires a great deal of specialist knowledge about the spacecraft. There will be significant differences between the debris lists for different types of spacecraft. A debris list is a necessary input to carry out a individual risk assessment for a specific type of spacecraft.

The duration of a launch is broken up into time steps and the chances of a failure and subsequent break-up of the spacecraft is modelled at each time step. The debris dispersion is carried out for all of the pieces of debris on the debris list. The mathematical modelling is used to assess the impact on the ground to calculate the casualty areas.

The casualty areas generated by the FAA AST models are where a person could be injured. The individual risk limits identified in the HSE guidance[4] are based on individual risk of fatality. The use of the FAA AST models, therefore, provide a 'safety margin' in the levels of individual risk calculated.

Again, this is not to say that only the FAA AST models should be used. There are other mathematical models available that can simulate these hazardous scenarios. In all cases, the use of a particular mathematical model should be explained and justified, identifying any assumptions and inputs used.

One area of modelling that is not well-described in the FAA AST documentation is how to simulate a release from toxic debris. Dispersion models are used by HSE to assess toxic releases from chemical sites, so suitable models are available. HSE publishes toxic dose limits for setting Hazardous Substance Consent / Land Use Planning risk zones[5]. These could be used for assessments.

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[4] http://www.hse.gov.uk/risk/theory/r2p2.htm
[5] http://www.hse.gov.uk/chemicals/haztox.htm

Working out the probability of a person being harmed

Once casualty areas have been identified then the probability of a person on the ground being harmed needs to be calculated.

Figure 3 illustrates a simplified diagram showing the break-up along the flight path and how the debris impacts on the ground. The casualty areas show the areas where there is a chance that someone could be injured or killed by the debris, whether that is by impact, explosion, or toxic effects.

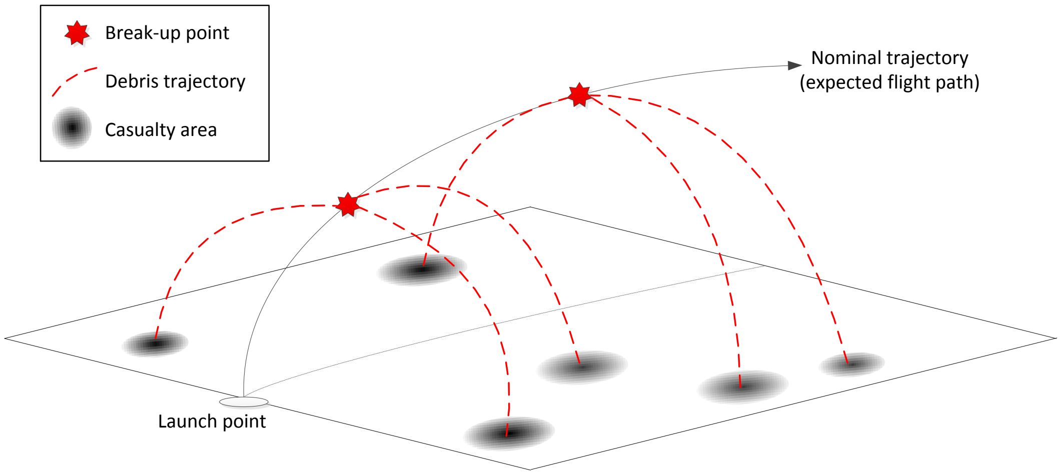

Figure 3 Debris dispersion and the probability of a person being harmed in a casualty area

The casualty areas shown in Figure 3 are shaded to be a darker shade in the middle of the area than at the edges of the area. This is to show visually the statistical process used to determine the chance of a person being harmed in a casualty area when calculating the individual risk.

Statistical methods are used to calculate the chance of a person being harmed within a casualty area. The most likely point where a person could be harmed is the centre of the casualty area. The chance of being harmed is less towards the edges of the casualty area and the statistical analysis allows that to be calculated.

As well as the chance of a person at a location being harmed within a casualty area, the probability of people being at those locations in the first place needs to be included in the individual risk calculation. Obviously, there is more chance of people being present at a location in a city or town than being in the middle of the sea.

The worst case is to assume that there will be someone present at a location all of the time. In many cases, this will be a cautious guess, as people tend to move around in their lives. Ideally, more realistic probabilities should be used to identify the chance of a person being at a casualty area location.

