Imperial College
London

HOT FIRE TESTING EMERGENCY RESPONSE PROCEDURES

1. PERSON CARRYING OUT ASSESSMENT

Person Responsible:	[redacted]	**Position:**	Propulsion Lead, Imperial College London Rocketry
Date:	January 2023	**Review Date:**	

2. DOCUMENT OUTLINE

This document covers a list of possible incidents which may occur during engine hot fire tests, for which a set of Emergency Response Procedures (ERPs) has been produced. It is required that the responsible persons listed in this document are familiar with this document and its contents prior to any and all such activity.

3. INCIDENT CLASSIFICATION

“Incidents”, in the context of this document, are defined as any event not within the standard operating procedure listed in the accompanying risk assessment, under Section 7. In the event of any incident, the severity must be assessed. For all purposes and intents, incidents will be classified and logged in one of the two following categories:

1. **Minor Incident**
    - Any contamination/spill event that does not result in direct interaction with the persons conducting the test
2. **Major Incident**
    - Any unusual or unexpected behaviour from apparatus that may inflict damage or harm to nearby

personnel or property
  - Any failure of components that may reduce effectiveness of preventative measures
  - Any significant danger or harm to persons, infrastructure, and/or property during testing, including imminent or potential danger or harm
  - Any event of public encroachment

4. PERSONS RESPONSIBLE

This section details the necessary, standardised steps required to be taken in the event of each incident occurring. Note that the procedures involve the following responsible persons:

1. Chief Test Operator (CTO):
2. Propulsion Safety Officer (PSO):
3. Nitrous Oxide Specialist (NOS):
4. Ignition Specialist (IS):

Due to restrictions on social gathering, only those required to conduct the activities will be able to attend.

5. EMERGENCY RESPONSE PROCEDURES

Emergency	**Type**	**Description**	**Preventative Actions**	**Immediate Actions (On-site)**	**Persons Responsible**	**Follow-up Actions**
N2O tank dropped	Major	1) Could cause direct injury if it lands on feet or hands 2) Could damage tank or connectors, potentially causing a sudden release of high pressure gas or shrapnel	• Care taken during all relevant steps outlined in the standard operating procedure. • Ensure all participating team members are thoroughly briefed on how the tank will be moved • 1) Wear UK certified safety boots during handling • 2) Tank has a protective	• 1) Lift the tank off hands or feet quickly and check movement in fingers or toes. Seek medical attention if necessary • 2) If no gas is leaking, carefully inspect connectors for any damage. If gas is leaking, quickly exit the area and allow the tank to fully depressurise	CTO	1) Check there is no long term damage to hands or feet - if so seek medical advice 2) Stop testing if connectors are damaged and replace before next test

			guard around outlet connectors			
Muscle strains while lifting N2O tank	Major	Transfer of N2O tank from trolley to the tank inverter could cause injury if too much load is placed on one team member	● Transfer process designed to minimise amount of lifting of the tank (see Standard Operating Procedure); ● Clear communication will be given to team members to ensure correct coordination when lifting the tank so that load is spread equally	● Tank should be placed down as quickly as safe to do so if any team member becomes overstrained	CTO	Injured team member should rest and seek medical attention if necessary; Assess whether lifting method needs to be altered
N2O tank explodes due to overheating	Major	A large, uncontrolled fire causes significant overheating of the N2O, leading to an explosion of the tank. Resulting shockwave and shrapnel could cause serious injury or death	● Tank is placed several meters behind the test cell, with the engine firing in the opposite direction. ● Tank inverter and equipment are built from non-flammable materials. ● Surrounding area is cleared of potentially flammable objects prior to test fires (e.g. small plants). ● All members are required to be either inside the Spars Building control room or more than 50 meters away from the engine during any test fire. ● Fire extinguishers and sand buckets are required for all tests to put out any small fires well before they spread to potentially larger fires	● Press emergency shutoff on the test controller ● Make sure everybody is uninjured in the test bunker - emergency services should be called on 999 immediately for any serious injuries. Call fire department on 999 as well as an ambulance ● Check the live video for any fire in the visible surrounding area - if video feed does not work then proceed outside cautiously to gain a visual of the testing area ● If video shows it is safe to do so, CTO and PSO will exit the bunker with a fire extinguisher and evaluate the situation outside - put out fires if necessary ● Check that any members outside the bunker at a distance are uninjured - call 999 immediately for serious	CTO	Check all members for injuries (damaged eardrums, shock, cuts, burns etc.); Report the incident to Silwood Campus security and Aeronautics department; Investigate the root cause of the fire and explosion; Assess whether control measures need to be altered

				injuries		
N2O tank explodes due to damage from shrapnel	Major	Large amounts of shrapnel from an exploding combustion chamber impacts the tank, causing an explosion of the tank. Resulting shockwave and shrapnel could cause serious injury or death.	● Engine is placed in a steel test cell that is sunk into the ground which will contain the majority of shrapnel in case of an explosion. ● Tank is placed several meters behind the test cell, with engine firing in the opposite direction. ● Steel mesh shield is placed between the lower part of the tank and the engine to shield against any large debris ● All members are required to be either inside the Spars Building control room or more than 50 meters away from the engine during any test fire. ● Fire extinguishers and sand buckets are required for all tests to put out any small fires well before they spread to potentially larger fires.	● Press emergency shutoff on the test controller ● Make sure everybody is uninjured in the test bunker - emergency services should be called on 999 immediately for any serious injuries. Call fire department on 999 as well as an ambulance ● Check the live video for any fire in the visible surrounding area - if video feed does not work then proceed outside cautiously to gain a visual of the testing area ● If video shows it is safe to do so, CTO and PSO will exit the bunker with a fire extinguisher and evaluate the situation outside - put out fires if necessary ● Check that any members outside the bunker at a distance are uninjured - call 999 immediately for serious injuries	CTO	Check all members for injuries (damaged eardrums, shock, cuts, burns etc.); Report the incident to Silwood Campus security and Aeronautics department; Investigate the root cause of the fire and explosion; Assess whether control measures need to be altered
Small N2O leak in plumbing	Minor	Small amount of N2O leaks from the plumbing either	● Hydrostatically test plumbing upstream of solenoid valve prior to	● Check gauges to see if pressure is stable; ● Carefully assess whether leak	CTO	Fix small leaks after testing to prevent future

after opening tank valve		upstream or downstream of the solenoid valve. Depending on severity of leak, tests may still proceed	Cold Flow Tests, ● Follow comprehensive Swagelok wiki guide when tightening all fittings; ● Wear thermally-insulating gloves and face shield in case leak increases	is small enough for tests to continue; ● Turn off valve and disconnect N2O cylinder before trying to fix any leaks		issues
Large N2O leak in plumbing after opening tank valve	Major	Large amounts of high pressure N2O leaking could lead to extreme cold temperatures and ice buildup	● Open tank slowly so any large leaks become obvious at lower pressures; ● Spray soap water on suspected leak locations to identify leak location; ● Ensure proper assembly and testing (see above measures); ● Wear cryogenic-insulating gloves and face shield	● Close N2O valve and disconnect tank, ● Move hands away from leak area to reduce chance of cold burns and frostbite - remove any gloves as soon as hands are removed from cold areas; ● Seek medical attention/treat with first aid if there is damage to skin or eyes	CTO	Report incident, Assess whether leak can be fixed on site or if additional work or hydrostatic testing needs to be done
N2O leak/injector exhaust starts a fire	Major	Oxidising properties of N2O could cause a fire to start if it comes into contact with a fuel + ignition source. Fire could cause burns to any personnel	● Sections of plumbing containing N2O around any personnel will be hydrostatically tested to ensure there are no leaks; No highly flammable materials will be placed near any plumbing sections; ● Plumbing cleaned with degreasing agent prior to testing to remove any potential fuel sources; ● Tests are performed remotely so any fires can be assessed from a distance before action is taken	● If safe to do so extinguish fire with a CO2 fire extinguisher (located in Spars Hallway) and/or close N2O tank valve; Evacuate all team members from the area and call emergency services if fire continues to spread	CTO	Report incident, assess whether test setup or procedures need to be altered to prevent future fires
Hot combustion gas	Major	Could cause detonation of N2O within the run tank,	● Injector designed with high pressure drop to eliminate possibility of backflow	● Press emergency shutoff on the test controller to ensure all valves return to a safe	CTO	Report incident; investigate the root cause and

backflows through injector		causing an explosion. Resulting shrapnel or shockwave could cause serious injury	● Procedures are strictly followed to ensure no scenarios where backflow could occur ● Filling of the run tank and igniting of the engine is only ever done remotely when people are at a safe distance of 50+ m or inside the Spars Building control room ● Filling valve is always closed prior to tests to ensure no flashback to the larger N2O cylinder occurs ● Run tank only contains a small amount of N2O (< 3kg) which minimises explosive potential ● Run tank is fitted with an overpressure relief valve and is designed to fail in a safe manor without producing shrapnel	position ● Make sure everybody is uninjured in the test bunker - Call emergency services on 999 for any serious injuries Call Silwood Security on 4444 for any large fires that develop to direct fire brigade to location ● Check the live video for any fire in the visible surrounding area - if video feed does not work then proceed outside cautiously to gain a visual of the testing area ● If video shows it is safe to do so, CTO and NOS will exit the bunker with a CO2 fire extinguisher and evaluate the situation outside - put out fires if necessary ● If safe to do so, CTO and NOS walk over to the testing area and turn off the manual tank valve (while wearing face shield and thermally insulating gloves)		review control measures if any serious injuries or near misses occurred. Review injector design and procedures to ensure accident is not repeated
N2O from a leak/injector exhaust is inhaled	Major	N2O is an anaesthetic so could cause drowsiness or dizziness if inhaled. In cases of extreme amounts of inhalation it can displace oxygen and cause suffocation	● All nitrous handling is done outside in a well ventilated space (leaks will dissipate quickly); ● All tests are performed remotely from a safe distance to prevent inhalation	● Move anyone who has inhaled large amounts of N2O away from the source immediately and allow them to breathe fresh air ● Close the regulator to stop leakage if safe to do so ● Seek further medical attention (dial 999) if a person appears drowsy, fatigued or is shivering, sweating excessively or vomiting.	CTO	Report incident; ensure affected team members have fully recovered or seek further medical attention if symptoms remain

				● Be alert to symptoms of an allergic reaction (difficulty breathing, wheezing, fever or chills). If this is the case seek medical help immediately		
Fitting or hose disconnects after opening N2O tank valve	Major	Components or hoses can whip around in the the air and cause injury if uncontrolled	● Wear a face shield, UK certified safety boots and gloves around the plumbing anytime it is pressurized, ● Open tank valve slowly to prevent shocks ● Use whip check hose restraints in case connectors fail, ● Perform tightness check on all high pressure fittings before connecting N2O cylinder	● Quickly move away from any components flying around and wait until they settle, ● Use emergency stop for downstream hose; ● Close tank valve if safe to do so ● Use first aid kit to treat any minor injuries caused by flying components or sudden release of pressure (seek further medical attention if necessary)	CTO	Report incident, Assess any damage to equipment and whether issues can be fixed safely on site before any further testing is conducted
Mechanical issue with remote valve during test	Minor	1) Valve gets stuck in open position due to mechanical failure 2) Valve loses power or does not respond to close command during operation Could cause injury if system is improperly approached; Potentially leads to minor or major leak or continuous hot-firing	● Control system is tested each time before connecting the N2O cylinder, ● Tests are done remotely so low risk of injury ● 1) Valve is chosen to handle pressure and temperature requirements with adequate safety factor. A dry run of all valves is done prior to each test to ensure good working order. ● 2) Easy to access emergency stop button means tests can be shut off quickly if needed. Independent power supplies from mains and batteries are used to prevent power loss	● 1) If considered safe CTO and NOS carefully approach test rig and shut off N2O valve manually (otherwise allow the entire tank to vent to the atmosphere before approaching) ● 2) If key switch fails to close valve, shut off power to valve using emergency stop button and disconnect the 24V power supply from the remote	CTO	Report incident and examine root cause; Inspect equipment for any damage; Test control systems before proceeding further

			3) Plumbing assembly is hydrostatically tested and valve actuated to ensure it can open & close under pressurised conditions			
Accidental trigger of valve	Major	Valve is unintentionally triggered before all personnel are at a safe distance	● Control system is tested each time before connecting the N2O cylinder; ● Safing method for the controller is in place to prevent unintended activation (key switch is required which will be worn by nitrous specialist at all times); ● Power will also be disconnected from controller while work is conducted around test stand for additional insurance; ● Clear audible warning is given before commanding the valve to open (i.e. a countdown)	● Press emergency stop button to close ● Seek medical attention if any personnel near the test rig was injured by cold gas or ruptured plumbing	CTO	Report incident; examine root cause and any damage.
Member of public walking into test area	Major	Member of public could tamper with system or be in vicinity of system during a failure, which could cause injury to them. Noise could also be damaging to ears if members of the public are within close proximity	● Tests conducted within a fenced off area; signs will 100m radius exclusion zone, with cordon tape and signs used to prevent perimeter breaches ● Loud announcement of imminent testing will be given using a megaphone along with a loud countdown; ● A team member is stationed at each entrance to the site (wearing high visibility clothing) to warn	● Press emergency stop button if tests have begun, otherwise remove arming key ● Check if member of public is injured if catastrophic failure occurred nearby to them and treat injuries with first aid (seek further medical attention if necessary) ● Wait until member of public walks past and away from test area; ● If they remain after a long time, speak to them to let them know that hazardous	PSO	Report incident; assess whether tests can continue without additional control measures to stop public intervention

			people of imminent tests ● Test are performed on private college land ● Nearby residents are warned at least 2 days in advance of testing activities, and on the test day itself	testing is taking place; ● Test preparations will be halted if any members of the public are spotted walking near the test area		
Members of ICLR are in the test area during tests	Major	If critical component failure occurs in high pressure system, could cause serious injury	● PSO conducts a register to ensure every member is in the Spars building prior to tests; ● Arming key is always worn by one of the team members working in the test area to prevent accidental triggers	● Press emergency stop button if tests have begun; ● Check team member is injured if catastrophic failure occurred nearby and treat injuries with first aid (seek further medical attention if necessary) ● Quickly tell team member to make their way into the building, remind them of the safety procedures and location of exclusion zone	PSO	Report incident; assess whether tests can continue of if further checks of registers need to be done
Combustion chamber explodes	Major	Combustion chamber pressure exceeds twice the standard operating conditions. Could cause injury due to shrapnel of exploding combustion chamber	● Nozzle closure is designed to separate from the combustion chamber before the chamber itself fails. ● Combustion chamber is placed in a steel test cell that is sunk into the ground which will contain the majority of shrapnel in case of an explosion.	● Press emergency shutoff on the test controller ● Make sure everybody is uninjured in the test bunker - emergency services should be called on 999 immediately for any serious injuries ● Check the live video for any fire in the visible surrounding area - if video feed does not work then proceed outside cautiously to gain a visual of the testing area ● If video shows it is safe to do so, CTO and NOS will exit the bunker with a CO2 fire extinguisher and evaluate the situation outside - put out fires	CTO	Report incident; investigate the root cause and review control measures if any serious injuries or near misses occurred

				if necessary and safe to do so ● If safe to do so, CTO and NOS walk over to the testing area and turn off the manual tank valve (while wearing face shield and thermally insulating gloves)		
Run Tank Explodes	Major	Run Tank pressure exceeds twice the maximum designed operating pressure of 70 bar. Shrapnel from a resulting explosion could cause serious injury	● Run Tank is proof tested to 1.5x maximum expected operating pressure (MEOP) and design to burst at no less than twice the MEOP ● Tank is fitted with a safety pressure relief valve that is set to release below the proof pressure of the tank ● Tank is fitted with a remote vent valve to quickly release pressure if needed ● Tank is transported carefully to prevent damage that could lead to a lower failure pressure ● Tank is designed to fail in a manner that minimises shrapnel ● Run Tank will only be pressurised remotely when all personnel are at a safe distance of 50+ m or in the Spars Control room	● Press emergency shutoff on the test controller to ensure all valves return to a safe position ● Make sure everybody is uninjured in the test bunker - Call emergency services on 999 for any serious injuries Call Silwood Security on 4444 for any large fires that develop to direct fire brigade to location ● Check the live video for any fire in the visible surrounding area - if video feed does not work then proceed outside cautiously to gain a visual of the testing area ● If video shows it is safe to do so, CTO and NOS will exit the bunker with a CO2 fire extinguisher and evaluate the situation outside - put out fires if necessary ● If safe to do so, CTO and NOS walk over to the testing area and turn off the manual tank valve (while wearing face shield and thermally insulating gloves)	CTO	Report incident; investigate the root cause and review control measures if any serious injuries or near misses occurred

Sloughing of paraffin wax fuel grain inside combustion chamber	Major	Could cause a blockage of the nozzle leading to a buildup of pressure and injury due to shrapnel of exploding combustion chamber	● Addition of carbon black powder to the wax makes it harder for heat to transfer through the grain and cause melting. ● Nozzle closure is designed to separate from the combustion chamber if pressure builds up due to a blockage.	● Press emergency shutoff on the test controller ● Check the live video for any fire in the visible surrounding area - if video feed does not work then proceed outside cautiously to gain a visual of the testing area ● If video shows it is safe to do so, CTO and NOS will exit the bunker with a fire extinguisher and evaluate the situation outside - put out fires if necessary ● If safe to do so, CTO and NOS walk over to the testing area and turn off the manual tank valve (while wearing face shield and thermally insulating gloves)		Report incident; investigate the root cause and review control measures if any serious injuries or near misses occurred
Ignition of paraffin wax prematurely	Major	Could cause burns due to extreme heat and a potential fire hazard	● Ignition system can only be armed by inserting a key that is held by the CTO at all times. Ignition system is only armed once all members are in the Spars Building control room or at least 50m from the test area ● Fire extinguishers and sand buckets are required for all tests to put out any small fires	● Evacuate all members from test area ● Make sure everybody is uninjured - emergency services should be called on 999 immediately for any serious injuries, burns should be treated with first-aid ● CTO and NOS proceed cautiously back to the testing area with a fire extinguisher and bucket of sand ● Put out the fire if safe to do so	CTO	Report incident; investigate the root cause and review control measures if any serious injuries or near misses occurred

Engine becomes detached from the test stand	Major	Could spread fire away from the test area and/or impact other components or people causing critical damage or serious injury.	● Engine is securely mounted to the test stand at 3 points to take both the axial thrust load and any side loading that occurs. ● Test stand is placed inside a steel test cell that is sunk into the ground to contain the engine in the event it detaches from its mounting points	● Press emergency shutoff on the test controller ● Make sure everybody is uninjured in the test bunker - emergency services should be called on 999 immediately for any serious injuries ● Check the live video for any fire in the visible surrounding area - if video feed does not work then proceed outside cautiously to gain a visual of the testing area ● If video shows it is safe to do so, CTO and NOS will exit the bunker with a fire extinguisher and evaluate the situation outside - put out fires if necessary ● Check that any members outside the bunker at a distance are uninjured - call 999 immediately for serious injuries ● If safe to do so, CTO and NOS walk over to the testing area and turn off the manual tank valve (while wearing face shield and thermally insulating gloves)	CTO	Report incident; investigate the root cause and review control measures if any serious injuries or near misses occurred

Test stand moves during a hot fire	Major	Could direct the hot exhaust in unintended directions causing fires or damage to equipment that could lead to serious injury	● Test stand is securely fastened to a ~50kg steel box that is sunk into the ground and packed in place to prevent movement	● Press emergency shutoff on the test controller ● Make sure everybody is uninjured in the test bunker - emergency services should be called on 999 immediately for any serious injuries ● Check the live video for any fire in the visible surrounding area - if video feed does not work then proceed outside cautiously to gain a visual of the testing area ● If video shows it is safe to do so, CTO and NOS will exit the bunker with a fire extinguisher and evaluate the situation outside - put out fires if necessary ● Check that any members outside the bunker at a distance are uninjured - call 999 immediately for serious injuries ● If safe to do so, CTO and NOS walk over to the testing area and turn off the manual tank valve (while wearing face shield and thermally insulating gloves)	CTO	Report incident; investigate the root cause and review control measures if any serious injuries or near misses occurred