Assuming that someone is always at a location, however, does give an upper limit risk level for the impact to a person. For example, there are always going to be people at hospitals, no matter the time of the day. Even at sea, an oil rig could be at a location where debris could impact, or a small inhabited island could be near the spacecraft flight path.

If the risks generated for this cautious case are small, then this gives more confidence that the risks should be acceptable for more realistic probabilities of people being at a location.

Bringing all this together to calculate the individual risk

HSL has identified a quantitative risk assessment (QRA) process to calculate individual risk for locations around a spaceport and near to the flight path using the steps identified in the previous sections. This approach can be summarised as follows:

- Identify the hazardous failure scenarios.
- Calculate failure frequencies for each hazardous scenario.
- Model the effects of each hazardous scenario.
  - Obtain the casualty area where a person on the ground could be harmed.
- Calculate the probability of a person on the ground being within the casualty area.
- Multiply the probability of a person being within the casualty area by the failure frequency for that scenario.
  - This gives the risk contribution from that scenario at that location.
- Repeat the modelling and casualty area probability analysis for all scenarios identified.
- Add the risk calculated for each scenario at each location modelled.
  - This gives the spacecraft flight individual risk of a person being harmed at each location.

Each of the steps can involve some complex mathematical modelling or statistics to allow the risk levels to be calculated. This type of approach is sometimes referred to as a *deterministic model*. The path from the input to the output is determined as part of the method and, therefore, when the same inputs are used this should give the same answer.

This approach is not the only method that could be used, however. Using similar hazardous scenarios and mathematical models to simulate the scenarios, what is known as a *stochastic modelling* approach could be used. This is where random variations in the inputs are simulated to determine whether a hazardous scenario occurs or not. An example of this type of approach could involve the following process:

- Identify the hazardous failure scenarios.
- Calculate failure probability statistics to allow random inputs to be used for the simulations of each hazardous scenario.
- Undertake a simulation by using random variations to select whether a failure occurs.
  - A failure occurs if a random input is less than the probability for a failure, otherwise, the simulation assesses the next phase of the launch for a failure, and so on.
- Model the effects of the hazardous scenario identified by the failure.
  - Obtain the casualty area where a person on the ground would be harmed.
- Repeat for another simulation using random variations of the inputs.
  - Hundreds of thousands, or even millions, of simulations might be required.
- Divide the number of times that a person would be harmed at a location by the total number of simulations undertaken.
  - This gives the spaceflight individual risk of a person being harmed at each location.

Slightly different answers could be generated each time the *stochastic model* approach is used, even if the same 'inputs' are used. This is due to the random variations modelled for the inputs used.

There will be other approaches that could be used to calculate the individual risk. There is a possibility that risk assessments for spaceports will need to use combinations of different techniques to calculate the risks, depending upon how much data and input information is available.

High level cautious risk calculation as a first step

In the USA, a two-tiered approach is used when assessing the risks. Tier 1 uses relatively simple processes and cautious assumptions to approximate the risk. It is used:

- To determine if a more detailed analysis is required.
- When only limited or basic mathematical models are available to simulate an accident.
- When there is little or no data, so that it is sensible to include an additional margin of safety.

If a Tier 1 assessment generates a level of risk lower than the FAA AST risk limit, then this suggests that the operation should be acceptable since the assumptions and inputs used for a Tier 1 analysis are pessimistic rather than being optimistic that things will work as intended.

If a Tier 1 assessment generates a level of risk higher than the FAA AST risk limit then a more detailed analysis is required using more realistic values. This is known as a Tier 2 analysis.

A Tier 2 risk assessment uses more accurate and sophisticated methods than Tier 1. Since the inputs, assumptions and mathematical models used for Tier 1 are cautious then using more realistic numbers in the Tier 2 approach should generate a level of risk that is smaller than the risk generated using the Tier 1 approach.

A similar two-tier approach should be adopted for assessing the risks for launches from the UK. This adds that extra 'safety margin' since there is not the detailed data available yet for UK launches. The methods used can be refined over time as more knowledge, experience and data is obtained for UK launches.

When there is a known spaceport location but the type of spacecraft is not known

As discussed earlier, the FAA AST in the USA describes two methods for assessing the collective risk from a space mission. When a spaceport location is being assessed for a launch licence, the method described in the FAA AST 'Code of Federal Regulations Title 14 – Aeronautics and Space, Chapter III: Commercial Space Transportation Part 420 – Licence to operate a launch site' is used.

This method uses relatively simple calculations (simple compared to the more detailed calculations described in the previous sections) to generate an area on the ground defining the outer limits of where a spacecraft could impact on the ground if an abort was required at different phases of the flight. Figure 4 shows this region on the ground relative to the spacecraft's flight path.

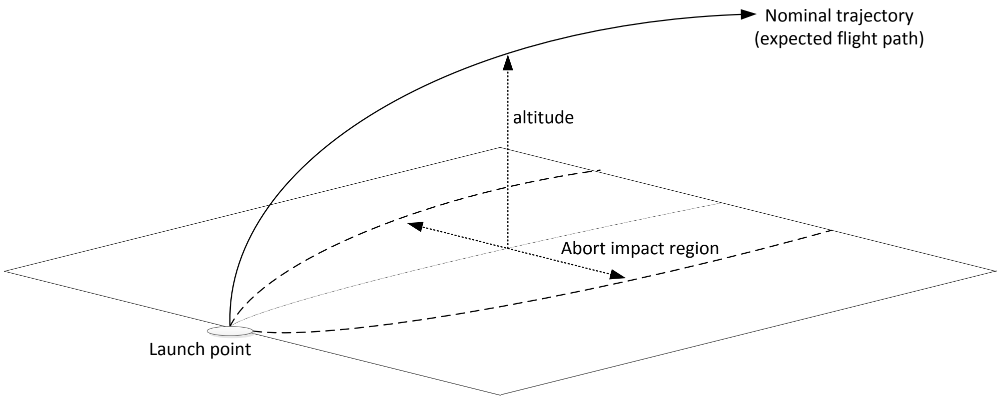

Figure 4 Identifying the at-risk limits for spacecraft flight using FAA AST Part 420 regulations

HSL has identified methods to calculate the individual risk around the spaceport and flight path using this Part 420 approach. As the range of inputs could vary considerably for different types of spacecraft then this approach requires more assumptions to be made than the Part 417 method. Using cautious assumptions in this case is encouraged to ensure that the risks calculated include a 'safety margin'.

There is likely to be no specific data available on how likely failures are to occur for a launch for this type of assessment. Assessing failure probabilities or frequencies for different phases of the flight would be useful but may not be possible with the limited data available. It may have to be assumed that a failure is equally likely at any point during the launch into space.

Debris impact areas are identified where a person could be harmed on the surface. Debris lists outlining the size, shape and mass of the debris fragments are needed to allow the dispersion of debris following break-up to be simulated. A debris list from NASA[6] can be used to identify impact areas for the different debris hazards (debris impact, explosion, toxic) for this high level assessment.

The risk of a person being harmed for a particular debris hazard is calculated. This is repeated for each debris impact area identified at each time step. If a person could be harmed from multiple scenarios then the risk of each impact is added at that location. Once all the time steps for the flight have been modelled, the total risk added at each location gives the level of individual risk of a person being harmed from the launch.

[6] **NL Johnson, PH Krisko, J-C Liou and PD Anz-Meador (2001)** *NASA's new breakup model of EVOLVE 4.0*. Adv. Space Res. Vol. 28, No. 9 pp. 1377-1384

ASSESSING PEOPLE'S SAFETY USING INDIVIDUAL RISK

Once the individual risk of a person being harmed per year around a spaceport and spacecraft flight path has been calculated, different zones of risk can help determine whether the risk to the public is tolerable. This can help identify where flight path changes might be appropriate or where additional controls are needed to minimise the risk.

Three zones of individual risk are overlaid on the map of the launch area and along the flight path. Within each zone of risk, there are types of population that it would be deemed unacceptable to expose to that level of risk. For example, vulnerable populations, like hospitals and schools, would not be considered acceptable within any of the three risk zones calculated.

These spaceport risk zones are not being used in the same way as DfT's Public Safety Zones (PSZ) or HSE's Land Use Planning (LUP) advice zones, but the overall approach of using risk zones to understand the risk to people is similar.

Figure 5 shows hypothetical individual risk zones of a person being harmed from a rocket launch.