Power loss occurs	Minor	Could cause the plumbing system to enter an unknown state if the electronic system shuts down unexpectedly.	● Vent valves are designed to have a backup “slow leak” line that will slowly depressurise the tank in case of electrical valve failure. ● Camera system and engine control systems are battery powered so unaffected by mains power issues. ● Batteries will be charged before any test day to ensure they don't run out during a test. Batteries are tested with a multimeter during setup of equipment on the day.	● If live camera system is working, assess whether it is safe to proceed to the test area ● If no live video feed is available, proceed with extra caution ● CTO and NOS will exit the bunker and evaluate the situation outside ● If safe to do so, CTO and NOS walk over to the testing area and turn off the manual tank valve (while wearing face shield and thermally insulating gloves)	CTO	Report incident; investigate the root cause and review control measures if any serious injuries or near misses occurred
Burns to hands	Major	Engine components can be hot after a test fire and could cause burns if touched before it has cooled down	∉ Brief all participating members that they should not touch the engine for at least 15 minutes after a test fire.	∉ Quickly move team member to the sink in the Spars Building and run the burnt area of skin under cold water for several minutes ∉ Apply first aid (seek further medical attention for serious burns)	CTO	Report incident; investigate the root cause and review control measures if any serious injuries or near misses occurred
Exposure to methanol liquid/vapors	Major	Ingestion/inhalation of methanol can cause headaches, nausea and visual disturbances including partial or total loss of vision Skin/eye exposure can cause irritation, redness and pain	∉ Methanol should only be stored in clearly labeled containers ∉ Methanol containers should be stored in an isolated room when not in use, away from areas where food is consumed ∉ Containers of methanol should only be opened outside or in well ventilated	∉ If the team member experiences eye exposure, immediately begin eye wash and seek further medical attention ∉ If the team member ingests or inhales large amounts of methanol, remove them to an area with fresh air and immediately seek further medical attention.	PSO	Report incident; ensure affected team members have fully recovered or seek further medical attention if symptoms remain

			areas to avoid significant inhalation ∉ Those working with methanol should wear appropriate PPE, including face shield, lab coat, and methanol safe gloves	∉ If the team members skin is exposed, wash affected area with soap and water. Rinse/flush exposed skin gently using water for 15-20 minutes		
Fire near methanol storage container or propellant tank	Major	Methanol is a very flammable chemical, open fires near a storage container could result in an explosion or uncontrollable fire.	∉ Methanol is stored in a closed container, outside in a well ventilated space, and away from any oxidising agents ∉ When methanol is being used all potential ignition sources and oxidisers are kept far away	∉ Wait until all tanks are safely depressurized. If safe to do so extinguish fire with a CO2 fire extinguisher (located in Spars Hallway). Evacuate all team members from the area and call emergency services if fire continues to spread.	PSO	Report incident, assess whether test setup or procedures need to be altered to prevent future fires.
Small fire in test cell or surrounding area	Minor	Sparks or hot material ejected from the engine during firing could ignite flammable material in the surrounding area	∉ Flame trench is designed to catch and contain objects ejected in the engine exhaust rather than deflect them out of the test cell ∉ Flammable material in the direction of firing should be cleared prior to each test	∉ Wait until all tanks are safely depressurized. If safe to do so extinguish fire with a Foam or CO2 fire extinguisher (located in Spars Hallway). Evacuate all team members from the area and call emergency services if fire continues to spread.	PSO	Report incident, assess whether test setup or procedures need to be altered to prevent future fires.

Imperial College
London

FORM FW1

HAZARD AND RISK IDENTIFICATION FOR FIELDWORK ACTIVITIES

This form aids in identifying the hazards and risks associated with conducting offsite work, including all fieldwork, in the UK or abroad and conference travel or hosted activities defined as high risk or where local circumstances require a risk assessment.

This form must be used in conjunction with the Offsite Work Emergency Response Procedures (OWERP)- See Appendix 1, and any associated risk assessment forms identified within this document and should be completed with reference to the Safety Department Off-Site working guidance and Staff travel advice.

All risk assessments must be reviewed by the Principal Investigator, offsite co-ordinator, where appointed, and the faculty appointed safety officer.

Approval from the HoD is required for high-risk offsite work. Check with your Faculty Policy on whom else may be required to give consent. High risk work is defined as:

- **Any activity taking place in a country or region that the Foreign and Commonwealth Office (FCO) advise against.**
- **Any activity taking place in a country or region listed with the College insurance with limitations in Insurance cover**
- **Work including taught fieldwork involving undergraduate students**
- **Any activity requiring residence overseas for more than 3 months (Please contact OH and your strategic HR partner for further advice)**
- **The activity or procedure is high risk (refer to the questions highlighted in red within this document)**

It is the responsibility of the ICL person directing the research (E.g. the Principal Investigator) to ensure that all these requirements are complied with and that this risk assessment remains valid.

This form and the OWERP, once completed and reviewed, must be retained by the offsite coordinator or the Faculty appointed Safety Officer. This is especially important in the event of an incident when the contact details may need to be accessed quickly.

ICL PRINCIPAL INVESTIGATOR OR PERSON IN CHARGE.		
Name: [redacted] [redacted]		Position: Academic Supervisor
Department/ Section: Aeronautics	Division:	Faculty: Engineering

PERSON CONDUCTING THIS ASSESSMENT.	
Name: [redacted]	Position: ICLR Propulsion Technical Lead
Department/ Section: Aeronautics	Date risk assessment undertaken: 30/01/2023

THE ACTIVITY		
Title: Hot-fire testing of ICLR Hybrid and Bipropellant engines		
Proposed start date for this work: February 2023	Proposed end date for this work (if known):	
Purpose of the activity: Taught fieldwork: ☐	Research: ☐	Other: ☒ (if other, describe): Project Testing

LOCATION OF THE ACTIVITY OR ACTIVITIES		
Country: United Kingdom	City/town: London	Province/Region:

Full address (include GPS coordinates if known): Buckhurst Rd, Berks SL5 7PY	Is this your home country Yes ☒ No ☐	

INDEPENDENT OR JOINT ACTIVITIES	
Will this work be conducted with any other organisation or institution? Yes ☐ No ☒	**If no, proceed to Section 1**
Name, address and contact number of the other organisation:	
Describe this involvement:	
Name and address of local contact:	

1. INTRODUCTION

1.1 DESCRIPTION OF THE FIELDWORK ACTIVITY

Provide a detailed description. This must be sufficiently detailed so as to provide the reviewer with an adequate insight into the work. If possible please include an itinerary, if not included elsewhere, even if it is approximate. You may refer to and append documents as necessary.

The activity is undertaken by Imperial College London Rocketry at the Silwood Park campus, and entails the ground testing of student-developed hybrid and liquid rocket engines on a bespoke test stand, specifically designed to facilitate testing at this scale. This activity is scheduled to start during December 2022 - September 2023, and further tests will be planned, provided their initial success and the ultimate suitability of the testing site. In addition, this is to be a multi-event series of tests, as research goals may require that multiple tests be conducted in a day - a more detailed overview of the relevant procedures is provided below.

The testing consists of hot-fire testing of a 3kN liquid rocket engine which uses nitrous oxide as an oxidiser and methanol alcohol as a fuel. The test setup consists of a static testing rig to contain the engine, load cell mounting bracket, exhaust plume diverter, fluid system with nitrous oxide run tank, methanol fuel tank, BOC Nitrogen cylinder for system's pressurisation and a BOC nitrous oxide cylinder on a tank inverter rig. See Figure 1 and Figure 2 for further details.

Cold flow testing shall test the fluid system connections for leaks, and will only be conducted once per testing session. Hot fire testing shall be performed up to 10 times per test date. During the first hot fire testing campaign, tests shall last a maximum of 15 seconds. The maximum testing frequency is once per week.

These tests will be conducted in a remote area with little-to-no human activity, owing to the inherent risks of propulsion systems testing; however, there are two primary mechanisms in place to prevent large-scale accidents. The first is an over-pressurisation prevention system, which detaches the nozzle closure in the direction of the exhaust plume (a safe direction). This fail-safe design will ensure that a catastrophic explosion cannot take place. By virtue of their design, upon catastrophic failure (i.e. an explosion), combustion ceases for liquid engines, as there is no longer contact between the oxidiser and fuel, and neither is flammable on their own. The second major safety mechanism is an emergency shutoff system that will stop the flow of nitrous oxide and methanol if commanded, or in the event of a power failure. This will immediately shut down the engine. Furthermore, although the testing site will have a paved section, it is surrounded by grassland - therefore, a plume diverter will be used to direct the exhaust flames upwards, away from flammable materials.

For a detailed itinerary as well as procedures and safety measures taken, please see the dedicated risk assessment for the hot fire tests.

1.2 JUSTIFICATION FOR THE ACTIVITY

Provide a justification for the offsite activity, which takes into account the risk from the activity and location and the academic and educational benefits of the trip. E.g. if the work can be conducted equally well from ICL premises using video conferencing why is it necessary to travel?

Rocket engine engineering is by nature quite difficult and somewhat empirical. As such, despite advanced modelling software, it is impossible to fully understand or predict the behaviour of bespoke engines. In order to understand how effective the design is and if it is suitable for flight, the engine must be thoroughly tested with a series of short & long duration firing tests. Additionally, the conditions must aptly resemble those of flight, as such using similar (or identical) fluid systems, maintaining the same procedure for filling and emptying. These tests will give the team experience and knowledge of the engine's behaviour, ensuring flight tests can be conducted safely, or the engine modified.

Given the risks taken when testing a rocket engine, it is incredibly difficult to find suitable locations within London to effectively and safely test the engine. The remote setting of Silwood park provides an advantage in that, if something were to go wrong, very few people would be in harms way. Additionally, the remote location provides a more flexible test set-up allowing for more accurate testing conditions that better mimic how the engine will be used.

1.3 DURATION OF THE PROJECT AND NUMBER OF PERSONS INVOLVED

Number of trips	**Duration of each trip**	**Number of Imperial College members per trip**	**Number of non-Imperial staff members involved**
2 – 3	6 hours	5 – 10	0

2. CONTACT DETAILS

2.1.1 Available emergency support

Full name	**CID**	**Position**	Email	**Mobile / Satellite phone**	**Land line**
[redacted]		Principal Investigator	[redacted]@imperial.ac.uk	[redacted]	[redacted]
		Person in charge e.g. Supervisor			
		Offsite co-ordinator			
		In country offsite leader or local contact			
		Other.			

College insurance medical and emergency hot line (24/7, 365 days / year): [redacted]	
Imperial College Security on call Support No. (24/7): College 24hr 365 days security control room: 020 7589 1000 & 0207 594 8910	
Local emergency services, Police, Ambulance, fire etc:	Telephone:
British Embassy, High Commission or consulate, (Overseas trips only):	Telephone:
Other:	Telephone:

2.1.2 Nearest hospital or medical field station.

Name and address.

Telephone number.

2.1.3 Names and contact details of ICL personnel conducting the offsite work

Full name	**CID**	**Position / Role in group**	**Email**	**Telephone (Imperial)**	**Telephone (offsite)**
[redacted]	[redacted]	Propulsion Team Lead	[redacted]@ic.ac.uk		[redacted]
[redacted]	[redacted]	Propulsion Technical Lead and Safety Officer	[redacted]@ic.ac.uk		[redacted]

3. TRAVEL TO, FROM AND DURING THE FIELDWORK

♣ *Guidance on fieldwork travel and Staff travel and expenses*

3.1 ALL METHODS OF TRAVEL TO, FROM AND DURING THE FIELDWORK ACTIVITY

Mode	**Type e.g. plane, helicopter, ferry, inflatable dinghy**	**Commercial carrier or private hire (or other)?**	**If commercial carrier, how will they be selected?**	**If using a private motor vehicle, who will be driving or in control of the vehicle?**	**How frequently and at what stage of the trip will the different modes of travel be used?**	**Carrier name and trip ID where applicable e.g. Airline and flight No.** **OUT**	**Carrier name and trip ID where applicable e.g. Airline and flight No.** **RETURN**
Air							
Rail							
Road	Car	Private			Once at the start Once at the end		
Water							
Other							

3.2 HAZARDS AND RISKS

3.2.1 Describe the hazards and risks that may be encountered during the travel and the precautions that will be taken to address these

Hazard/risk	**Hatch if applicable**	**Detail the precautions to be taken**
Navigation in remote areas	☐	
Security in unsafe or insecure regions	☐	
Off road or poor road conditions	☐	
Lack of adequate training in use of the vehicle or equipment	☐	
Poorly maintained vehicles or equipment	☐	
Lone travel For example: Travel without a trusted companion in an environment where help in the event of a medical emergency would not be reasonably expected to be forthcoming or where there is a foreseeable risk of abduction, assault, or robbery.	☐	*Note: Refer to Lone working policy.*
Other (specify)	☐	

4. ACCOMMODATION

♣ *Guidance on Accommodation*

4.1 LIST THE ACCOMODATION USED WHEN TRAVELLING TO OR FROM THE ACTIVITY OR DURING THE ACTIVITY

Type	**Details**	**When will this be used?**	**What reliable information do you have on the suitability of the accommodation?**

			Note: Indicate if this is parental or own home
Private, includes parental or own home			
Hotel/Motel			
Camping			
Other			

4.2 HAZARDS AND RISKS

4.2.1 Describe the hazards and risks that may be associated with the accommodation

Hazard/risk	**Provide details of the hazard/risk and the precautions to be taken**
Security	
Food/water quality	(See also Sections 4.2.2 and 4.2.3)
Fire	
Other	

5. HAZARDS AND RISKS ASSOCIATED WITH THE LOCATION

5.1 ALL DESTINATIONS OUTSIDE OF THE UK

5.1.1 Are you going abroad?

Yes ☐	No ☒	**If not, then proceed to Section 5.2**

5.1.2 Have you checked the Foreign and Commonwealth Office (FCO) country advice and the College Insurers web pages?

Yes ☐	No ☐
If no why not?	

5.1.3 Does the FCO or the College Insurer advise against travel to the country or to particular regions thereof in which the fieldwork will be conducted?

Yes ☐	No ☐	N/R ☐

If yes, ensure that the FCO advice is incorporated into this risk assessment and sufficient detail is included to demonstrate to the reviewer that the particular risks posed by the region or activity have been controlled and justification is given in section 1.2 as to why the work should proceed. Typical risks might include: Civil unrest, robbery, abduction, poor health care, natural disasters, violent crime, discrimination etc

Risk	**Controls**

5.1.4 Are members able to speak the local language?

Yes ☐	No ☐
If no, how will they communicate?	

5.2 ALL DESTINATIONS

5.2.1 For the terrain on, and climate in which the fieldwork will be undertaken describe the hazards and risk and the precautions to be taken to control these. Guidance is available and should be consulted when completing this section.

Terrain		**Hazards/risks**	**Precautions**
Areas of high relief, altitude, mountains and cliffs	☐		
Agricultural land	☐		
Railways, motorways and roads	☐		
Woods and forests	☐		
Coastlines, estuaries, mudflats and salt marshes	☐		
Bogs, mires and swamps	☐		
Rivers, lakes, reservoirs and their margins	☐		
Tropical or hot climates	☐		
Deserts, uplands and arid zones	☐		
Cold climates	☐		
Other	☐		

5.2.2 Will you have an unlimited supply of safe drinking water?

Yes ☒ No ☐

If yes, describe the source and any treatment to be carried out:

If no, how much will you have access to per day:

5.2.3 Where will you source your food? Describe how this will be prepared and any restrictions regarding what can and cannot be consumed.

5.2.4 Describe the hygiene facilities available

5.2.5 Will the group split up at any stage of the trip?

Yes ☐ No ☒

If yes, describe how this will be managed and what additional precautions are required:

5.2.6 How will the group maintain communications? Guidance is available.

Between those in the field?

Between those in the field and those at Imperial College?

6. HAZARDS AND RISKS ASSOCIATED WITH THE FIELDWORK ACTIVITY

6.1.1 Will the work involve any of the following?

Hazard	**Hatch if expected**	**Risk assessment form**
Will you be using hazardous chemicals	☒	COSHH form or equivalent
Deliberate use of biological agents?	☐	Bio1 or equivalent
Processing of human blood, excreta or other bodily fluids?	☐	Bio1 or equivalent

This form and the ERP, once completed, must be retained by the offsite coordinator or the Faculty appointed Safety Officer.

Use of genetically modified organisms	☐	Bio1 or equivalent
Work with ionising radiation (sealed and unsealed sources)	☐	Registration Forms

6.1.2 Will the activity involve the use of any hazardous equipment? E.g. cranes for lifting operations, lasers etc

Yes ☐ No ☒

If yes, provide details and describe the precautions required:

6.1.3 Will any member of the party be engaged in sub aqua diving?

Yes ☐ No ☒

If yes, provide details of the activity and the precautions to be taken. Separate risk assessment / SOP's for these activities will be required and should be referenced here:

Note that if diving, a health clearance form will need to be completed for each member.

6.1.4 Will the activity involve any members of the party working at height? E.g. climbing, ladders, abseiling etc

♣ *Yes ☐ No ☒*

♣ *If yes, provide details and describe the precautions required or reference a separate risk assessment:*

6.1.5 Will the activity involve and members of the party working in excavations or confined spaces? E.g. archaeological excavation trenches, caving etc

♣ *Yes ☐ No ☒*

♣ *If yes, provide details and describe the precautions required or reference a separate risk assessment:*

6.1.6 Will any part or stage of the work be carried out by a lone worker?

Yes ☐ No ☒

If yes, you must speak to you Faculty appointed Safety Officer.

Describe what this work is, how this will be managed and what additional precautions are required.

Note: Lone work is strongly discouraged. Where it occurs there must be justification and systems in place to mitigate the risks. Consult College and your Faculty Policy on lone work

6.1.7 Does the project involve sensitive or emotive subjects e.g. that might upset or cause offence to individuals or the populace?

Yes ☐ No ☒

If yes justify the activity, are staff sufficiently experienced or trained to deal with this professionally and sensitively:

6.1.8 Will you be taking any of the following substances or materials from Imperial College to the fieldwork site?

Item	**Hatch if expected**	**Comments**
Material known or suspected of containing Genetically Modified Organisms or micro-organisms	☐	Permission **may** be required before the material is taken. Contact the College Biological Safety Officer (BSO)
Material known or suspected of containing Biological agents categorised in Hazard Group 2, 3 or 4	☐	Permission **may** be required before the material is taken. Contact BSO.
Material known or suspected of containing substances covered by the Anti-Terrorism, Crime and Security act	☐	Permission **will** be required before the material is taken. Contact BSO.
Radioactive material *See Who's who in the Safety Department*	☐	Permission **may** be required before the material is taken. Contact the College Radiation Protection Adviser (RPA).

6.1.9 Does the work involve bringing back any of the following to Imperial College?

Item	**Hatch if expected**	**Comments**
Material known or suspected of containing Genetically Modified Organisms or micro-organisms	☐	Permission must be obtained before the material is brought onto College premises. Contact BSO

Material known or suspected of containing Biological agents categorised in Hazard Group 2, 3 or 4	☐	Permission must be obtained before the material is brought onto College premises. Contact BSO
Material known or suspected of containing substances covered by the Anti-Terrorism, Crime and Security Act	☐	Permission must be obtained before the material is brought onto College premises. Contact BSO
Radioactive materials *See Who's who in the Safety Department*	☐	Permission **may** be required before the material is brought onto College premises. Contact RPA.
Animal by-products – See DEFRA guidance	☐	Permission may be required before the material is brought onto College premises. Contact BSO
Animal pathogens – See DEFRA guidance	☐	Permission may be required before the material is brought onto College premises. Contact BSO
Plant material or soils – See DEFRA guidance	☐	Permission may be required before the material is brought onto College premises. Contact BSO
Drug precursors *See Who's who in the Safety Department*	☐	Permission may be required before the material is brought onto College premises.

6.1.10 If any of the above are to be brought back to the College (or elsewhere in the UK) describe how these will be transported? See Dangerous goods transportation

	N/R ☐

6.1.11 If any of the above are to brought back to the College (or elsewhere in the UK) describe how any relevant permissions e.g. licensing have been obtained (or state whether any exemptions apply).

	N/R ☐

6.1.12 Will the activity generate any hazardous waste not described within the specific risk assessments listed in Section 5.1.1?

Yes ☐ No hazardous waste generated Hazardous waste is generated but is described elsewhere ☐ in form
If yes, how will this be treated and/or disposed of?

6.1.13 Are there any other hazards, not covered above, that may be encountered?

Yes ☒ No ☐
If yes, please describe: There are several risks associated with the hot-firing of a bespoke hybrid engine. These have been outlined in detail in the dedicated risk assessment that is provided alongside this fieldwork risk assessment.

7. OCCUPATIONAL HEALTH

7.1.1 Confirm that all trip members have read Occupational Health travel guidance

Yes, they have ☒ No, they have not ☐Comments?

7.1.2 Does the trip involve working in malaria endemic tropical countries, areas more than 24 hours travel distance from medical support, or activities requiring a high standard of physical fitness or is the trip duration longer than 3 months?

Yes ☐ No ☒	
If yes, have all members completed the Travel Questionnaire form from Occupational Health?	Yes ☐ No ☐ N/R ☐
If any specific precautions have been advised have these been implemented?	Yes ☐ No ☐ N/R ☐
Summarise these precautions here.	

7.1.3 Are any vaccinations recommended or required for travel to this country or region? See Occupational Health travel guidance, and Fit for travel link http://www.fitfortravel.nhs.uk/destinations.aspx

Yes ☐ No ☒
If yes, what are these?
If yes, have all members arranged to obtain these vaccinations?

7.1.4 Is malaria prophylaxis required?

Yes ☐ No ☒
If yes, what drugs are recommended?
If yes, have all members of the trip made arrangements to obtain this prophylaxis?

7.1.5 Is vector-borne (e.g. by insect) or parasitic disease a hazard in the area of travel or fieldwork?

Yes ☐ No ☒
If yes, describe with the vectors and the disease and the precautions to be taken to minimize the likelihood of transmission. If this has been dealt with already in this form then provide the section reference:

7.1.6 Will you be working with patients, or collecting or handling clinical specimens?

Yes ☐ No ☒
If yes, then those involved should be vaccinated against Hepatitis B
If yes, and if working for > 1month in a high TB prevalence country then BCG vaccination may be advised
If yes, and if working in a high HIV prevalence country, then HIV prophylaxis may be advised

7.1.7 Will you be working with wild, domestic or agricultural animals, or material collected from these?

Yes ☐ No ☒
If yes, describe any details of this aspect of the activity not already described in Section 1.1:
If yes, what are the risks of zoonosis and describe the precautions taken to minimise this?
If yes, what are the risks of physical injury being caused and the precautions that will be taken?
If yes, are there any other hazards associated with this aspect of the activity?

8. OFFSITE WORK EMERGENCY RESPONSE PROCEDURES (OWERP)

Please complete the relevant sections of the OWERP form, also available in Appendix 1, for the following.

1. Whenever an FW1 is completed.
2. ALL high risk offsite work, See page 1 of the FW1 for the definition of high risk.
3. Where Faculty Policy requires it.
4. Any trip where the person in charge has determined by risk assessment that there is a need for more detailed planning.

Note that incidents (accidents [including ill-health] or near misses) that occur during fieldwork trips must be reported to the College Safety Department via Salus.

9. TRAINING

9.1.1 Identify those trip members that require and have received the following training? See Safety Training and Occupational Health First Aid

Training type	**Full name**	**Date of training**
Personal First Aid		
Basic Fieldwork First Aid		
Fieldwork First Aid		
Advanced Fieldwork First Aid		
RGS: Offsite Safety Management (OSSM)		
RGS: Off-road driving		
Personal Security & Kidnap (Clarity Security Training)		

9.1.2 Identify any other training courses and those that have attended these.

Training type	**Full name**	**Date of training**

This form and the ERP, once completed, must be retained by the offsite coordinator or the Faculty appointed Safety Officer.

10. APPROVALS

The PI must approve the offsite activity before commencement. Where the PI is the person engaged in the activity then approval must be obtained from their line manager.

The off-site coordinator or Faculty appointed safety officer must review all fieldwork activities before commencement.

All other approvals identified within any associated activity risk assessments must also be in place.

The Principal Investigator and Offsite Coordinator must confirm the following statements by adding their details and date below.

I have reviewed this risk assessment, OWERP and other supporting documentation and consider them suitable and sufficient for the proposed activity.	Title and name [redacted]	Date: 10th December 2021
I retain managerial responsibility for the safety and welfare of those persons listed in Section 6.1.1 and, as such, confirm the validity of the information provided in this form and give assurance that all reasonably practicable measures have been put in place to manage the risks associated with this fieldwork activity and give my approval for the work to commence.	Title and name: [redacted]	Date: **24/02/2023**

11. APPROVAL FOR HIGH RISK OFFSITE WORK.

The HoD must approve any high-risk offsite work. Please refer to your Faculty Policy for any additional approvals that may be required. High risk work is defined on page 1.

HEAD OF DEPARTMENT APPROVAL		
I have reviewed this risk assessment and consider that the additional risks posed by the country or region in which the work is taking place and the activities being undertaken have been controlled so far as is reasonably practical and there is a continued academic requirement for the work to proceed which justifies the increased risk.	Title and Name:	Date:
ADDITIONAL APPROVAL (Where required by Faculty Policy)	Title and Name:	Date:

12. OFF SITE EMERGENCY RESPONSE PROCEDURES (OWERP)

Appendix 1.

Relevant sections to be completed under the following circumstances:

1. All work requiring an FW1.
2. ALL high risk offsite work.
3. Where Faculty Policy requires it.
4. Any trip where the person in charge has determined by risk assessment that there is a need for more detailed planning.

Sections can be omitted where this information is already included in the risk assessment for example in the FW1.

1. AVAILABLE EMERGENCY SUPPORT

Full name	**CID**	**Position**	Email	**Mobile / Satellite phone**	**Land line**
		Principal Investigator			
		Person in charge e.g. Supervisor			
		Offsite co-ordinator			
		In country offsite leader or local contact			
		Other			

Nearest hospital or medical field station.	Name: Address: Telephone:
College insurance medical and emergency hot line (24/7, 365 days / year):	[redacted]
Imperial College Security on call Support No. (24/7):	College South Kensington 24hr 365 days security control room: 020 7589 1000 & 0207 594 8910
Local emergency services, Police, Ambulance, fire etc:	Telephone:
British Embassy, High Commission or consulate:	Telephone:
Other:	Telephone:

2. Names and contact details of ICL personnel conducting the offsite work

Full name	**CID**	**Position / Role in group**	**Email**	**Telephone (Imperial)**	**Telephone (offsite)**

3. Emergency Response Procedures

This form and the ERP, once completed, must be retained by the offsite coordinator or the Faculty appointed Safety Officer.

Event	**Procedure**
Missing persons	Give details of planned check in times and what to do if a check in time is missed. Use the separate sheet below if necessary:
	Who will you attempt to contact and in what order: Add more rows as necessary. 1. 2.
Civil unrest and natural disasters	Give details of how the field worker will be alerted to the problem and what they will do in response:
Medical emergencies and repatriation	Give details of how the field worker will respond to illness or injury. If they are unable to self help give details of who will assist and what they will be expected to do:
Financial plan for emergencies	Give details of what funds are available for medical assistance, repatriation and other emergencies such as vehicle breakdowns and how these funds would be made available:
Communication strategy	Give details of the communications equipment that you are taking with you, when it will be used, and how effective it will be:
Media management plan	In the event of an emergency give details of how you will manage the media attention, e.g. who will inform the college media department:
Next of Kin	Before travel ensure that your next of kin details are up to date with ICL HR
College insurance policy no:	Policy number: [redacted]

4. MISSING PERSONS: PLANNED CHECK IN TIMES CONTINUATION SHEET

Serial	**Phase in Itinerary / Activity**	**Date**	**Local Time**	**UK Time**

5. Flight / travel details, continuation from FW1 for complex travel

Carrier name and trip ID e.g. Airline and flight No. OUT	Carrier name and trip ID e.g. Airline and flight No. RETURN

6. ACTIVITY PHASES, where requested for more complex projects.

Serial	Details of Activity	**Dates**

This form and the ERP, once completed, must be retained by the offsite coordinator or the Faculty appointed Safety Officer.

Imperial College
London

FORM FW1

HAZARD AND RISK IDENTIFICATION FOR FIELDWORK ACTIVITIES

This form aids in identifying the hazards and risks associated with conducting offsite work, including all fieldwork, in the UK or abroad and conference travel or hosted activities defined as high risk or where local circumstances require a risk assessment.

This form must be used in conjunction with the Offsite Work Emergency Response Procedures (OWERP)- See Appendix 1, and any associated risk assessment forms identified within this document and should be completed with reference to the Safety Department Off-Site working guidance and Staff travel advice.

All risk assessments must be reviewed by the Principal Investigator, offsite co-ordinator, where appointed, and the faculty appointed safety officer.

Approval from the HoD is required for high-risk offsite work. Check with your Faculty Policy on whom else may be required to give consent. High risk work is defined as:

- **Any activity taking place in a country or region that the Foreign and Commonwealth Office (FCO) advise against.**
- **Any activity taking place in a country or region listed with the College insurance with limitations in Insurance cover**
- **Work including taught fieldwork involving undergraduate students**
- **Any activity requiring residence overseas for more than 3 months (Please contact OH and your strategic HR partner for further advice)**
- **The activity or procedure is high risk (refer to the questions highlighted in red within this document)**

It is the responsibility of the ICL person directing the research (E.g. the Principal Investigator) to ensure that all these requirements are complied with and that this risk assessment remains valid.

This form and the OWERP, once completed and reviewed, must be retained by the offsite coordinator or the Faculty appointed Safety Officer. This is especially important in the event of an incident when the contact details may need to be accessed quickly.

ICL PRINCIPAL INVESTIGATOR OR PERSON IN CHARGE.

Name: [redacted] [redacted]		Position: Academic Supervisor
Department/ Section: Aeronautics	Division:	Faculty:

PERSON CONDUCTING THIS ASSESSMENT.

Name: [redacted]	Position: ICLR Propulsion Technical Lead
Department/ Section: Aeronautics	Date risk assessment undertaken: 30/01/2023

THE ACTIVITY

Title: Hot-fire testing of ICLR Hybrid and Bipropellant engines		
Proposed start date for this work: February 2023	Proposed end date for this work (if known):	
Purpose of the activity: Taught fieldwork: ☐	Research: ☐	Other: ☒ (if other, describe): Project Testing

LOCATION OF THE ACTIVITY OR ACTIVITIES

Country: United Kingdom	City/town: London	Province/Region:

Full address (include GPS coordinates if known): Buckhurst Rd, Berks SL5 7PY	Is this your home country Yes ☒ No ☐	

INDEPENDENT OR JOINT ACTIVITIES

Will this work be conducted with any other organisation or institution? Yes ☐ No ☒	**If no, proceed to Section 1**
Name, address and contact number of the other organisation:	
Describe this involvement:	
Name and address of local contact:	

1. INTRODUCTION

1.1 DESCRIPTION OF THE FIELDWORK ACTIVITY

Provide a detailed description. This must be sufficiently detailed so as to provide the reviewer with an adequate insight into the work. If possible please include an itinerary, if not included elsewhere, even if it is approximate. You may refer to and append documents as necessary.

The activity is undertaken by Imperial College London Rocketry at the Silwood Park campus, and entails the ground testing of student-developed hybrid and liquid rocket engines on a bespoke test stand, specifically designed to facilitate testing at this scale. This activity is scheduled to start during December 2022 - September 2023, and further tests will be planned, provided their initial success and the ultimate suitability of the testing site. In addition, this is to be a multi-event series of tests, as research goals may require that multiple tests be conducted in a day - a more detailed overview of the relevant procedures is provided below.

The testing consists of hot-fire testing of a 3kN liquid rocket engine which uses nitrous oxide as an oxidiser and methanol alcohol as a fuel. The test setup consists of a static testing rig to contain the engine, load cell mounting bracket, exhaust plume diverter, fluid system with nitrous oxide run tank, methanol fuel tank, BOC Nitrogen cylinder for system's pressurisation and a BOC nitrous oxide cylinder on a tank inverter rig. See Figure 1 and Figure 2 for further details.

Cold flow testing shall test the fluid system connections for leaks, and will only be conducted once per testing session. Hot fire testing shall be performed up to 10 times per test date. During the first hot fire testing campaign, tests shall last a maximum of 15 seconds. The maximum testing frequency is once per week.

These tests will be conducted in a remote area with little-to-no human activity, owing to the inherent risks of propulsion systems testing; however, there are two primary mechanisms in place to prevent large-scale accidents. The first is an over-pressurisation prevention system, which detaches the nozzle closure in the direction of the exhaust plume (a safe direction). This fail-safe design will ensure that a catastrophic explosion cannot take place. By virtue of their design, upon catastrophic failure (i.e. an explosion), combustion ceases for liquid engines, as there is no longer contact between the oxidiser and fuel, and neither is flammable on their own. The second major safety mechanism is an emergency shutoff system that will stop the flow of nitrous oxide and methanol if commanded, or in the event of a power failure. This will immediately shut down the engine. Furthermore, although the testing site will have a paved section, it is surrounded by grassland - therefore, a plume diverter will be used to direct the exhaust flames upwards, away from flammable materials.

For a detailed itinerary as well as procedures and safety measures taken, please see the dedicated risk assessment for the hot fire tests.

1.2 JUSTIFICATION FOR THE ACTIVITY

Provide a justification for the offsite activity, which takes into account the risk from the activity and location and the academic and educational benefits of the trip. E.g. if the work can be conducted equally well from ICL premises using video conferencing why is it necessary to travel?

Rocket engine engineering is by nature quite difficult and somewhat empirical. As such, despite advanced modelling software, it is impossible to fully understand or predict the behaviour of bespoke engines. In order to understand how effective the design is and if it is suitable for flight, the engine must be thoroughly tested with a series of short & long duration firing tests. Additionally, the conditions must aptly resemble those of flight, as such using similar (or identical) fluid systems, maintaining the same procedure for filling and emptying. These tests will give the team experience and knowledge of the engine's behaviour, ensuring flight tests can be conducted safely, or the engine modified.

Given the risks taken when testing a rocket engine, it is incredibly difficult to find suitable locations within London to effectively and safely test the engine. The remote setting of Silwood park provides an advantage in that, if something were to go wrong, very few people would be in harms way. Additionally, the remote location provides a more flexible test set-up allowing for more accurate testing conditions that better mimic how the engine will be used.

1.3 DURATION OF THE PROJECT AND NUMBER OF PERSONS INVOLVED

Number of trips	**Duration of each trip**	**Number of Imperial College members per trip**	**Number of non-Imperial staff members involved**
2 – 3	6 hours	5 – 10	0

2. CONTACT DETAILS

2.1.1 Available emergency support

Full name	**CID**	**Position**	Email	**Mobile / Satellite phone**	**Land line**
[redacted]		Principal Investigator	[redacted]@imperial.ac.uk		
		Person in charge e.g. Supervisor			
		Offsite co-ordinator			
		In country offsite leader or local contact			
		Other.			

College insurance medical and emergency hot line (24/7, 365 days / year): [redacted]	
Imperial College Security on call Support No. (24/7): College 24hr 365 days security control room: 020 7589 1000 & 0207 594 8910	
Local emergency services, Police, Ambulance, fire etc:	Telephone:
British Embassy, High Commission or consulate, (Overseas trips only):	Telephone:
Other:	Telephone:

2.1.2 Nearest hospital or medical field station.

Name and address.

Telephone number.

2.1.3 Names and contact details of ICL personnel conducting the offsite work

Full name	**CID**	**Position / Role in group**	**Email**	**Telephone (Imperial)**	**Telephone (offsite)**
[redacted]	[redacted]	Propulsion Team Lead	[redacted]@ic.ac.uk		[redacted]
[redacted]	[redacted]	Propulsion Technical Lead and Safety Officer	[redacted]@ic.ac.uk		[redacted]

3. TRAVEL TO, FROM AND DURING THE FIELDWORK

♣ *Guidance on fieldwork travel and Staff travel and expenses*

3.1 ALL METHODS OF TRAVEL TO, FROM AND DURING THE FIELDWORK ACTIVITY

Mode	**Type e.g. plane, helicopter, ferry, inflatable dinghy**	**Commercial carrier or private hire (or other)?**	**If commercial carrier, how will they be selected?**	**If using a private motor vehicle, who will be driving or in control of the vehicle?**	**How frequently and at what stage of the trip will the different modes of travel be used?**	**Carrier name and trip ID where applicable e.g. Airline and flight No.** **OUT**	**Carrier name and trip ID where applicable e.g. Airline and flight No.** **RETURN**
Air							
Rail							
Road	Car	Private			Once at the start Once at the end		
Water							
Other							

3.2 HAZARDS AND RISKS

3.2.1 Describe the hazards and risks that may be encountered during the travel and the precautions that will be taken to address these

Hazard/risk	**Hatch if applicable**	**Detail the precautions to be taken**
Navigation in remote areas	☐	
Security in unsafe or insecure regions	☐	
Off road or poor road conditions	☐	
Lack of adequate training in use of the vehicle or equipment	☐	
Poorly maintained vehicles or equipment	☐	
Lone travel For example: Travel without a trusted companion in an environment where help in the event of a medical emergency would not be reasonably expected to be forthcoming or where there is a foreseeable risk of abduction, assault, or robbery.	☐	*Note: Refer to Lone working policy.*
Other (specify)	☐	

4. ACCOMMODATION

♣ *Guidance on Accommodation*

4.1 LIST THE ACCOMODATION USED WHEN TRAVELLING TO OR FROM THE ACTIVITY OR DURING THE ACTIVITY

Type	**Details**	**When will this be used?**	**What reliable information do you have on the suitability of the accommodation?**

			Note: Indicate if this is parental or own home
Private, includes parental or own home			
Hotel/Motel			
Camping			
Other			

4.2 HAZARDS AND RISKS

4.2.1 Describe the hazards and risks that may be associated with the accommodation

Hazard/risk	**Provide details of the hazard/risk and the precautions to be taken**
Security	
Food/water quality	(See also Sections 4.2.2 and 4.2.3)
Fire	
Other	

5. HAZARDS AND RISKS ASSOCIATED WITH THE LOCATION

5.1 ALL DESTINATIONS OUTSIDE OF THE UK

5.1.1 Are you going abroad?

Yes ☐	No ☒	**If not, then proceed to Section 5.2**

5.1.2 Have you checked the Foreign and Commonwealth Office (FCO) country advice and the College Insurers web pages?

Yes ☐	No ☐
If no why not?	

5.1.3 Does the FCO or the College Insurer advise against travel to the country or to particular regions thereof in which the fieldwork will be conducted?

Yes ☐ No ☐ N/R ☐

If yes, ensure that the FCO advice is incorporated into this risk assessment and sufficient detail is included to demonstrate to the reviewer that the particular risks posed by the region or activity have been controlled and justification is given in section 1.2 as to why the work should proceed. Typical risks might include: Civil unrest, robbery, abduction, poor health care, natural disasters, violent crime, discrimination etc

Risk	**Controls**

5.1.4 Are members able to speak the local language?

Yes ☐	No ☐
If no, how will they communicate?	

This form and the ERP, once completed, must be retained by the offsite coordinator or the Faculty appointed Safety Officer.

5.2 ALL DESTINATIONS

5.2.1 For the terrain on, and climate in which the fieldwork will be undertaken describe the hazards and risk and the precautions to be taken to control these. Guidance is available and should be consulted when completing this section.

Terrain		**Hazards/risks**	**Precautions**
Areas of high relief, altitude, mountains and cliffs	☐		
Agricultural land	☐		
Railways, motorways and roads	☐		
Woods and forests	☐		
Coastlines, estuaries, mudflats and salt marshes	☐		
Bogs, mires and swamps	☐		
Rivers, lakes, reservoirs and their margins	☐		
Tropical or hot climates	☐		
Deserts, uplands and arid zones	☐		
Cold climates	☐		
Other	☐		

5.2.2 Will you have an unlimited supply of safe drinking water?

Yes ☒ No ☐

If yes, describe the source and any treatment to be carried out:

If no, how much will you have access to per day:

5.2.3 Where will you source your food? Describe how this will be prepared and any restrictions regarding what can and cannot be consumed.