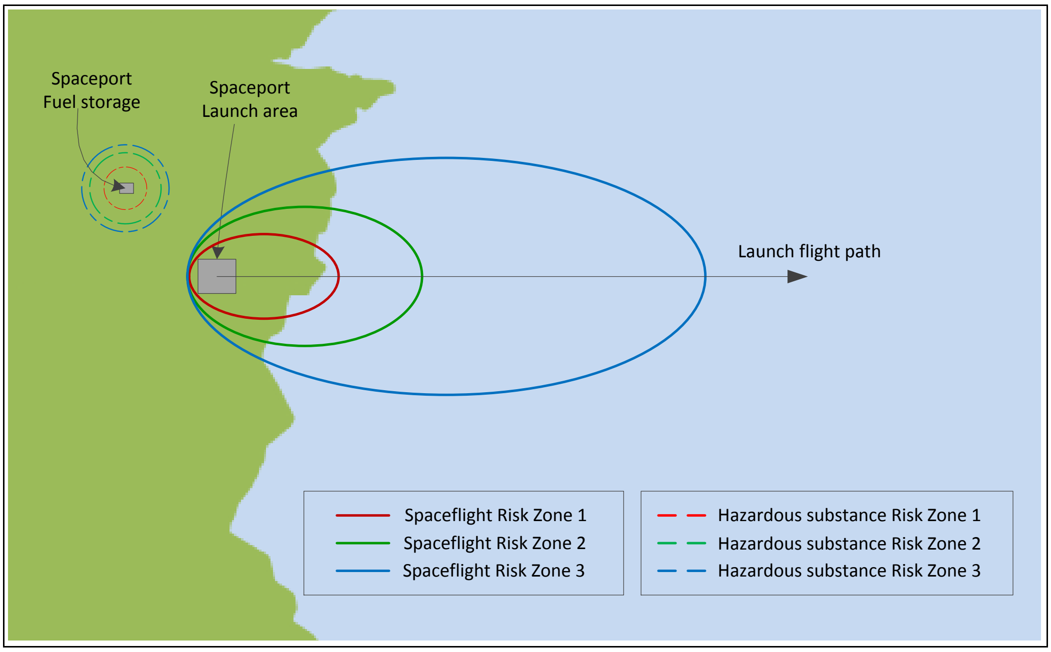

Figure 5 Spaceport risk zones concept

For illustrative purposes only; calculated risk zones for a person being harmed from a launch and for a fuel depot might look completely different in shape and size.

For example, if there was a hospital or a school within any of the zones shown in Figure 5, then this would not be deemed a suitable location for this spaceport. The risk zones allow an understanding of where and why risks are unacceptable; changes can then be made to reduce or eliminate the unacceptable risks. In this case, choosing a slightly different location, or choosing a different flight path, might ensure that the hospital or school were outside the recalculated risk zones.

The use of these risk zones does not mean that risks are reduced as low as reasonably practicable (ALARP). Rather, these zones allow an understanding of where risk reduction measures could help control the risks to people nearby. A spaceport or operator will have to show that they are actively taking measures to control and reduce their risks to demonstrate that risks are reduced ALARP.

SUMMARY

The government is in the process of setting out the legal framework to allow commercial spaceflight to happen from the UK. A key requirement for the government is that any spaceport or spacecraft operator should make sure that people are not exposed to unacceptable risks from the spaceflight activities.

There are a number of existing health and safety legal requirements that might need to be applied by any spaceport or spacecraft operator when launching from the UK. Depending on the operations being carried out there is likely to be a need to ensure the health and safety of workers and the general public from the hazardous fuels used for spacecraft.

There is also a need to make sure that a spaceport location is suitable from a public safety perspective. People near to a spaceport or near to a spacecraft flight path should not be exposed to unacceptable levels of risk from a spacecraft launch.

Methods for assessing the risks to individuals from a spacecraft launch have been identified. Using zones of individual risk per year can show where people may be exposed to unacceptable risks. The use of individual risk per year of a person being harmed also allows spaceflight risks to be compared against other high hazard industries and activities, such as aircraft transportation, and large chemical sites, and so on.