5.2.4 Describe the hygiene facilities available

5.2.5 Will the group split up at any stage of the trip?

Yes ☐ No ☒

If yes, describe how this will be managed and what additional precautions are required:

5.2.6 How will the group maintain communications? Guidance is available.

Between those in the field?

Between those in the field and those at Imperial College?

6. HAZARDS AND RISKS ASSOCIATED WITH THE FIELDWORK ACTIVITY

6.1.1 Will the work involve any of the following?

Hazard	**Hatch if expected**	**Risk assessment form**
Will you be using hazardous chemicals	☒	COSHH form or equivalent
Deliberate use of biological agents?	☐	Bio1 or equivalent
Processing of human blood, excreta or other bodily fluids?	☐	Bio1 or equivalent

Use of genetically modified organisms	☐	Bio1 or equivalent
Work with ionising radiation (sealed and unsealed sources)	☐	Registration Forms

6.1.2 Will the activity involve the use of any hazardous equipment? E.g. cranes for lifting operations, lasers etc

Yes ☐ No ☒

If yes, provide details and describe the precautions required:

6.1.3 Will any member of the party be engaged in sub aqua diving?

Yes ☐ No ☒

If yes, provide details of the activity and the precautions to be taken. Separate risk assessment / SOP's for these activities will be required and should be referenced here:

Note that if diving, a health clearance form will need to be completed for each member.

6.1.4 Will the activity involve any members of the party working at height? E.g. climbing, ladders, abseiling etc

♣ *Yes ☐* *No ☒*

♣ *If yes, provide details and describe the precautions required or reference a separate risk assessment:*

6.1.5 Will the activity involve and members of the party working in excavations or confined spaces? E.g. archaeological excavation trenches, caving etc

♣ *Yes ☐* *No ☒*

♣ *If yes, provide details and describe the precautions required or reference a separate risk assessment:*

6.1.6 Will any part or stage of the work be carried out by a lone worker?

Yes ☐ No ☒

If yes, you must speak to you Faculty appointed Safety Officer.

Describe what this work is, how this will be managed and what additional precautions are required.

Note: Lone work is strongly discouraged. Where it occurs there must be justification and systems in place to mitigate the risks. Consult College and your Faculty Policy on lone work

6.1.7 Does the project involve sensitive or emotive subjects e.g. that might upset or cause offence to individuals or the populace?

Yes ☐ No ☒

If yes justify the activity, are staff sufficiently experienced or trained to deal with this professionally and sensitively:

6.1.8 Will you be taking any of the following substances or materials from Imperial College to the fieldwork site?

Item	**Hatch if expected**	**Comments**
Material known or suspected of containing Genetically Modified Organisms or micro-organisms	☐	Permission **may** be required before the material is taken. Contact the College Biological Safety Officer (BSO)
Material known or suspected of containing Biological agents categorised in Hazard Group 2, 3 or 4	☐	Permission **may** be required before the material is taken. Contact BSO.
Material known or suspected of containing substances covered by the Anti-Terrorism, Crime and Security act	☐	Permission **will** be required before the material is taken. Contact BSO.
Radioactive material *See Who's who in the Safety Department*	☐	Permission **may** be required before the material is taken. Contact the College Radiation Protection Adviser (RPA).

6.1.9 Does the work involve bringing back any of the following to Imperial College?

Item	**Hatch if expected**	**Comments**
Material known or suspected of containing Genetically Modified Organisms or micro-organisms	☐	Permission must be obtained before the material is brought onto College premises. Contact BSO

Material known or suspected of containing Biological agents categorised in Hazard Group 2, 3 or 4	☐	Permission must be obtained before the material is brought onto College premises. Contact BSO
Material known or suspected of containing substances covered by the Anti-Terrorism, Crime and Security Act	☐	Permission must be obtained before the material is brought onto College premises. Contact BSO
Radioactive materials *See Who's who in the Safety Department*	☐	Permission **may** be required before the material is brought onto College premises. Contact RPA.
Animal by-products – See DEFRA guidance	☐	Permission may be required before the material is brought onto College premises. Contact BSO
Animal pathogens – See DEFRA guidance	☐	Permission may be required before the material is brought onto College premises. Contact BSO
Plant material or soils – See DEFRA guidance	☐	Permission may be required before the material is brought onto College premises. Contact BSO
Drug precursors *See Who's who in the Safety Department*	☐	Permission may be required before the material is brought onto College premises.

6.1.10 If any of the above are to be brought back to the College (or elsewhere in the UK) describe how these will be transported? See Dangerous goods transportation

	N/R ☐

6.1.11 If any of the above are to brought back to the College (or elsewhere in the UK) describe how any relevant permissions e.g. licensing have been obtained (or state whether any exemptions apply).

	N/R ☐

6.1.12 Will the activity generate any hazardous waste not described within the specific risk assessments listed in Section 5.1.1?

Yes ☐ No hazardous waste generated Hazardous waste is generated but is described elsewhere ☐ in form
If yes, how will this be treated and/or disposed of?

6.1.13 Are there any other hazards, not covered above, that may be encountered?

Yes ☒ No ☐
If yes, please describe: There are several risks associated with the hot-firing of a bespoke hybrid engine. These have been outlined in detail in the dedicated risk assessment that is provided alongside this fieldwork risk assessment.

7. OCCUPATIONAL HEALTH

7.1.1 Confirm that all trip members have read Occupational Health travel guidance

Yes, they have ☒ No, they have not ☐Comments?

7.1.2 Does the trip involve working in malaria endemic tropical countries, areas more than 24 hours travel distance from medical support, or activities requiring a high standard of physical fitness or is the trip duration longer than 3 months?

Yes ☐ No ☒			
If yes, have all members completed the Travel Questionnaire form from Occupational Health?	Yes ☐	No ☐	N/R ☐
If any specific precautions have been advised have these been implemented?	Yes ☐	No ☐	N/R ☐
Summarise these precautions here.			

7.1.3 Are any vaccinations recommended or required for travel to this country or region? See Occupational Health travel guidance, and Fit for travel link http://www.fitfortravel.nhs.uk/destinations.aspx

Yes ☐ No ☒
If yes, what are these?
If yes, have all members arranged to obtain these vaccinations?

7.1.4 Is malaria prophylaxis required?

Yes ☐ No ☒
If yes, what drugs are recommended?
If yes, have all members of the trip made arrangements to obtain this prophylaxis?

7.1.5 Is vector-borne (e.g. by insect) or parasitic disease a hazard in the area of travel or fieldwork?

Yes ☐ No ☒
If yes, describe with the vectors and the disease and the precautions to be taken to minimize the likelihood of transmission. If this has been dealt with already in this form then provide the section reference:

7.1.6 Will you be working with patients, or collecting or handling clinical specimens?

Yes ☐ No ☒
If yes, then those involved should be vaccinated against Hepatitis B
If yes, and if working for > 1month in a high TB prevalence country then BCG vaccination may be advised
If yes, and if working in a high HIV prevalence country, then HIV prophylaxis may be advised

7.1.7 Will you be working with wild, domestic or agricultural animals, or material collected from these?

Yes ☐ No ☒
If yes, describe any details of this aspect of the activity not already described in Section 1.1:
If yes, what are the risks of zoonosis and describe the precautions taken to minimise this?
If yes, what are the risks of physical injury being caused and the precautions that will be taken?
If yes, are there any other hazards associated with this aspect of the activity?

8. OFFSITE WORK EMERGENCY RESPONSE PROCEDURES (OWERP)

Please complete the relevant sections of the OWERP form, also available in Appendix 1, for the following.

1. Whenever an FW1 is completed.
2. ALL high risk offsite work, See page 1 of the FW1 for the definition of high risk.
3. Where Faculty Policy requires it.
4. Any trip where the person in charge has determined by risk assessment that there is a need for more detailed planning.

Note that incidents (accidents [including ill-health] or near misses) that occur during fieldwork trips must be reported to the College Safety Department via Salus.

9. TRAINING

9.1.1 Identify those trip members that require and have received the following training? See Safety Training and Occupational Health First Aid

Training type	**Full name**	**Date of training**
Personal First Aid		
Basic Fieldwork First Aid		
Fieldwork First Aid		
Advanced Fieldwork First Aid		
RGS: Offsite Safety Management (OSSM)		
RGS: Off-road driving		
Personal Security & Kidnap (Clarity Security Training)		

9.1.2 Identify any other training courses and those that have attended these.

Training type	**Full name**	**Date of training**

This form and the ERP, once completed, must be retained by the offsite coordinator or the Faculty appointed Safety Officer.

10. APPROVALS

The PI must approve the offsite activity before commencement. Where the PI is the person engaged in the activity then approval must be obtained from their line manager.

The off-site coordinator or Faculty appointed safety officer must review all fieldwork activities before commencement.

All other approvals identified within any associated activity risk assessments must also be in place.

The Principal Investigator and Offsite Coordinator must confirm the following statements by adding their details and date below.

I have reviewed this risk assessment, OWERP and other supporting documentation and consider them suitable and sufficient for the proposed activity.	Title and name [redacted]	Date: 10th December 2021
I retain managerial responsibility for the safety and welfare of those persons listed in Section 6.1.1 and, as such, confirm the validity of the information provided in this form and give assurance that all reasonably practicable measures have been put in place to manage the risks associated with this fieldwork activity and give my approval for the work to commence.	Title and name: [redacted]	Date: **03/12/2021**

11. APPROVAL FOR HIGH RISK OFFSITE WORK.

The HoD must approve any high-risk offsite work. Please refer to your Faculty Policy for any additional approvals that may be required. High risk work is defined on page 1.

HEAD OF DEPARTMENT APPROVAL		
I have reviewed this risk assessment and consider that the additional risks posed by the country or region in which the work is taking place and the activities being undertaken have been controlled so far as is reasonably practical and there is a continued academic requirement for the work to proceed which justifies the increased risk.	Title and Name:	Date:
ADDITIONAL APPROVAL (Where required by Faculty Policy)	Title and Name:	Date:

12. OFF SITE EMERGENCY RESPONSE PROCEDURES (OWERP)

Appendix 1.

Relevant sections to be completed under the following circumstances:

1. All work requiring an FW1.
2. ALL high risk offsite work.
3. Where Faculty Policy requires it.
4. Any trip where the person in charge has determined by risk assessment that there is a need for more detailed planning.

Sections can be omitted where this information is already included in the risk assessment for example in the FW1.

1. AVAILABLE EMERGENCY SUPPORT

Full name	**CID**	**Position**	Email	**Mobile / Satellite phone**	**Land line**
		Principal Investigator			
		Person in charge e.g. Supervisor			
		Offsite co-ordinator			
		In country offsite leader or local contact			
		Other			

Nearest hospital or medical field station.	Name: Address: Telephone:
College insurance medical and emergency hot line (24/7, 365 days / year):	[redacted]
Imperial College Security on call Support No. (24/7):	College South Kensington 24hr 365 days security control room: 020 7589 1000 & 0207 594 8910
Local emergency services, Police, Ambulance, fire etc:	Telephone:
British Embassy, High Commission or consulate:	Telephone:
Other:	Telephone:

2. Names and contact details of ICL personnel conducting the offsite work

Full name	**CID**	**Position / Role in group**	**Email**	**Telephone (Imperial)**	**Telephone (offsite)**

3. Emergency Response Procedures

This form and the ERP, once completed, must be retained by the offsite coordinator or the Faculty appointed Safety Officer.

Event	**Procedure**
Missing persons	Give details of planned check in times and what to do if a check in time is missed. Use the separate sheet below if necessary:
	Who will you attempt to contact and in what order: Add more rows as necessary. 1. 2.
Civil unrest and natural disasters	Give details of how the field worker will be alerted to the problem and what they will do in response:
Medical emergencies and repatriation	Give details of how the field worker will respond to illness or injury. If they are unable to self help give details of who will assist and what they will be expected to do:
Financial plan for emergencies	Give details of what funds are available for medical assistance, repatriation and other emergencies such as vehicle breakdowns and how these funds would be made available:
Communication strategy	Give details of the communications equipment that you are taking with you, when it will be used, and how effective it will be:
Media management plan	In the event of an emergency give details of how you will manage the media attention, e.g. who will inform the college media department:
Next of Kin	Before travel ensure that your next of kin details are up to date with ICL HR
College insurance policy no:	Policy number: [redacted]

4. MISSING PERSONS: PLANNED CHECK IN TIMES CONTINUATION SHEET

Serial	**Phase in Itinerary / Activity**	**Date**	**Local Time**	**UK Time**

5. Flight / travel details, continuation from FW1 for complex travel

Carrier name and trip ID e.g. Airline and flight No. OUT	Carrier name and trip ID e.g. Airline and flight No. RETURN

6. ACTIVITY PHASES, where requested for more complex projects.

Serial	Details of Activity	**Dates**

This form and the ERP, once completed, must be retained by the offsite coordinator or the Faculty appointed Safety Officer.

Imperial College
London

Engine Test Fire Standard Operating Procedure

Academic Supervisor: [redacted]
Department: Department of Aeronautics
Team Name: Imperial College London Rocketry (ICLR)
Academic year: 2022-2023
Authors: ICLR Saftey Team
Date: January 29, 2023

Department of Aeronautics
South Kensington Campus
Imperial College London
London SW7 2AZ
U.K.

1 Executive Summary

1.1 Background

Imperial College London Rocketry (ICLR) is a student run rocketry team, based in the aeronautics department and founded in 2018. Consisting of over 100 students, the primary goal is to educate students about the space industry through the design, build and launch of technically complex high powered rockets.

The propulsion teams aim is specifically to design, manufacture, and test rocket propulsion systems. In the 2021-2022 academic year, the team designed and tested Hypnos, a hybrid rocket engine, and successfully completed 8 hot fire tests. The team needs to test engines to validate designs, characterise performance, and practice safe and reliable operation of new propulsion systems.

1.2 Standard Operating Procedure Guidance

As the nature of ICLR's testing is mostly research and development, the engines and feed systems that are being tested go through many iterations. Therefore, the procedures regularly change and evolve to cater for new test conditions or designs. The main aim of the following Standard Operating Procedures (SOP) is to detail the how to conduct a safe test fire of a bi-propellant or hybrid rocket engines. Focus will be made into the safe handling of energetic materials, ensuring a complete test set up, keeping the public clear of the exclusion zone, keeping members of the team out of harms way, and safe filling, firing, and venting of the test systems.

This document should be accompanied with a Risk Assessment (RA), Emergency Response Procedures (ERP), Fieldwork Activities (FW1), Gas Cylinder Manual Handling Assessment, and relevant Control of Substances Hazardous to Health (COSHH) documentation.

1.3 Summary of Version Changes

The newest version of the SOP cover testing bi-propellant engines using an nitrogen pressure fed system. Bi-propellant engines use a liquid fuel that is pressurised and supplied to the engine through an injector, as compared to a hybrid engine that uses a solid fuel stored in the combustion chamber. The main additions to the SOP are as follows:

- Safe handling, storage, and use of liquid fuels and oxidisers in conjunction with each other.
- Liquid fueling procedures.
- Use of a nitrogen pressurised feed system and pressure regulators.
- Increased safety measures for the public and members of the team.
- Manual depressurisation of nitrous and nitrogen filling lines.
- Addition of version history, executive summary, and a new writing format.

2 Version History

Version	Summary of Changes	Version Author(s)	Approved By	Approval Date
1.0	Initial Release	[redacted]	[redacted]	12/04/2022
1.1	Minor Safety Revisions	[redacted]	[redacted]	05/09/2022
2.0	Bi-Propellant Engine	[redacted]	TBA	TBA

Nomenclature

CSO	Chief Safety Officer
CTO	Chief Test Officer
ERP	Emergency Response Procedures
$N2$	Nitrogen
$N2O$	Nitrous Oxide
RA	Risk Assessment
SOP	Standard Operating Procedures

Contents

3 Roles and Contacts

3.1 Team Member Roles

Test Site Role	Responsibility
Chief Test Officer (CTO)	• Take lead on Experimental Procedure. • Ensure Experimental checklist is followed exactly.
Chief Safety Officer (CSO)	• Ensure all relevant safety guidelines are adhered to. • Ensure the environment is clear and no members of the public are present in the exclusion zone.
Pressurised Fluids Specialist (PFS)	• Open and close high pressure cylinders. • Safe operation of high pressure fluid systems and observing for leaks or damage. • Must complete the ICL online Compressed Gases Training course: `https://www.imperial.ac.uk/staff-development/safety-training/safety-courses-/compressed-gases-e-learning/`

Test site roles will be selected before travelling to the test site. Those who take on roles must be well versed in the safety documentation and fully competent at performing the selected role. Team members performing the duties of CTO, CSO, or PFS will need to have been to at least two previous hot fires.

3.2 Useful Staff Contact

The following contacts should always be informed of safety documentation changes, testing at Silwood Park campus, any accidents or incidents as a result of testing, and for approval of safety documentation.

[redacted] | ICLR Supervisor | a.knoll@imperial.ac.uk

[redacted] | Experimental Research Safety Manager| [redacted]@imperial.ac.uk

[redacted] | Facility Manager (Silwood Park) | [redacted]@imperial.ac.uk

[redacted] | Head of Health and Safety (FONS) | [redacted]@imperial.ac.uk

[redacted] | Experimental Services Manager (Aeronautics) | [redacted]@imperial.ac.uk

4 Standard Operating Procedure

4.1 Test Site Overview

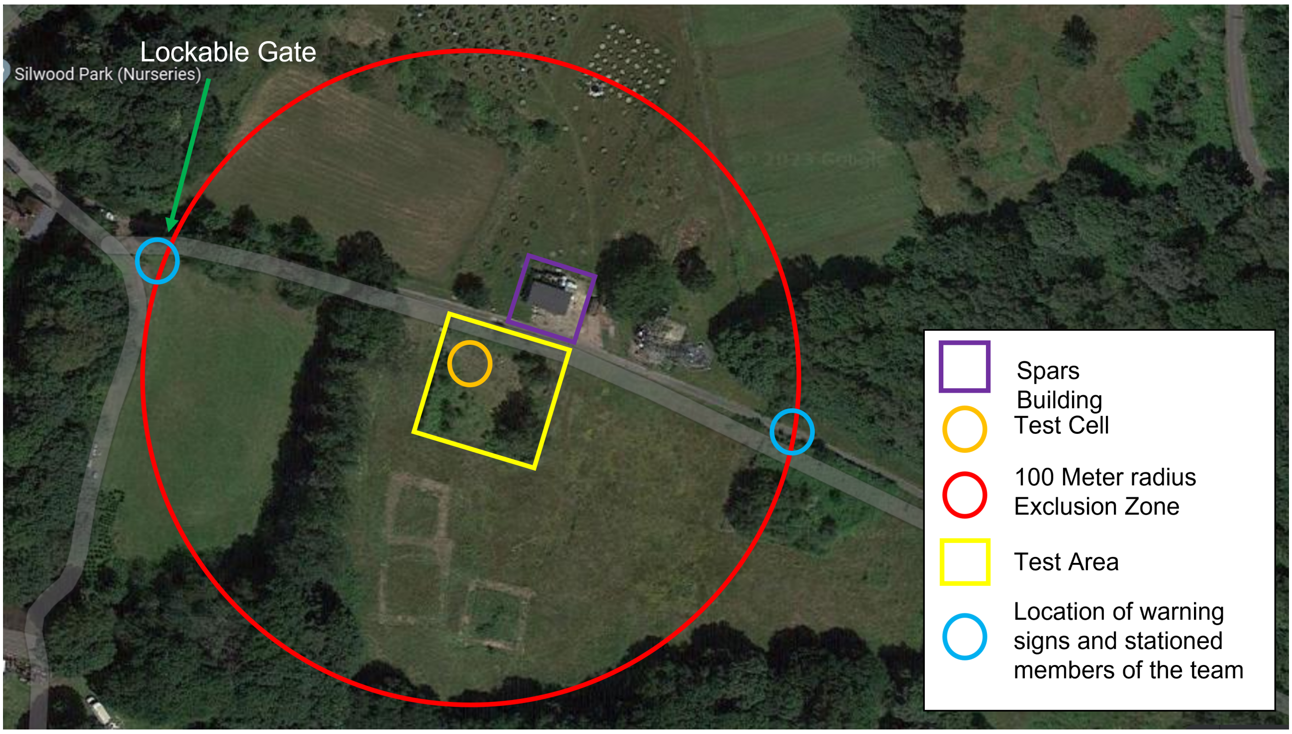


Figure 1: Overview of the Silwood test site (51.414858, -0.6525818)

- **Spars Building**: Non-essential members of the team should be inside the building during hazardous procedures, and all members of the team should be inside the building during a test fire. The building is 25 meters from the test cell, brick construction, and windows covered with poly-carbonate sheets.

- **Test Area**: The test area is a 30 by 30 meter square patch of land enclosed by 2 meter high chain link fence, acts as a physical barrier between public and members of the team to the most dangerous equipment during tests.

- **Exclusion Zone**: This area will be evacuated of all public during hazardous procedures and test fires. Members of the team will actively monitor the area using visual inspections, cameras, and (if available) drones.

- **Test Cell**: The test cell is a open ended steel box containing the test fire mount for the engine. The box is placed inside a 70 cm deep trench which is back filled to stop the test stand from moving during a test.

- **Stationed members of the team**: The trail leading through the site is the most common route for the public to pass through the area, therefore members of the team will be wearing hi-vis at these locations during the test fires to advise and block passage of the public. The members of the team will also have radios to advise the CTO and CSO of any exclusion zone breaches during hazardous operations.

Personnel logistics when on site

1. Once entered the test site, no members should leave the 100 meter radius without informing the CSO

2. Before the warning horn is signalled, the 100 meter radius exclusion zone should be swept for clearance

3. Once the setup of testing equipment is done, non-essential members of the team should remain in the spars building (highlighted in purple)
4. During the testing, ALL members of the team should remain in the spars building

Security setup locations on the test site

1. Warning signs will be placed at blue circles as shown in figure 1
2. Two cameras will each be set up facing the two ends of the road installed at the two bottom corners of the purple box at the spars building
3. Two more cameras will be set up facing back of the spars building and further beyond the test area (facing top corners of the purple box and the bottom of the yellow box)

Roles of stationed members of the team

1. During hazardous procedures one member of the team will be stationed at either end of the access trail shown in Figure 1.
2. The members of the team will wear high visibility clothing and ear defenders, and have a radio to remain in contact with the CSO and CTO.
3. They will ensure appropriate signage is placed in around them.
4. During hazardous operations they will constantly observe the surrounding area for members of the public.
    (a) If a member of the public is nearby, but outside the exclusion zone, then the team member should inform them of the upcoming test and the boundaries of the exclusion zone.
    (b) If a member of the public breaches the exclusion zone, the member of the team should announce **”ABORT”** on the radio 3 times to stop the current tests. Then they should advise the member of the public of the current tests and escort them to safety. A perimeter check should be completed again before continuing operations and the CSO will have the final call on when to continue.
5. They will remain at their post until called to return by the CSO.

4.2 Before Starting Operations

1. _Before entering the test site:
    (a) Members performing tasks must have read the Standard Operating Procedures and should ask about anything unclear.
    (b) Members operating equipment must be trained in using the equipment to prevent damage or improper setup.
    (c) Silwood security staff, management and students should be advised when and where the tests are being conducted.
2. After entering the test site:
    (a) All team members must sign in to the register.
    (b) Ensure everyone knows the evacuation routes.
    (c) Ensure everyone is aware of the exclusion zone location during tests.
    (d) Ensure everyone knows the location of the nearest first aid kit or fire extinguisher.
    (e) Ensure everyone knows the contact number in case of an emergency (999 for emergency services and 4444 for college security).
    (f) All team members put on high-vis jackets (and steel toed shoes if necessary) during hazardous operations and test fires.

4.3 Onsite Set Up Procedure

There are two types of hot fire testing that could be performed on site:

- **Hybrid Engine Tests**
- **Bi-Propellant Engine Tests**

The only difference between the two systems is the type of fuel used: hybrid engines use a solid fuel that is placed within the combustion chamber, and bi-propellant engines use a liquid fuel that is pressurised and supplied to the engine through an injector. The following SOP will detail set up and operation of both systems as the majority of the procedure will be the same. Processes for fueling the bi-propellant rocket can simply be omitted when conducting a hybrid engine test and will be marked with the following label:

****Omit This Step for Hybrid Engine Tests****

The procedures below covers all equipment needed for the fullest setup. Some equipment may not be needed for some developing stage test fire setups. Refer to the most relevant P&ID for the required set up.

4.3.1 N2O Cylinder Transport and Set Up

1. Transport N2O tank to the test area from behind Spars building
    (a) Unlock tank storage shed
    (b) Ensure chain is holding the tank to the trolley and secure further with two ratchet straps
    (c) Wheel the tank on the trolley out of the shed, turn right to wheel it out over the concreted area then head towards the gate of the test area
    (d) Wheel tank into the test area and remove the tarp covering the outlet connectors
2. Transport Hydraulic hoist to the test area from the Spar building
    (a) Perform visual inspection of hoist prior to use. Check no components have excessive rust and all screws are present and tightened correctly
    (b) Pump the hydraulic cylinder with no load to verify there are no leaks and the vent works correctly
3. Transfer N2O tank from trolley to tank inverter using hydraulic lifting hoist
    (a) The hoist arm is moved over the bottle and the hook is attached to the top handle.
    (b) The bottle is slowly lifted using the hydraulic cylinder until the dolly can be removed from underneath. The hoist (with bottle) is then wheeled to the inversion rig.
    (c) Bottle is lowered onto support frame of inversion rig. Ensure all members keep do not place their hands between the bottom and the frame to avoid pinching. Ratchet straps are used to secure the bottle to the rig. Once in place, hook is removed.
    (d) Add crossbeams to other side of the tank holder and adjust until tank is held firmly
    (e) Rotate tank holder + tank 180 degrees and lock into place

4.3.2 N2 Cylinder Transport and Set Up

1. Unlock tank storage shed
2. Ensure chain is holding the tank to the trolley and secure further with two ratchet straps
3. Wheel the tank on the trolley out of the shed, turn right to wheel it out over the concreted area then head towards the gate of the test area
4. Wheel tank into the test area and remove the tarp covering the outlet connectors
5. The cylinder will be left on the dolly for testing.

4.4 Operating Checklists

4.4.1 Before Methanol Fueling

****Omit This Step for Hybrid Engine Tests****

- Has the test fire set up been fully configured to match the relevant P&ID for testing?
- Has the N2O and N2 filling cylinders been moved 3 meters away from the test fire box?
- Are the N2O and N2 cylinders disconnected from the system?
- Are methanol safe gloves, lab coat, and eye protection being worn by the PFS?
- Has the PFS read the methanol COSHH form and is aware of the dangers of its use.
- Has the PFS collected the nessicary equipment for cleaning up methanol spills?
- Is the area clear of any possible ignition sources?

If the answer to any of these points is NO, the procedure should be halted until all measures are satisfied.

1. Bring the methanol out of storage to the test site.
   (a) Ensure the lid is securely fastened during transport to prevent spills.
   (b) Travel carefully to avoid tripping and dropping the container.
   (c) If the container is heavy, two people should transport it.
2. Filling the methanol pressure vessel.
   (a) Open the methanol vent valve manually.
   (b) Place a container under the vent.
   (c) Remove the cap from the methanol filling port and add a funnel.
   (d) Pour the methanol into the funnel being careful not to overfill or spill.
   (e) Continue filling until the desired volume of methanol is in the pressure vessel or the vent line overflows.
   (f) Close the methanol vent valve manually.
   (g) Remove the funnel, and replace the methanol fill valve cap and tighten.
   (h) Clean up any spilt methanol.
3. Return the methanol back to storage.

4.4.2 Before Non Essential Test Site Evacuation

1. Remove unnecessary tools and equipment from the test area.
    - (a) Any items near the test cell or flame trench must be removed.
    - (b) Rubbish or debris must be thrown in the bin.
    - (c) Essential tools must be stored away from the test cell and in an easily accessible area.
2. Evacuate exclusion zone of any members of the public
    - (a) One team member will head to either end of the main trail that passes through the test site to block members of the public entering the exclusion zone. Each member will be equipped with high visibility clothing, and a radio to contact the CSO and Spars building team. This member will also set up signage in these locations.
    - (b) High visibility cordon tape supported on temporary fence posts will be set up to maintain the 100-meter radius exclusion zone in areas that are difficult to inspect visually from the designated vantage points.
    - (c) Visual inspection will be made by the CSO and accompanying safety officers around the full exclusion zone, areas that are not easily visible from the test site must be cleared before proceeding.
    - (d) If people are spotted, let them know of the hazardous tests that are occurring and ask them to leave the area.
    - (e) An announcement of imminent testing will be made on a megaphone stating this phrase “Rocket engine testing in progress, please evacuate the area around the Spars building” every 5 mins from this point until the end on the hazardous activities.
    - (f) Upon completion of inspection, the CSO will place warning signs at the remaining entrances to exclusion area with instructions to wait for the test to be completed.
3. Evacuate test area of non-critical team members to the Spars building kitchen
    - (a) CTO, CSO and PFS remain in the test area (ensure that CTO is carrying arming key at all times)

4.4.3 Before Oxidiser and Nitrogen valve is Opened

- Are all non-essential team members clear of the test site and in the Spars Kitchen?
- Are all members of the testing team on the attendance sheet accounted for?
- Are both arming keys in the possession of the CTO?
- Are nitrous/CO2 safe gloves and face shield being worn by the PFS?
- Are all the swagelok nuts and other threaded connections tight? Is the filling hose properly attached?
- Has the fuel cylinder been removed from the test site and stored safely?
- Is the whip check hose connector properly in place?
- Has the safety relief valve been properly calibrated during a prior hydrostatic test?

If the answer to any of these points is NO, the procedure should be halted until all measures are satisfied.

1. Connect the e-match ignition leads to the firing electronics.
2. PFS will open the valve on the N2O tank to allow fluid into the plumbing section upstream of the main remote valve **(Skip for repeated tests as valve can remain open)**.
   (a) PFS must wear appropriate PPE (Face shield, nitrous/CO2 safe gloves).
   (b) Valve opened slowly to avoid pressure spikes and allow leaks to be seen earlier on.
   (c) CSO must be present in case of any failures to oversee appropriate ERPs (Emergency Response Procedures).
3. PFS will open the valve on the N2 tank to allow gas into the plumbing section upstream of the main remote valve **(Skip for repeated tests as valve can remain open)**.
   (a) PFS must wear appropriate PPE (Face shield, nitrous/CO2 safe gloves).
   (b) Valve opened slowly to avoid pressure spikes and allow leaks to be seen earlier on.
   (c) CSO must be present in case of any failures to oversee appropriate ERPs (Emergency Response Procedures).

4.4.4 Before The Full Evacuation of The Test Area

- Are all non-essential team members clear of the test site and in the Spars Kitchen?
- Are all members of the testing team on the attendance sheet accounted for?
- Are both arming keys in the possession of the CTO?
- Has a visual check of nearby areas been done by the CSO to ensure no members of the public are nearby?
- Are team members stationed at either ends of the trail to stop people enter the exclusion zone?
- Have all areas not visable from the Spars building in the exclusion zone had adequate signage and cordon tape placed to deter the public from entering the area?
- Is the test fire electronics box powered on correctly?
- Has the tank valve been opened properly with no leaks in the system?

If the answer to any of these points is NO, the procedure should be halted until all measures are satisfied.

1. Begin full evacuation of the test area
   (a) CSO, CTO and PFS exit to the Spars kitchen
   (b) CSO takes a register of all ICLR members at the test to make sure they are all inside
   (c) CSO checks surrounding area again to ensure there are no members of the public nearby
   (d) CSO will radio the safety officers at the entrance and exit of the trail to confirm the exclusion zone is clear.
   (e) CSO check windows to ensure poly-carbonate sheets are covering windows at risk of shattering
   (f) CSO ensures all ICLR members are wearing noise protection devices
   (g) CSO gives final go/no before entering Spars kitchen
   (h) Announcement is made on a mega phone to warn the public that hazardous procedures are taking place.
   (i) Spars building door is closed

4.4.5 Before N20 and N2 Run Tank Filling Begins

- Are all members of the testing team on the attendance sheet in the Spars kitchen?
- Are both arming keys in the possession of the CTO?
- Has a visual check of nearby areas been done by the CSO to ensure no members of the public are nearby?
- Does the live feed of the test equipment show that nothing unexpected is happening?

If the answer to any of these points is NO, the procedure should be halted until all measures are satisfied.

1. N20 filling sequence
   - (a) CSO gives go ahead for the test if there are no issues.
   - (b) All valve switches should be in the ”CLOSED” position and other switches should be in there inactive or normal states.
   - (c) Remote control filling system is armed by the CTO using the arming key **The firing system should be left disarmed**.
   - (d) N2O filling is armed by opening the red ARM switch cover and flicks the toggle switch forward for the N2O filling controls.
   - (e) CTO announces that filling is about to commence. CTO turns the rotary switch for the N2O fill valve to “OPEN”. The filling valve is now open and live data should show that pressure in the system is increasing.
   - (f) As the pressure equalises between the N2O filling tank and run tank, the filling rate should slow. The CTO turns the rotary switch for the N2O vent valve to ”SLOW”. Run tank pressure should drop slightly, a louder hissing sound may be heard, and filling will continue at a slower rate.
   - (g) When either the desired N2O mass is reached in the run tank or a white plume is observed from the N2O vent, the CTO turns the rotary switch for the N2O vent valve to ”CLOSED” and the N2O fill valve to “CLOSED”.
   - (h) All valves should be in the closed position and the N2O arming switch should be disarmed.
   - (i) CTO should check that the system is performing nominally.
   - (j) N2O filling is now complete.
2. N2 filling sequence
   - (a) N2 filling is armed by opening the red ARM switch cover and flicks the toggle switch forward for the N2 filling controls.
   - (b) CTO announces that filling is about to commence. CTO turns the rotary switch for the N2 fill valve to “OPEN”. The filling valve is now open and live data should show that pressure in the system is increasing.
   - (c) Once the pressure between the N2 fill tank and N2 run tank has equalised, the CTO turns the rotary switch for the N2 fill valve to “CLOSED”.
   - (d) CTO should check that the system is performing nominally.
   - (e) N2 filling is now complete.
3. Pressurising the fuel and oxidiser
   - (a) CTO checks that all N2O and fuel valves are closed.
   - (b) CTO turns the rotary switch for the N2O pressurise valve to “OPEN”.
   - (c) CTO checks that the pressures are nominal.
   - (d) CTO turns the rotary switch for the fuel pressurise valve to “OPEN”.

(e) CTO checks that the pressures are nominal.
(f) All valves BUT the N2O and fuel pressurise valves should be in the closed position.
(g) Fuel and oxidiser are now pressurised and ready for firing.

4.4.6 Before Beginning Hot Fire

- Are all members of the testing team on the attendance sheet in the Spars kitchen?
- Are both arming keys in the possession of the CTO?
- Has a visual check of nearby areas been done by the CSO to ensure no members of the public are nearby?
- Does the live feed of the test equipment show that nothing unexpected is happening?
- Are all pressure readings nominal and is the filling valves closed according to the live video stream?
- Have both e-matches been properly connected? Has continuity been checked with a multimeter?
- Has the desired firing time been decided and made clear?

If the answer to any of these points is NO, the procedure should be halted until all measures are satisfied.

1. Test sequence initiation.
    - (a) CSO informs the safety officers at the ends of the trail of the beginning of the test.
    - (b) CSO announces on the megaphone "Engine testing will commence in 60 seconds, evacuate the area immediately"
    - (c) CTO announces that the test is about to commence. CTO inserts and turns the firing key.
    - (d) CTO opens the red ARM switch cover and flicks the toggle switch forward.
    - (e) CTO gives a countdown on the megaphone starting at T-minus 10 seconds.
    - (f) At T-minus 0 seconds, CTO presses the RED button marked "FIRE".
    - (g) Live video feed is watched to verify that the test is working as expected. A sustained flame should be visible. Release button and press emergency stop button if any visible anomalies occur.
    - (h) CTO waits for the pre-planned test fire duration before releasing the RED button.
    - (i) CTO closes the red ARM switch cover and removes the engine firing key.
    - (j) Test fire has been completed.
2. N2O Run tank venting.
    - (a) CTO turns the N2O pressurise valve from ”OPEN” to ”CLOSED”.
    - (b) CTO arms the N2O filling controls by opening the red ARM switch cover and flicks the toggle switch forward.
    - (c) CTO turns the N2O vent valve switch from "CLOSED" to "OPEN". N2O should begin venting.
    - (d) When the pressure in the N2O run tank reduces to atmospheric pressure the CTO turns the N2O vent valve switch from "OPEN" to "CLOSED".
    - (e) CTO disarms the N2O filling controls by closing the red ARM switch cover.
3. Fuel run tank venting.
    - (a) CTO arms the fuel filling controls by opening the red ARM switch cover and flicks the toggle switch forward.
    - (b) CTO turns the fuel vent valve switch from "CLOSED" to "OPEN". Fuel and N2 should begin venting.
    - (c) When the pressure in the fuel run tank reduces to atmospheric pressure the CTO turns the fuel vent valve switch from "OPEN" to "CLOSED".
    - (d) CTO disarms the fuel filling controls by closing the red ARM switch cover.
4. N2 run tank venting
    - (a) CTO turns the N2 vent valve switch from "CLOSED" to "OPEN". N2 should begin venting.

(b) When the pressure in the N2 run tank reduces to atmospheric pressure the CTO turns the N2 vent valve switch from "OPEN" to "CLOSED".

(c) All remaining open valves should be CLOSED.

(d) CTO disarms the N2 filling controls by closing the red ARM switch cover.

(e) CTO checks the run tank pressures are at atmospheric pressure, if not, vent the remaining pressure accordingly.

(f) Remote control filling system is disarmed by the CTO removing the arming key. **The CTO should now be in possession of both arming keys**.

(g) CSO informs the safety officers at the ends of the trail via radio of the end of the test. Exculsion zone should be kept in place however until remaining pressure in the system is vented.

4.4.7 Before CTO and PFS Enter The Paddock

- Are all members of the testing team on the attendance sheet in the Spars kitchen?
- Have all valves been closed?
- Are both arming keys in the possession of the CTO?
- Has a visual check of nearby areas been done by the CSO to ensure no members of the public are nearby?
- Does the live feed of the test equipment show that nothing unexpected is happening?

If the answer to any of these points is NO, the procedure should be halted until all measures are satisfied.

1. PSO opens the Spars door and walks to within line of sight 10m from the test setup and performs a visual inspection.
2. If everything looks good; CTO, CSO and PFS will enter paddock and immediately close N2O and N2 tank valve.
    (a) PFS must wear appropriate PPE (Face shield, nitrous/CO2 safe gloves).
    (b) CSO must be present in case of any failures to oversee appropriate ERPs (Emergency Response Procedures).
3. PFS will manually vent the small amount of remaining fluid in the filling systems feed lines.
    (a) PFS must wear appropriate PPE (Face shield, nitrous/CO2 safe gloves).
    (b) CSO must be present in case of any failures to oversee appropriate ERPs (Emergency Response Procedures).
    (c) The venting side of the valve must be facing away from PFS
    (d) The valve should be opened very slowly and the PFS should observe a slow reduction in pressure on the analogue pressure gauge.
    (e) Once the pressure in the line is at atmospheric pressure the valve should be opened fully and then closed tight.
    (f) This process should be completed for both the N2O and N2.
4. Once the main tank valves are closed, the feed lines are at atmospheric pressure and everything looks safe, other members may enter
    (a) The CSO informs the team members at either end of the trail that they may come back to the test site.
    (b) The CSO announces on the megaphone that testing is now complete and the area is safe.
    (c) Visually check all plumbing carefully to ensure there are no leaks or disconnected lines.
    (d) Collect data from the any storage devices and back it up on laptops so analysis can be performed later.
    (e) Stop recording on camera and replace batteries/swap SD cards if necessary.
5. Inspect engine for any damage or evidence of failure
    (a) **Wear thermally insulating gloves (engine may still be warm).**
    (b) Screws holding engine assembly to the test stand are loosened and removed with a screwdriver + wrench.
    (c) Engine assembly is removed carefully, being wary of inlet hose that is attached.
    (d) Carefully transport engine to inside Spars Building where it can be inspected
    (e) Fasteners holding injector assembly to the engine are loosened and removed with a screwdriver + wrench

(f) Injector head is removed and inspected.