GLOSSARY

Health & safety and scientific terms

ALARP	*As Low As Reasonably Practicable.*
Collective risk	*Collective risk is used in the licencing of commercial spaceports and space operators in the USA by the FAA AST. The collective risk is taken to be the expected number of casualties that could result from a mission.*
COMAH	*Control Of Major Accident Hazards Regulations 2015.*
COSHH	*Control Of Substances Hazardous to Health Regulations 2002.*
Dangerous dose	*A dangerous dose is a level of harm used by HSE when assessing the impact of accidental hazardous chemical releases from chemical sites.*
DSEAR	*Dangerous Substances and Explosive Atmospheres Regulations 2002.*
Frequency	*A frequency is the number of times an event could occur over a specified measurable period. For example, frequency of failure per year. A frequency can be a number greater than one over this period.* *In general language, probability and frequency are often incorrectly used to mean the same thing.*
Hazard	*The potential for harm arising from an intrinsic property or disposition of something to cause detriment. In other words, a hazard is something, or an event, that could lead to harm.*
HSC	*Hazardous Substance Consent. It is a legal requirement for a Hazardous Substances Authority to consult HSE when a site wants to store or use hazardous chemical substances above quantities specified in the COMAH Regulations 2015.*
HSWA	*Health and Safety at Work etc. Act 1974.*
Individual risk	*Individual risk is a measure of risk over time to a hypothetical individual at a given location from exposure to a hazard.*
LUP	*Land Use Planning. It is a legal requirement for Local Planning Authorities to consult HSE on proposed developments near to major hazard chemical sites and major hazard pipelines. LUP zones are individual risk zones that guide HSE's advice to control exposure to a risk of harm from these hazards.*
Probability	*A probability is a number indicating the chance that something could happen. A probability must be a value between zero and one, where zero represents something that can never happen and one represents something that definitely happens.* *In general language, probability and frequency are often incorrectly used to mean the same thing.*
PSZ	*Public Safety Zone. Individual risk zones used by DfT to control exposure to a risk of harm around larger civil airfields.*
QRA	*Quantitative Risk Assessment.*
Risk	*The chance that someone or something that is valued will be adversely affected in a stipulated way by a hazard. In other words, a risk is the possibility that a person is harmed or something is damaged from a hazard occurring.*
SFAIRP	*So Far As Is Reasonably Practicable.*

Space transportation terms

Launch	*Within this document, the term launch is used to express an initiation of a spacecraft on either an orbital flight or a suborbital flight. It is not intended to be limited to a 'traditional' rocket launch and includes the launch of rockets carried by a carrier aircraft as well as any other type of launch within the scope of the Space Industry Act 2018.*
Orbital flight	*An orbital flight refers to a launch where the spacecraft either enters into an orbit around the earth or is used to insert a satellite or any other item into an orbit around the earth.*
Spacecraft	*In this document, the term spacecraft is used to refer to any vehicle that can be used to initiate an orbital or a suborbital flight. It is not intended to be limited to rockets, but is intended to include spaceplanes and any other vehicle within the scope of the Space Industry Act 2018.*
Spaceport	*Within this document, the term spaceport is used to mean any location where a spacecraft takes off or is launched for the intention of carrying out an orbital or a suborbital flight.*
Suborbital flight	*A suborbital flight refers to a launch where the spacecraft travels above an altitude of 100 km but does not enter orbit around the earth. Spaceplanes and reusable rockets are currently under development to allow space tourists and scientific experiments to be carried out on suborbital flights. Theoretically, the launch location and landing location for a suborbital flight could be at different spaceports, although current operations are proposing launching and landing at the same spaceport location.*

Organisational abbreviations

CAA	*Civil Aviation Authority*
DfT	*Department for Transport*
FAA AST	*Federal Aviation Administration Office of Commercial Space Transportation in the USA (AST is an abbreviation for 'Associate Administrator for Commercial Space Transportation')*
HSE	*Health and Safety Executive*
HSENI	*Health and Safety Executive for Northern Ireland*
HSL	*Health and Safety Laboratory*
NASA	*National Aeronautics and Space Administration in the USA*
UKSA	*UK Space Agency*

HEALTH & SAFETY LABORATORY

HSL: HSE's Health and Safety Laboratory is one of the world's leading providers of health and safety solutions to industry, government and professional bodies.

The main focus of our work is on understanding and reducing health and safety risks. We provide health and safety expert advice and consultancy, research, specialist training and products.

At HSL, we have been developing health and safety solutions for over 100 years. Our long history means that we're well placed to understand the changing health and safety landscape, and anticipate future issues.

We employ over 450 scientific, medical and technical specialists, including occupational health and risk management experts to help our clients manage a wide range of issues in workplace health and safety.

ISO 9001 OHSAS 18001

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