(g) Visually inspect o-rings for damage

(h) Carefully remove the ablatives by tipping the engine upside-down, allowing everything to slide out

(i) Inspect the ablatives, taking pictures and recession measurements

(j) fasteners holding nozzle to the engine are loosened and removed with a screwdriver + wrench

(k) Carefully remove nozzle, being wary of loose graphite nozzle

(l) Visually inspect internal walls of combustion chamber for damaged sections

(m) Visually inspect threads of all fasteners for signs of shear or other damage

(n) Scrub inside of combustion chamber, removing charred fuel.

4.4.8 Before Follow Up Testing

The setup required should be referred to the most relevant PID. The procedure below refers to a full engine test. For some testings, not all procedures are required.

1. Reconfigure the Engine
   (a) Prepare the engine for the next test according to the test plan.
   (b) Ensure o-rings, ablatives, and nozzle are replaced if necessary.
2. Reattach all filling hoses with the Quick Disconnects
3. Restart data logging of DaQ as well as recording cameras (ensure live video feed is still running correctly)
4. Repeat the **”relevant test procedure”** above
5. Total number of tests may be decided ahead of time or on the test day depending on time constraints

5 General Checklist

Stored at Silwood:

1. Test stand with thrust plate attached
2. Nitrous run tank stand
3. Tank inverter
4. N2O and N2 cylinders with dollies
5. $\sim$50m ethernet cable
6. Ear defenders (10x)
7. 2 Ton Hydraulic Hoist

Test Components (to bring from South Kensington):

1. Engine assembly and lower feed system
2. Upstream plumbing systems
3. N2O and N2 tank fittings
4. Power supplies
5. Control system cables
6. Pressure transducer cables
7. Load cells
8. E-matchs and ignition motors
9. Ablative chamber liners
10. Thermocouples
11. Micro SD to USB converter
12. O-Ring Spares
13. Spare Nozzles
14. Nozzle Inserts

Tools/Things to fix stuff:

1. Spanners (2x Imperial sets and 1x Metric set)
2. 2x adjustable spanners
3. Large flat head screwdriver
4. Interchangeable screwdriver set (with driver)
5. Small flat head screwdrivers
6. Allen Keys (4x Metric sets)
7. 2x Pliers

8. Rubber mallet
9. Multimeter
10. PTFE tape
11. Duct tape
12. Masking tape
13. Kapton tape
14. Cable ties
15. M8 bolts and T Nuts (for Aluminium Extrusion)

PPE and safety equipment:

1. 1x Face shield
2. 8x pairs Safety glasses/goggles
3. 4x blue/orange ratchet straps
4. 6x high visibility jackets
5. 2x pairs of nitrous safe gloves
6. 2x pairs of working gloves
7. Box of nitrile gloves
8. 6x Restricted Area signs
9. Clear poly-carbonate sheets to cover windows
10. 300m of high visability cordon tape
11. Megaphone
12. 4x radios
13. 4x CCTV cameras and a DVR

Additional:

1. Silwood Keys (IMPORTANT!!)
2. Go Pro Action camera (for analysis of injector flow)
3. Additional cameras
4. Large Tripod + camera mounts

Imperial College
London

RISK ASSESSMENT FOR AN ACTIVITY INVOLVING THE USE OF HAZARDOUS CHEMICALS

as required under the **CONTROL OF SUBSTANCES HAZARDOUS TO HEALTH REGULATIONS (COSHH)** *and the* **DANGEROUS SUBSTANCES AND EXPLOSIVE ATMOSPHERES REGULATIONS (DSEAR)**

This form aids in assessing the hazards associated with the use of chemicals and the subsequent application of suitable controls. Guidance on completion of the form can be found on Safety Department website.

The sections below correspond approximately to the sections in the Guidance Note.

- The form **does not** address the risks associated with biological agents or ionising radiation – other Safety Department forms exist for this purpose.
- With respect to *DSEAR*, this form may be used to assess risks arising from small scale laboratory operations where hazard zoning is not usually applicable and the controls required largely mirror those of COSHH.
- This form is not suitable for assessing flammability and explosion risks arising from large scale operations (including pilot scale) where hazard zoning is necessary – this will require a more detailed assessment.

It is the responsibility of the person directing the research i.e. the Principal Investigator to ensure that risk assessments are carried out, remain valid and that the control measures identified are applied.

****Before undertaking workplace risk assessments, assessors should complete Risk Assessment Foundation Training (RAFT)****

PERSON RESPONSIBLE FOR THIS WORK (THE PRINCIPAL INVESTIGATOR)

Name: [redacted]		Position: Reader
Department/ Section: Aeronautics	Division:	Faculty: Engineering

PERSON CONDUCTING THIS ASSESSMENT

Name: [redacted]	Position: Safety officer
Department/ Section: Aeronautics	Date risk assessment undertaken: 28/1/2023

Review history	The person responsible must ensure that this risk assessment remains valid			
	Initial Review	Review 1	Review 2	Review 3
Due date	09/05/2023	09/11/2023	09/05/2024	09/11/2024
Date conducted	24/02/2023			
Conducted by	[redacted]			

THE ACTIVITY or PROCEDURE	
Title: Storage and use of methanol at Imperial College, Silwood Campus (Drive Field location) for the purpose of testing a rocket motor designed by Imperial College London Rocketry	Assessment reference No:
Description (describe the procedure step by step or attach a Standard Operating Procedure): **Note that the risk assessment for the testing of the entire motor, including the standard operating procedure is appended, which gives further detail as to the specific use and application of the methanol.**	

1. HAZARDS AND RISKS

1.1 HAZARD EVALUATION & RISK DETERMINATION

List each of the chemical substances used in the activity or procedure in the table below and use this matrix to determine the risk level for each one.

(A) Health Hazard	(B) Dustiness or *Volatility	(C) **Quantity	Score
Low ***Hazard Statements:*** H303; 305 H313; 315; 316 H320 H336 EUH066	Low ***Solids:*** Pellet-like solids that do not break up. Little or no dust observed during use. Solids forming large crystals ***Liquids:*** Boiling point > 150ºC	Small <1g (ml)	1
Medium ***Hazard Statements:*** H301; H302; H304 H311; H312; H314; H317 H318; H319 H332; H335 H371; H373	Medium ***Solids:*** Smaller crystalline or granular solids. Minimal dust, or if any dust is seen it settles out quickly. ***Liquids:*** Boiling point between 50 and 150ºC	Medium 1 to 100g (ml)	2
High ***Hazard Statements:*** H300 H310 H330; H331; H334 H340; H341 H350; H351 H360; H361; H362 H370; H372 EUH070	High ***Solids:*** Fine, light powders. Dust can be seen during use and possibly remains airborne for several minutes. ***Liquids:*** Boiling point < 50ºC	Large > 100g (ml)	3

Multiply (A)x(B)x(C) to estimate overall risk level: ≤ 7 Low; 8-11 Medium; ≥ 12 High

* For purposes of calculation, if a chemical has more than one risk phrase, use the one(s) with the highest health hazard score

** When stating quantity, this should consider the quantity in the stock bottle as well as the quantity of the aliquots, since loss of containment from the entire stock bottle whilst removing aliquots may represent the greatest risk.

Substance	**Route of exposure** Inhalation (In) Ingestion (Ig) Skin contact (Sk) Penetration (P) Eye splash (Es)	**Hazard Statement(s)* (see safety data sheet) Please include all applicable**	**‡WEL**	**Health Hazard Score**	**Dustiness / Volatility Score**	**Quantity Score**	**Overall Risk Level L/M/H**
Methanol	Sk	H225		3	2	3	H
Methanol	Ig	H301	250 ppm	2	2	3	H
Methanol	In	H331	250 ppm	3	2	3	H
Methanol	Sk	H311	250 ppm	2	2	3	H
Methanol	Es	H370	250 ppm	3	2	3	H

‡Workplace Exposure Limit (if one has been assigned - see safety data sheet) – usually in ppm for vapours or mg/m^3 for particulates.

1.2 PROCESS FACTORS INFLUENCING THE RISK OF EXPOSURE

Are there any process factors that influence the route of exposure (See Section 2.2.10)?			
Weighing ☐	**Pipetting** ☐	**Filtering** ☐	**Elevated Temperature** ☒
Shaking / Mixing ☐	**Centrifugation** ☐	**Use of Sharps** ☐	**High Pressure** ☐
Other			

1.3 IDENTIFICATION OF THOSE AT RISK OF EXPOSURE

Are there any substances listed in this activity having the Hazard Statements H360, 361 or 362 (those affecting women of child-bearing age)?

Yes ☐	No ☒	**If 'Yes':** • any females working with the substance must be informed that the substance(s) present a reproductive toxicity hazard. • should they fall pregnant or are trying for pregnancy, then they have the option of contacting Occupational Health for a detailed confidential health assessment. • they should also avoid being involved in any large-scale spillage clean up in the event that such an incident arises.

Are there any substances listed in this activity having the Hazard Statement H317 (skin sensitisers)?

Yes ☒	No ☐	**If 'Yes':** • ensure these substances are never handled without gloves and all other skin areas are covered during handling.

Are there any substances listed in this activity having the Hazard Statements H334, H340, 341, 350 or 351 (respiratory sensitisers, substances causing genetic defects or cancer)?

Yes ☐	No ☒	**If 'Yes', this risk assessment once completed, must be submitted to the Safety Department (safetydept@imperial.ac.uk) for review before work is carried out. Information will be uploaded to a central database for record keeping purposes.**

If 'Yes' is answered to either of the above questions, indicate the frequency and duration of use

Once a month	Frequency (how often is the substance used) e.g. every day; once a month etc.
Two minutes	Duration (how long is possible exposure likely to be) e.g. five minutes; one hour etc.

Are there any external factors that increase the risks associated with exposure to any of these substances e.g. contact lens wearing?

Yes ☐	No ☒	If '**Yes**' give details:

Are there any personnel other than laboratory workers who may be at risk from exposure? (e.g. maintenance workers, cleaners etc.)

Yes ☐	No ☒	If '**Yes**' give details:

1.4 SUBSTANCES SUBJECT TO OTHER LEGISLATION

Are there any substances involved in this activity that are subject to either the Chemical Weapons Act or the Anti-terrorism, Crime and Security Act? *You must keep a record of usage for Schedule 2 chemical weapons precursors as you will be contacted by the Safety Department on an annual basis prior to the College making its annual declaration to the Department of Business, Energy and Industrial Strategy.*

Yes ☐	No ☒	If '**Yes**' give details:

Are there any substances involved in this activity that are listed by the Home Office as drugs precursors?

Yes ☐	No ☒	If '**Yes**' give details:

Are there any substances involved in this activity that are defined as controlled drugs?

Yes ☐	No ☒	If '**Yes**' give details:

Are there any substances involved in this activity that are explosive, flammable or oxidising? (See Q2.2.2e)

Yes ☒	No ☐	If '**Yes**' give details: Methanol is flammable.

1.5 OTHER HAZARDS

Are there any other hazards involved with this activity? (e.g. pathogens, GMOs, ionising radiation etc.) If '**Yes**' have these risks been assessed and any necessary approvals obtained?

Yes ☐	No ☒	If '**Yes**' give details and / or reference numbers of related documentation:

2. CONTROL MEASURES

2.1 PREVENTION OF EXPOSURE

2.1.1 Elimination, substitution and procedural change

a) Can any of the substances be eliminated from the process?

Yes ☐	No ☒	Give details: The bipropellant engine requires a liquid fuel in order to function.

b) Can any of the substances be substituted by a safer alternative or a safer form of the same substance?

Yes ☐	No ☒	Give details: The bipropellant engine has been designed with methanol as a propellant due to its clean combustion, therefore it cannot be substituted.

c) Can the method of work be changed so that the operation giving risk to exposure is no longer necessary?

Yes ☐	No ☒	Give details: The propellant tank on the test stand must be filled manually, as standard containers of methanol do not allow for any method of remote filling.

d) Are measures in place to exclude non-essential personnel from the area?

Yes ☒	No ☐	Give details: As stated in the dedicated risk assessment, all non-essential personnel are to retreat to a safe distance, and an exclusion zone to be enforced.

2.2 CONTROL OF EXPOSURE

2.2.1 Minimising quantities

Can the quantities of the substances stored, used and produced as waste be reduced?

Yes ☐	No ☒	If '**Yes**' give details:

2.2.2 Containment and ventilation

a) Can some or all parts of the process be carried out on the open bench with good general ventilation? (if additional containment such as drip trays are required, give details)

Yes ☒	No ☐	If '**Yes**' give details: All operations are to be conducted in an open-air environment, at Silwood Park by the Spars building. Containers of methanol shall be closed tightly whenever transferred indoors for storage.

b) Is a fume cupboard or other form of local exhaust ventilation required for any part of the process?

Yes ☐	No ☒	If '**Yes**' give details including type and location:

c) Is the fume cupboard or other form of local exhaust ventilation subject to a maintenance regime?

Yes ☐	No☒	N/A ☐	If '**Yes**' give date of last test and state who is responsible for organising maintenance:

d) Does any part of the process need to be totally enclosed e.g. inside a glove box?

Yes ☐	No ☒	If '**Yes**' give details:
		If '**Yes**' describe the maintenance regime of the glove box:

e) Do measures need to be taken to control sources of ignition?

Yes ☒	No ☐	If '**Yes**' give details: Ignition sources are to be kept away. All methanol storage containers are to be stored inside the SPARS building during static fire engine testing. Thorough training is to be conducted and safety precautions taken when handling the methanol.

f) Is a chemical spill kit required?

Yes ☐	No ☒	If '**Yes**' give details:

2.2.3 Storage and transportation

a) Storage. If relevant, outline the storage arrangements:

Toxic	
Corrosive	
Flammable / Highly Flammable / Extremely Flammable	Methanol is a Flammable Liquid, and will be stored in the COSHH cupboard in Room 223 on South Kensington
Other	

b) Transportation on site. Will any of these substances need to be transported to other parts of the building or other parts of the site?

Yes ☒	No ☐	If '**Yes**' give details of how containment will be assured: Container will be sealed throughout the transportation and all personnel will be notified prior the transportation.

c) Transportation off site. Will any of these substances need to be transported to other sites?

Yes ☐	No ☒	If '**Yes**' give:	Name of other sites: Substance and quantity: Method of transport proposed: Containment precautions:	

2.2.4 Personal protective equipment (PPE)

Gloves ☐ Type Chemical resistant gloves (eg. KCL GmbH) EN 374 protocol	Eye / face protection ☒ Type Face shield
Respiratory protection ☐ Type	Clothing or footwear (in addition to lab coats) ☒ Type Boiler suit (full body)
Respirator filter type:	
State which parts of the process PPE is required for (e.g. experimental process or in emergencies only): Primarily for re-fuelling the methanol tank and during transport.	

If respiratory protection has been identified as required, has the user been face-fit tested?	Yes ☐ No ☒	If '**Yes**', provide date of face-fit test:
If respiratory protection is available for emergencies, describe the location, the names of trained users and the procedures for maintenance:		

2.2.5 Waste disposal

Outline the disposal route for each substance or derivative

Please note - cytotoxic waste has its own specific waste route – please contact your facility manager to arrange.

Substance	Drain	Specialist waste contractor	Other (specify)
Spent tank with leftover methanol	☐	☐	Reuse and store
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	

2.2.6 Hygiene measures

Describe the hygiene measures in place for work involving these substances, e.g. handwash facilities, laundering of protective clothing, storage of personal clothing, prohibition of eating and drinking etc.:

First aid kit with eyewash solution present at the facility.

2.2.7 Monitoring

Is monitoring necessary to validate the efficacy of control measures for any of these substances?

Incident reports will be created, as necessary, and disseminated to all personnel involved.

2.2.8 Information, instruction, training and supervision

Describe the information, instruction, training and supervision requirements for those working with these substances (include details of record keeping):

All personnel working with the material have been actively involved in designing the testing process and, as such, is aware of the risk. No additional training is required. A full safety instruction will be provided to the personnel handling methanol.

2.2.9 Lone working

Lone working is not permitted for any activity which involves the use of a substance that presents the risk of rapidly incapacitating a lone worker (e.g. toxic, flammable gases).
Lone working permission:

Is lone working permitted for this activity?	Yes ☐ No ☒	If '**No**', please continue to Section 2.2.10
Is specific consent required for lone working?	Yes ☐ No ☐	If '**Yes**', describe all specific activities and instances when consent for lone working is required:
Are there any restrictions as to when lone working can take place?	Yes ☐ No ☐	If '**Yes**', describe the restrictions and why these are in place:
Describe additional precautions to be implemented to overt risk to the lone worker (e.g. safe access to facility, safe use of equipment, adequate emergency procedures):		SOP/CoP/Protocol Reference:

2.2.10 Additional controls

Are there any additional controls required in relation to the process factors identified in Section 1.2 that are not covered anywhere else?

Process factor	**Identified route of exposure**	**Description of how exposure is controlled**
Weighing		
Pipetting		
Filtering		
Elevated temperature		
Shaking / Mixing		
Centrifugation		
Use of Sharps		
High Pressure		
Other		

2.3 EMERGENCY PROCEDURES

Do not cut and paste information on emergency procedures and first aid from the MSDS – it must reflect procedures that are available within the local area (laboratory, building or campus concerned) and be proportional to the extent of exposure anticipated.

2.3.1 Spillage or release

If the spillage involves an unidentified chemical, evacuate the area and contact safety personnel.
Describe the procedures in place for a spillage / release:

Within the laboratory but outside any primary containment facility such as a fume cupboard:

Testing facility is open-air; hence, all personnel will retreat to a safe distance.

Within a fume cupboard (if relevant):

Outside the laboratory e.g. en route to another part of the building / site:

Evacuation of the exclusion zone.

2.3.2 First aid

For chemically contaminated needle stick injuries, encourage wound to bleed and wash with plenty of water. If there are any prolonged effects (e.g. inflammation, discolouration, pain) call Security to arrange for immediate transport to hospital and ensure you take the relevant SDS with you.
Describe the local first aid arrangements that are in place for accidental exposure to any of these substances:

In the event of exposure, the affected person (s) should be moved to the eyewash or kitchen for rinsing.

Notes to physician: Dizziness, drowsiness, metabolic acidosis, blurred vision, seizures, coma, blindness.

☒ Mains fed eyewash / shower available	☐ Alternative eyewash facilities (describe):

Chemical Weapons Act: http://www.opsi.gov.uk/Acts/acts1996/ukpga_19960006_en_1

Anti-terrorism, Crime and Security Act: http://www.legislation.gov.uk/ukpga/2001/24/contents

Drug Precursors: https://www.imperial.ac.uk/safety/safety-by-topic/laboratory-safety/drug-precursors/

Imperial College
London

RISK ASSESSMENT FOR AN ACTIVITY INVOLVING THE USE OF HAZARDOUS CHEMICALS

as required under the **CONTROL OF SUBSTANCES HAZARDOUS TO HEALTH REGULATIONS (COSHH)** *and the* **DANGEROUS SUBSTANCES AND EXPLOSIVE ATMOSPHERES REGULATIONS (DSEAR)**

This form aids in assessing the hazards associated with the use of chemicals and the subsequent application of suitable controls. Guidance on completion of the form can be found by pasting the address below into a browser and selecting the “Hazards and Risks” tab.

http://www.imperial.ac.uk/safety/safety-by-topic/laboratory-safety/chemical-safety/risk-assessment-for-hazardous-chemicals/

The sections below correspond approximately to the sections in the Guidance Note.

The form does not address the risks associated with biological agents or ionising radiation – other Safety Department forms exist for this purpose.

With respect to *DSEAR*, this form may be used to assess risks arising from small scale laboratory operations where hazard zoning is not usually applicable and the controls required largely mirror those of *COSHH*.

This form is not suitable for assessing flammability and explosion risks arising from large scale operations (including pilot scale) where hazard zoning is necessary – this will require a more detailed assessment.

It is the responsibility of the person directing the research i.e. the Principal Investigator to ensure that risk assessments are carried out, remain valid and that the control measures identified are applied.

****Before undertaking workplace risk assessments, assessors should complete Risk Assessment Foundation Training (RAFT)****

PERSON RESPONSIBLE FOR THIS WORK (THE PRINCIPAL INVESTIGATOR)

Name: [redacted]		Position: Reader
Department/ Section: Aeronautics	Division:	Faculty: Engineering

PERSON CONDUCTING THIS ASSESSMENT

Name: [redacted]	Position: Imperial College Rocketry Propulsion Lead
Department/ Section: Aeronautics	Date risk assessment undertaken: 24/11/2021

Review history	*The person responsible must ensure that this risk assessment remains valid*			
	Initial Review	Review 1	Review 2	Review 3
Due date	11/12/2021	11/06/2022	11/12/2022	11/06/2023
Date conducted	10/12/2021	22/04/2022	12/09/2022	
Conducted by	[redacted]	[redacted]	[redacted]	

THE ACTIVITY or PROCEDURE

Title: Storage and use of compressed nitrous oxide at Imperial College, Silwood Campus (Drive Field location) for the purpose of testing a rocket motor designed by Imperial College London Rocketry	Assessment reference No:

Description (describe the procedure step by step or attach a Standard Operating Procedure):

Note that the risk assessment for the testing of the entire motor, including the standard operating procedure is appended, which gives further detail as to the specific use and application of the nitrous oxide, under Subsection 7.

1. A commercial compressed nitrous oxide tank is to be delivered, and stored, in a locked cylinder enclosure, at Silwood Park campus.

2. The nitrous oxide will be used in the testing of a student-developed hybrid rocket motor, acting as the liquid oxidiser.

3. The nitrous oxide supply tank is to be connected to the motor's feed system, controlled by an electromagnetically-actuated master valve. PPE, including face shield, thermally-insulating gloves, and boiler suit, will be worn, as appropriate.

1.0 HAZARDS AND RISKS

1.1 HAZARD EVALUATION & RISK DETERMINATION

List each of the chemical substances used in the activity or procedure in the table below and use this matrix to determine the risk level for each one.

(A) Health Hazard	(B) Dustiness or *Volatility	(C) **Quantity	Score
Low ***Hazard Statements:*** H303; 305 H313; 315; 316 H320 H336 EUH066	**Low** ***Solids:*** Pellet-like solids that do not break up. Little or no dust observed during use. Solids forming large crystals ***Liquids:*** Boiling point > 150ºC	**Small** <1g (ml)	1
Medium ***Hazard Statements:*** H301; H302; H304 H311; H312; H314; H317 H318; H319 H332; H335 H371;H373	**Medium** ***Solids:*** Smaller crystalline or granular solids. Minimal dust, or if any dust is seen it settles out quickly. ***Liquids:*** Boiling point between 50 and 150ºC	**Medium** 1 to 100g (ml)	2
High ***Hazard Statements:*** H300	**High** ***Solids:*** Fine, light powders. Dust can be seen during use and possibly remains airborne for several minutes.	**Large** > 100g (ml)	3

H310 H330; H331; H334 H340; H341 H350; H351 H360; H361; H362 H370; H372 EUH070	***Liquids:*** Boiling point < 50ºC		

Multiply (A)x(B)x(C) to estimate overall risk level: ≤ 7 Low; 8-11 Medium; ≥ 12 High

* For purposes of calculation, if a chemical has more than one risk phrase, use the one(s) with the highest health hazard score
** When stating quantity, this should consider the quantity in the stock bottle as well as the quantity of the aliquots, since loss of containment from the entire stock bottle whilst removing aliquots may represent the greatest risk.

Substance	**Route of exposure** Inhalation (In) Ingestion (Ig) Skin contact (Sk) Penetration (P) Eye splash (Es)	**Hazard Statement(s) * (see safety data sheet) Please include all applicable**	**‡WEL**	**Health Hazard Score**	**Dustiness / Volatility Score**	**Quantity Score**	**Overall Risk Level L/M/H**
Nitrous Oxide	In, Ig, Sk, Es	H336	50ppm	1	3	3	M

‡Workplace Exposure Limit (if one has been assigned - see safety data sheet) – usually in ppm for vapours or mg/m^3 for particulates.

1.2 PROCESS FACTORS INFLUENCING THE RISK OF EXPOSURE

Are there any process factors that influence the route of exposure (See Section 2.2.10):							
Weighing	☐	**Pipetting**	☐	**Filtering**	☐	**Elevated Temperature**	☐
Shaking / Mixing	☐	**Centrifugation**	☐	**Use of Sharps**	☐	**High Pressure**	☒
Other							

1.3 IDENTIFICATION OF THOSE AT RISK OF EXPOSURE

Are there any substances listed in this activity having the Hazard Statements H360, 361 or 362 i.e. those affecting women of child-bearing age?

Yes ☐	No ☒	**If 'Yes':** • any females working with the substance must be informed that the substance(s) present a reproductive toxicity hazard. • should they fall pregnant or are trying for pregnancy, then they have the option of contacting Occupational Health for a detailed confidential health assessment. • they should also avoid being involved in any large-scale spillage clean up in the event that such an incident arises.

Are there any substances listed in this activity having the Hazard Statements H340, 341, 350 or 351? (Substances causing genetic defects or cancer)

Yes ☐	No ☒	**If 'Yes', this risk assessment once completed, must be submitted to the Safety Department (safetydept@imperial.ac.uk) for review before work is carried out. Information will be uploaded to a central database for record keeping purposes.**

Are there any substances listed in this activity having the Hazard Statements H317 or 334 (skin or respiratory sensitisers) **AND** have been determined to be in the high risk category using the matrix above?

Yes ☐	No ☒	**If 'Yes', this risk assessment once completed, must be submitted to Occupational Health (safetydept@imperial.ac.uk) for review before work is carried out.**

If 'Yes' is answered to either of the above question, indicate the frequency and duration of use

	Frequency (how often is the substance used) e.g. every day; once a month etc.
	Duration (how long is possible exposure likely to be) e.g. five minutes; one hour etc.

Are there any external factors that increase the risks associated with exposure to any of these substances e.g. contact lens wearing?

Yes ☐	No ☒	If 'Yes' give details:

Are there any personnel other than laboratory workers who may be at risk from exposure? (e.g. maintenance workers, cleaners etc.)

Yes ☐	No ☒	If 'Yes' give details:

1.4 SUBSTANCES SUBJECT TO OTHER LEGISLATION

Are there any substances involved in this activity that are subject to either the Chemical Weapons Act or the Anti-terrorism, Crime and Security Act? *You must keep a record of usage for Schedule 2 chemical weapons precursors as you will be contacted by the Safety Department on an annual basis prior to the College making its annual declaration to the Department of Energy and Climate Change.*

Yes ☐	No ☒	If 'Yes' give details:

Are there any substances involved in this activity that are listed by the Home Office as drugs precursors?

Yes ☐	No ☒	If 'Yes' give details:

Are there any substances involved in this activity that are defined as controlled drugs?

Yes ☐	No ☒	If 'Yes' give details:

Are there any substances involved in this activity that are explosive, flammable or oxidising? (See Q2.2.2e overleaf)

Yes ☒	No ☐	If 'Yes' give details: Nitrous oxide is a strong oxidiser, especially at elevated temperatures which is the reason for its use in these experiments.

1.5 OTHER HAZARDS

Are there any other hazards involved with this activity? (e.g. pathogens, GMO's, ionising radiation etc.) If 'Yes' have these risks been assessed and any necessary approvals obtained?

Yes ☒	No ☐	If 'Yes' give details and / or reference numbers of related documentation: The nitrous oxide is to be stored under compression; relevant compressed gas health codes OSHA-H01, CGA-HG01

2.0 CONTROL MEASURES

2.1 PREVENTION OF EXPOSURE

2.1.1 Elimination, substitution and procedural change

a). Can any of the substances be eliminated from the process?
http://www.imperial.ac.uk/safety/safety-by-topic/laboratory-safety/chemical-safety/risk-assessment-for-hazardous-chemicals/

Yes ☐	No ☒	Give details: The engine uses nitrous oxide as the oxidiser in a combustion reaction. The engine has been designed with nitrous oxide in mind and therefore cannot use an alternative chemical.

b). Can any of the substances be substituted by a safer alternative or a safer form of the same substance?

Yes ☐	No ☒	Give details: The risks associated with nitrous oxide are primarily those of any oxidiser, and as such substituting nitrous oxide for another will not be safer. It is worth noting that nitrous oxide is one of the safest oxidisers to use.

c). Can the method of work be changed so that the operation giving risk to exposure is no longer necessary?

Yes ☐	No ☒	Give details: The current method incorporates the simplest procedure for using the nitrous oxide, as well as preventative storage and use measures, as per the appended files, which contain the standard operating procedure, risk assessment and ERPs.

d). Are measures in place to exclude non-essential personnel from the area?

Yes ☒	No ☐	Give details: As stated in the dedicated risk assessment, all non-essential personnel are to retreat to a safe distance, and an exclusion zone to be enforced.

2.2 CONTROL OF EXPOSURE

2.2.1 Minimising quantities

Can the quantities of the substances stored, used and produced as waste be reduced?

Yes ☐	No ☒	If 'Yes' give details:

2.2.2 Containment and ventilation

a). Can some or all parts of the process be carried out on the open bench with good general ventilation? (if additional containment such as drip trays are required, give details)

Yes ☒	No ☐	If 'Yes' give details: All operations are to be conducted in an open-air environment, at Silwood Park by the Spars building.

b). Is a fume cupboard or other form of local exhaust ventilation required for any part of the process?

Yes ☐	No ☒	If 'Yes' give details including type and location:

c). Is the fume cupboard or other form of local exhaust ventilation subject to a maintenance regime?

Yes ☐	No ☐	N/A ☒	If 'Yes' give date of last test and state who is responsible for organising maintenance.

d). Does any part of the process need to be totally enclosed e.g. inside a glove box?

Yes ☐	No ☒	If 'Yes' give details:

e). Do measures need to be taken to control sources of ignition?

Yes ☒	No ☐	If 'Yes' give details: Ignition sources are to be kept away from the nitrous oxide tank, stored separately. As mentioned previously, the tank is to be stored in a gas cage. Thorough training is to be conducted and safety precautions taken when using the nitrous oxide.

f). Is a chemical spill kit required?

Yes ☐	No ☒	If 'Yes' give details:

2.2.3 Storage and transportation

a). Storage. If relevant, outline the storage arrangements:

Toxic	Stored in open-air gas cage, in purpose-built and certified pressure vessel. Storage has been approved by supplier (BOC).
Corrosive	Stored in open-air gas cage, in purpose-built and certified pressure vessel. Storage has been approved by supplier (BOC).

Flammable / Highly Flammable / Extremely Flammable	Stored in open-air gas cage, in purpose-built and certified pressure vessel. Storage has been approved by supplier (BOC).
Other	

b). Transportation on site. Will any of these substances need to be transported to other parts of the building or other parts of the site?

Yes ☒	No ☐	If 'Yes' give details of how containment will be assured: Trolley used to safely transport the tank out of the storage facility, and onto the testing field.

c). Transportation off site. Will any of these substances need to be transported to other sites?

Yes ☐	No ☒	If 'Yes' give:	Name of other site: Substance and quantity: Method of transport proposed: Containment precautions:	

2.2.4 Personal protective equipment (PPE)

Gloves EN511 protocol	☒	Type	Thermally-insulating,	Eye / face protection	☒	Type	Face shield
Respiratory protection	☐	Type		Clothing (in addition to lab coats)	☐	Type	Boiler suit (full-body)
State which parts of the process PPE is required for (e.g. experimental process or in emergencies only): Primarily for connecting and disconnecting the nitrous oxide line (flexible hose) between the storage tank and the feed system.							

2.2.5 Waste disposal

Outline the disposal route for each substance or derivative

Please note - cytotoxic waste has its own specific waste route – please contact your facility manager to arrange.

Substance	Drain	Specialist waste contractor	Other (specify)
Spent tank with leftover nitrous oxide (only matter of disposal concern – excess gas diffuses into atmosphere)	☐	☐	Collected by supplier
Excess nitrous oxide in plumbing system of test equipment	☐	☐	Vented to atmosphere while safety exclusion zone is in effect.
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	

2.2.6 Hygiene measures

Describe the hygiene measures in place for work involving these substances e.g. handwash facilities, laundering of protective clothing, storage of personal clothing, prohibition of eating and drinking etc.

First aid kit with eyewash solution present at the facility. Prohibition of eating and drinking on the premises.

2.2.7 Monitoring

Is monitoring necessary to validate the efficacy of control measures for any of these substances?

Incident reports will be created, as necessary, and disseminated to all personnel involved.

2.2.8 Information, instruction and training / supervision

Describe the information, instruction, training and supervision requirements for those working with these substances (include details of record keeping)

All personnel working with the material has been actively involved in designing the testing process, and, as such, is aware of the risk; however, all personnel actively handling nitrous oxide must undergo specialised training. The training will encompass the necessary PPE, and operational procedures and risks.

2.2.9 Lone working

Does any aspect of this activity present an overt risk to the lone worker due to any of the following factors?

		Details including additional precautions to be implemented	SOP/CoP/Protocol Reference:
Can a lone worker safely enter and exit the facility? Including donning and removing PPE?	Yes ☐ No ☐	If no, describe why and any additional precautions necessary for lone working:	
Can any associated equipment be used safely by the lone worker?	Yes ☐ No ☐	If no, describe why and any additional precautions necessary for lone working:	
Does any substance used present a risk of rapidly incapacitating a lone worker?	Yes ☐ No ☐	If yes, describe why and any additional precautions necessary for lone working:	
Will a lone worker be able to safely deal with a spillage or other emergency e.g. malfunctioning equipment?	Yes ☐ No ☐	If no, describe why and any additional precautions necessary for lone working:	
Will lone work take place in a secure or restricted access facility?	Yes ☐ No ☐	If yes, describe why and any additional precautions necessary for lone working:	
Is lone working permitted for this activity?		Yes ☐ No ☒	
Is specific consent required for lone working?		1. Yes (each lone working activity) ☐ 2. Yes (but not for each specific instance) ☐ Specific consent is not required for lone working ☐	
If lone working will take place, are there any restrictions as to when lone working can take place?		Yes ☐ No ☐ N/A ☐	If yes or no, describe the restrictions and why these are in place:

2.2.10 Additional controls

Are there any additional controls required in relation to the process factors identified in Section 1.2 that are not covered anywhere else?

Process factor	**Identified route of exposure**	**Description of how exposure is controlled**
Weighing		
Pipetting		
Filtering		
Elevated temperature		
Shaking / Mixing		
Centrifugation		
Use of Sharps		
High Pressure	In, Ig, Sk, Es	PPE (face shield, insulting gloves, boiler suit), remote master (shut-off) normally-closed control valve
Other		

2.3 EMERGENCY PROCEDURES

Note: Do not cut and paste information on emergency procedures and first aid from the MSDS – it must reflect procedures that are available within the local area (laboratory, building or campus concerned) and be proportional to the extent of exposure anticipated.

2.3.1 Spillage or release

If the spillage involves an unidentified chemical, evacuate the area and contact safety personnel.

Describe the procedures in place for a spillage / release:

Within the laboratory but outside any primary containment facility such as a fume cupboard:

Testing facility is open-air; hence, all personnel will retreat to a safe distance, clear of nitrous oxide gas.

Within a fume cupboard (if relevant):

Outside the laboratory e.g. en route to another part of the building / site:

Evacuation of the exclusion zone.

2.3.2 First aid

Describe the local first aid arrangements that are in place for accidental exposure to any of these substances.

In the event of accidental exposure to N2O, person should remove contaminated clothing and soak exposed area in lukewarm (30 - 35) water. A warm compresses should be applied (i.e. cloths or blankets soaked in warm water) and the area should be soaked every 20 minutes until the skin returns to a normal temperature. Once this has happened, the exposed area should be wrapped using medical gauze to prevent further infection. A soothing ointment could also be applied to unbroken skin.

In the event of prolonged exposure or if the skin begins to exhibit symptoms such as turning white or grey, or becoming numb, the same process should occur while calling emergency services.

In the event on inhalation, the affected person(s) should lie down in the recovery position and be covered with a first aid foil blanket.

☐	Mains fed eyewash / shower available	First Aid emergency eyewash station	Alternative eyewash facilities (describe)

Chemical Weapons Act: http://www.opsi.gov.uk/Acts/acts1996/ukpga_19960006_en_1

Anti-terrorism, Crime and Security Act: http://www.legislation.gov.uk/ukpga/2001/24/contents

Drug Precursors: https://www.imperial.ac.uk/safety/safety-by-topic/laboratory-safety/drug-precursors/

Assessment checklist for lifting and carrying

Section A: Preliminary

Task name: Moving a Nitrous Oxide Bottle

Task description: Transferring a nitrous oxide gas bottle from its storage dolly on to a tank inversion rig.

Load weight: <105 kg

Frequency of lift: 2 times per day

Carry distances (if applicable): N/A

Are other manual handling tasks carried out by these operators?

Assessment discussed with employees/safety representatives:

Is an assessment needed?
(An assessment will be needed if there is a potential risk of injury, eg if the task falls outside the guidelines in the L23 Appendix.)

[✓ Yes]/No*

If 'Yes' continue. If 'No' the assessment need go no further.

*Circle as appropriate

Operations covered by this assessment (detailed description):

A 2 Ton hydraulic hoist will be used to assist lifting. **1)** The hoist arm is moved over the bottle and the hook is attached to the top handle. **2)** The bottle is slowly lifted using the hydraulic cylinder until the dolly can be removed from underneath. The hoist (with bottle) is then wheeled to the inversion rig. **3)** Bottle is lowered onto support frame of inversion rig. Ratchet straps are used to secure the bottle to the rig. Once in place, hook is removed.

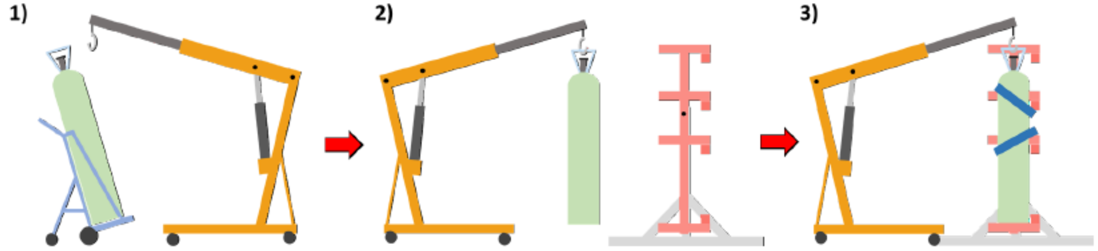
Locations:

Imperial College London Silwood Park, Buckhurst Rd,
Berks, SL5 7PY

Personnel involved: Team members of ICLR

Date of assessment: 28/03/22

Diagrams (other information including existing control measures):



Overall assessment of the risk of injury?
*Circle as appropriate

Low/[✓ Medium]/High*

Make your overall assessment **after** you have completed Section B.

Section B: Lifting and carrying – More detailed assessment, where necessary

Questions to consider:	If 'Yes', tick appropriate level of risk				Problems occurring from the task. (Make rough notes in this column in preparation for the possible remedial action to be taken.)	Possible remedial action, eg changes that need to be made to the task, load, working environment etc. Who needs to be involved in implementing the changes?
	Low	Med	High	N/A		
Do **the tasks** involve:					1. The bottle can swing when suspended, causing unpredictable movements or making the hoist unstable 2. The load is heavy 3. The load is difficult to grasp (see point 2 remedial action)	1. Hydraulic cylinder can be actuated slowly to ensure a controlled lift. The bottle will be steadied by at least 2 people as it is moved. The hoist has a wide base to prevent tipping. Safety officer ensures this is done 2. Hoist uses hydraulic cylinder to support weight of cylinder from the top handle
■ holding loads away from torso?	✓					
■ twisting?	✓					
■ stooping?	✓					
■ reaching upwards?	✓					
■ large vertical movement?	✓					
■ long carrying distances?	✓					
■ strenuous pushing or pulling?	✓					
■ unpredictable movement of loads?		✓				
■ frequent or prolonged physical effort?	✓					
■ insufficient rest or recovery?	✓					
■ a work rate imposed by a process?	✓					
Are **the loads:**						
■ heavy?			✓			
■ bulky or unwieldy?		✓				
■ difficult to grasp?			✓			
■ unstable or unpredictable?		✓				
■ intrinsically harmful (eg sharp/hot)?	✓					

Section B: Lifting and carrying – More detailed assessment, where necessary

Questions to consider:	If 'Yes', tick appropriate level of risk				Problems occurring from the task. (Make rough notes in this column in preparation for the possible remedial action to be taken.)	Possible remedial action, eg changes that need to be made to the task, load, working environment etc. Who needs to be involved in implementing the changes?
	Low	Med	High	N/A		
Consider **the working environment** Are there:					1. The task will be performed outside on dirt floors: potential tripping hazards, slippery if wet, uneven surface.	1. Appropriate area will be chosen to perform the lift which will be as flat as possible with plenty of open space. Tripping hazards like rocks or tools will be cleared before beginning the lift. Lift will not be attempted if area is slippery and lift will be cancelled if there is heavy rain.
■ constraints on posture?	✓					
■ poor floors?		✓				
■ variations in levels?	✓					
■ hot/cold/humid conditions?	✓					
■ strong air movements?	✓					
■ poor lighting conditions?	✓					
Consider **individual capability** Does the job:						
■ require unusual capability?	✓					
■ pose a risk to those with a health problem or a physical or learning difficulty?				✓		
■ pose a risk to those who are pregnant?				✓		
■ pose a risk to new workers/young people?				✓		
■ require special information/training?				✓		

Section B: Lifting and carrying – More detailed assessment, where necessary

Questions to consider:	Yes/No	Problems occurring from the task. (Make rough notes in this column in preparation for the possible remedial action to be taken.)	Possible remedial action, eg changes that need to be made to the task, load, working environment etc. Who needs to be involved in implementing the changes?
Other factors to consider			
Protective clothing			
■ Is movement or posture hindered by clothing or personal protective equipment?	Yes/[✓ No]		
■ Is there an absence of the correct/suitable PPE being worn?	Yes/[✓ No]		
Work organisation (psychosocial factors)			
■ Do workers feel that there has been a lack of consideration given to the planning and scheduling of tasks/rest breaks?	Yes/[✓ No]		
■ Do workers feel that there is poor communication between managers and employees (eg not involved in risk assessments or decisions on changes in workstation design)?	Yes/[✓ No]		
■ Are there sudden changes in workload, or seasonal changes in volume without mechanisms for dealing with the change?	Yes/[✓ No]		
■ Do workers feel they have not been given enough training and information to carry out the task successfully?	Yes/[✓ No]		

Section C: Lifting and carrying – Remedial action to be taken

Remedial steps that should be taken, in order of priority:	Person responsible for implementing controls	Target implementation date	Completed Y/N
1 Safety team and representatives will be involved in the risk assessment process and lifting procedure planning.	[redacted]	Ongoing	Yes
2 Ensure there are strong grip gloves and steel toe cap boots for all lifting participants.	[redacted]	Ongoing	Yes
3 Assess the potential of ordering smaller and lighter nitrous oxide cylinders.	[redacted]	July 2022	
4 Safety officer to ensure no rushing on the lift, and guide the participants to perform the lift safely	[redacted]	Ongoing	Yes
5			
6			
7			
8			
9			

Date by which actions should be completed: July 2022

Date for review of assessment: March 2023

Assessor's name: [redacted]

Signature:

Imperial College London

RISK ASSESSMENT FOR AN ACTIVITY INVOLVING THE USE OF HAZARDOUS CHEMICALS

as required under the **CONTROL OF SUBSTANCES HAZARDOUS TO HEALTH REGULATIONS (COSHH)** *and the* **DANGEROUS SUBSTANCES AND EXPLOSIVE ATMOSPHERES REGULATIONS (DSEAR)**

This form aids in assessing the hazards associated with the use of chemicals and the subsequent application of suitable controls. Guidance on completion of the form can be found by pasting the address below into a browser and selecting the "Hazards and Risks" tab.

http://www.imperial.ac.uk/safety/safety-by-topic/laboratory-safety/chemical-safety/risk-assessment-for-hazardous-chemicals/

The sections below correspond approximately to the sections in the Guidance Note.

The form does not address the risks associated with biological agents or ionising radiation – other Safety Department forms exist for this purpose.

With respect to *DSEAR*, this form may be used to assess risks arising from small scale laboratory operations where hazard zoning is not usually applicable and the controls required largely mirror those of *COSHH*.

This form is not suitable for assessing flammability and explosion risks arising from large scale operations (including pilot scale) where hazard zoning is necessary – this will require a more detailed assessment.

It is the responsibility of the person directing the research i.e. the Principal Investigator to ensure that risk assessments are carried out, remain valid and that the control measures identified are applied.

****Before undertaking workplace risk assessments, assessors should complete Risk Assessment Foundation Training (RAFT)****

PERSON RESPONSIBLE FOR THIS WORK (THE PRINCIPAL INVESTIGATOR)

Name: [redacted]		Position: Reader
Department/ Section: Aeronautics	Division:	Faculty: Engineering

PERSON CONDUCTING THIS ASSESSMENT

Name: [redacted]	Position: ICLR Propulsion Technical Lead
Department/ Section: Aeronautics	Date risk assessment undertaken: 09/11/2022

Review history	***The person responsible must ensure that this risk assessment remains valid***			
	Initial Review	Review 1	Review 2	Review 3
Due date	09/11/2022	09/05/2023	09/11/2023	09/05/2024
Date conducted	10/11/2022			
Conducted by	[redacted]			

THE ACTIVITY or PROCEDURE

Title: Storage and use of compressed pure nitrogen gas at Imperial College, Silwood Campus (Drive Field location) for the purpose of testing a rocket motor designed by Imperial College London Rocketry	Assessment reference No:

Description (describe the procedure step by step or attach a Standard Operating Procedure):

Note that the risk assessment for the testing of the entire motor, including the standard operating procedure is appended, which gives further detail as to the specific use and application of the compressed nitrogen.

1. A commercial compressed nitrogen tank is to be delivered, and stored, in a locked cylinder enclosure,

at Silwood Park campus.

2. The compressed nitrogen will be used in the testing of a student-developed hybrid rocket motor, acting as the pressurant gas for the liquid propellants

3. The nitrogen cylinder will be connected to the high-pressure plumbing system for the engine, where it will feed into a dome loaded pressure regulator before entering the propellant tanks to pressurise them. All components under pressure are to be rated for the expected pressures and hydrostatically pressure tested to at least 1.5x the maximum operating pressure. Pressure relief devices will be present on all enclosed volumes in the system to prevent an overpressure event.

PPE, including face shield will be worn as appropriate.

Valves are always opened slowly to prevent pressure shocks to plumbing and to give time to notice any leaks.

1.0 HAZARDS AND RISKS

1.1 HAZARD EVALUATION & RISK DETERMINATION

List each of the chemical substances used in the activity or procedure in the table below and use this matrix to determine the risk level for each one.

(A) Health Hazard	(B) Dustiness or *Volatility	(C) **Quantity	Score
Low ***Hazard Statements:*** H303; 305 H313; 315; 316 H320 H336 EUH066	**Low** ***Solids:*** Pellet-like solids that do not break up. Little or no dust observed during use. Solids forming large crystals ***Liquids:*** Boiling point > 150°C	**Small** <1g (ml)	1
Medium ***Hazard Statements:*** H301; H302; H304 H311; H312; H314; H317 H318; H319 H332; H335 H371;H373	**Medium** ***Solids:*** Smaller crystalline or granular solids. Minimal dust, or if any dust is seen it settles out quickly. ***Liquids:*** Boiling point between 50 and 150°C	**Medium** 1 to 100g (ml)	2
High ***Hazard Statements:***	**High**	**Large** > 100g (ml)	3

H300 H310 H330; H331; H334 H340; H341 H350; H351 H360; H361; H362 H370; H372 EUH070	***Solids:*** Fine, light powders. Dust can be seen during use and possibly remains airborne for several minutes. ***Liquids:*** Boiling point < 50ºC		🟦

Multiply (A)x(B)x(C) to estimate overall risk level: ≤ 7 Low; 8-11 Medium; ≥ 12 High

* For purposes of calculation, if a chemical has more than one risk phrase, use the one(s) with the highest health hazard score
** When stating quantity, this should consider the quantity in the stock bottle as well as the quantity of the aliquots, since loss of containment from the entire stock bottle whilst removing aliquots may represent the greatest risk.

Substance	**Route of exposure** Inhalation (In) Ingestion (Ig) Skin contact (Sk) Penetration (P) Eye splash (Es)	**Hazard Statement(s) *** **(see safety data sheet) Please include all applicable**	**‡WEL**	**Health Hazard Score**	**Dustiness / Volatility Score**	**Quantity Score**	**Overall Risk Level L/M/H**
Nitrogen	In	H280	50ppm	1	3	3	M

‡Workplace Exposure Limit (if one has been assigned - see safety data sheet) – usually in ppm for vapours or mg/m^3 for particulates.

1.2 PROCESS FACTORS INFLUENCING THE RISK OF EXPOSURE

Are there any process factors that influence the route of exposure (See Section 2.2.10):			
Weighing ☐	**Pipetting** ☐	**Filtering** ☐	**Elevated Temperature** ☐
Shaking / Mixing ☐	**Centrifugation** ☐	**Use of Sharps** ☐	**High Pressure** ☒
Other			

1.3 IDENTIFICATION OF THOSE AT RISK OF EXPOSURE

Are there any substances listed in this activity having the Hazard Statements H360, 361 or 362 i.e. those affecting women of child-bearing age?

Yes ☐	No ☒	**If 'Yes':** ● any females working with the substance must be informed that the substance(s) present a reproductive toxicity hazard. ● should they fall pregnant or are trying for pregnancy, then they have the option of contacting Occupational Health for a detailed confidential health assessment. ● they should also avoid being involved in any large-scale spillage clean up in the event that such an incident arises.

Are there any substances listed in this activity having the Hazard Statements H340, 341, 350 or 351? (Substances causing genetic defects or cancer)

Yes ☐	No ☒	**If 'Yes', this risk assessment once completed, must be submitted to the Safety Department (safetydept@imperial.ac.uk) for review before work is carried out. Information will be uploaded to a central database for record keeping purposes.**

Are there any substances listed in this activity having the Hazard Statements H317 or 334 (skin or respiratory sensitisers) **AND** have been determined to be in the high risk category using the matrix above?

Yes ☐	No ☒	**If 'Yes', this risk assessment once completed, must be submitted to Occupational Health (safetydept@imperial.ac.uk) for review before work is carried out.**

If 'Yes' is answered to either of the above question, indicate the frequency and duration of use

	Frequency (how often is the substance used) e.g. every day; once a month etc.
	Duration (how long is possible exposure likely to be) e.g. five minutes; one hour etc.

Are there any external factors that increase the risks associated with exposure to any of these substances e.g. contact lens wearing?

Yes ☐	No ☒	If 'Yes' give details:

Are there any personnel other than laboratory workers who may be at risk from exposure? (e.g. maintenance workers, cleaners etc.)

Yes ☐	No ☒	If 'Yes' give details:

1.4 SUBSTANCES SUBJECT TO OTHER LEGISLATION

Are there any substances involved in this activity that are subject to either the Chemical Weapons Act or the Anti-terrorism, Crime and Security Act? *You must keep a record of usage for Schedule 2 chemical weapons precursors as you will be contacted by the Safety Department on an annual basis prior to the College making its annual declaration to the Department of Energy and Climate Change.*

Yes ☐	No ☒	If 'Yes' give details:

Are there any substances involved in this activity that are listed by the Home Office as drugs precursors?

Yes ☐	No ☒	If 'Yes' give details:

Are there any substances involved in this activity that are defined as controlled drugs?

Yes ☐	No ☒	If 'Yes' give details:

Are there any substances involved in this activity that are explosive, flammable or oxidising? (See Q2.2.2e overleaf)

Yes ☒	No ☐	If 'Yes' give details: The high-pressure nitrogen is not flammable, explosive or oxidising. However, it will be used in conjunction with nitrous oxide (see separate COSHH form) which is a strong oxidiser.

1.5 OTHER HAZARDS

Are there any other hazards involved with this activity? (e.g. pathogens, GMO's, ionising radiation etc.) If 'Yes' have these risks been assessed and any necessary approvals obtained?

Yes ☒	No ☐	If 'Yes' give details and / or reference numbers of related documentation: The nitrogen is to be stored under compression of up to 300 bar; relevant compressed gas health codes OSHA-H01, CGA-HG01

2.0 CONTROL MEASURES

2.1 PREVENTION OF EXPOSURE

2.1.1 Elimination, substitution and procedural change

a). Can any of the substances be eliminated from the process?
http://www.imperial.ac.uk/safety/safety-by-topic/laboratory-safety/chemical-safety/risk-assessment-for-hazardous-chemicals/

Yes ☐	No ☒	Give details: The engine uses high pressure nitrogen as a pressurant gas to force propellants into the engine. Since the high pressure is necessary for the engine's function, this cannot be substituted.

b). Can any of the substances be substituted by a safer alternative or a safer form of the same substance?

Yes ☐	No ☒	Give details: The risks associated with the nitrogen gas are the high pressures involved, as well as concerns with displacing oxygen. Since high pressure is required for the pressurant gas, this cannot be substituted. The gas also needs to be non-oxidising, so air cannot be used. As such, compressed nitrogen is the safest option.

c). Can the method of work be changed so that the operation giving risk to exposure is no longer necessary?

Yes ☐	No ☒	Give details: The nitrogen cylinder will only be used

d). Are measures in place to exclude non-essential personnel from the area?

Yes ☒	No ☐	Give details: As stated in the dedicated risk assessment, all non-essential personnel are to retreat to a safe distance, and an exclusion zone to be enforced.

2.2 CONTROL OF EXPOSURE

2.2.1 Minimising quantities

Can the quantities of the substances stored, used and produced as waste be reduced?

Yes ☐	No ☒	If 'Yes' give details:

2.2.2 Containment and ventilation

a). Can some or all parts of the process be carried out on the open bench with good general ventilation? (if additional containment such as drip trays are required, give details)

Yes ☒	No ☐	If 'Yes' give details: All operations are to be conducted in an open-air environment, at Silwood Park by the Spars building.

b). Is a fume cupboard or other form of local exhaust ventilation required for any part of the process?

Yes ☐	No ☒	If 'Yes' give details including type and location:

c). Is the fume cupboard or other form of local exhaust ventilation subject to a maintenance regime?

Yes ☐	No ☐	N/A ☒	If 'Yes' give date of last test and state who is responsible for organising maintenance.

d). Does any part of the process need to be totally enclosed e.g. inside a glove box?

Yes ☐	No ☒	If 'Yes' give details:

e). Do measures need to be taken to control sources of ignition?

Yes ☒	No ☐	If 'Yes' give details: Ignition sources are to be kept away from the nitrous oxide tank, stored separately. As mentioned previously, the tank is to be stored in a gas cage. Thorough training is to be conducted and safety precautions taken when using the nitrous oxide.

f). Is a chemical spill kit required?

Yes ☐	No ☒	If 'Yes' give details:

2.2.3 Storage and transportation

a). Storage. If relevant, outline the storage arrangements:

Toxic	Stored in open-air gas cage, in purpose-built and certified pressure vessel. Storage has been approved by supplier (BOC).

Corrosive	Stored in open-air gas cage, in purpose-built and certified pressure vessel. Storage has been approved by supplier (BOC).
Flammable / Highly Flammable / Extremely Flammable	Stored in open-air gas cage, in purpose-built and certified pressure vessel. Storage has been approved by supplier (BOC).
Other	

b). Transportation on site. Will any of these substances need to be transported to other parts of the building or other parts of the site?

Yes ☒	No ☐	If 'Yes' give details of how containment will be assured: Trolley used to safely transport the tank out of the storage facility, and onto the testing field.

c). Transportation off site. Will any of these substances need to be transported to other sites?

Yes ☐	No ☒	If 'Yes' give:	Name of other site: Substance and quantity: Method of transport proposed: Containment precautions:	

2.2.4 Personal protective equipment (PPE)

Gloves EN511 protocol	☐	Type	Thermally-insulating,	Eye / face protection	☒	Type	Face shield
Respiratory protection	☐	Type		Clothing (in addition to lab coats)	☐	Type	Boiler suit (full-body)
State which parts of the process PPE is required for (e.g. experimental process or in emergencies only): Primarily for connecting and disconnecting the nitrogen between the cylinder and the high pressure feed system, including opening the cylinder valve and venting the line before disconnecting afterwards.							

2.2.5 Waste disposal

Outline the disposal route for each substance or derivative

Please note - cytotoxic waste has its own specific waste route – please contact your facility manager to arrange.

Substance	Drain	Specialist waste contractor	Other (specify)
Spent tank with leftover nitrogen (only matter of disposal concern – excess gas diffuses into atmosphere)	☐	☐	Collected by supplier
Excess nitrogen in plumbing system of test equipment	☐	☐	Vented to atmosphere
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	

2.2.6 Hygiene measures

Describe the hygiene measures in place for work involving these substances e.g. handwash facilities, laundering of protective clothing, storage of personal clothing, prohibition of eating and drinking etc.

First aid kit with eyewash solution present at the facility.

2.2.7 Monitoring

Is monitoring necessary to validate the efficacy of control measures for any of these substances?

Incident reports will be created, as necessary, and disseminated to all personnel involved.

2.2.8 Information, instruction and training / supervision

Describe the information, instruction, training and supervision requirements for those working with these substances (include details of record keeping)

All personnel working with the material has been actively involved in designing the testing process, and, as such, is aware of the risk; however, all personnel actively handling nitrogen must undergo specialised training. The training will encompass the necessary PPE, and operational procedures and risks.

All members handling high pressure nitrogen must complete the “Compressed gases and connecting regulators” e-Learning course: https://www.imperial.ac.uk/staff-development/safety-training/safety-courses-/compressed-gases-e-learning/

2.2.9 Lone working

Does any aspect of this activity present an overt risk to the lone worker due to any of the following factors?

		Details including additional precautions to be implemented		SOP/CoP/Protocol Reference:
Can a lone worker safely enter and exit the facility? Including donning and removing PPE?	Yes ☐ No ☐	If no, describe why and any additional precautions necessary for lone working:		
Can any associated equipment be used safely by the lone worker?	Yes ☐ No ☐	If no, describe why and any additional precautions necessary for lone working:		
Does any substance used present a risk of rapidly incapacitating a lone worker?	Yes ☐ No ☐	If yes, describe why and any additional precautions necessary for lone working:		
Will a lone worker be able to safely deal with a spillage or other emergency e.g. malfunctioning equipment?	Yes ☐ No ☐	If no, describe why and any additional precautions necessary for lone working:		
Will lone work take place in a secure or restricted access facility?	Yes ☐ No ☐	If yes, describe why and any additional precautions necessary for lone working:		
Is lone working permitted for this activity?		Yes ☐ No ☒		
Is specific consent required for lone working?		1. Yes (each lone working activity) ☐ 2. Yes (but not for each specific instance) ☐ Specific consent is not required for lone working ☐		
If lone working will take place, are there any restrictions as to when lone working can take place?		Yes ☐ No ☐ N/A ☐	If yes or no, describe the restrictions and why these are in place:	

2.2.10 Additional controls

Are there any additional controls required in relation to the process factors identified in Section 1.2 that are not covered anywhere else?

Process factor	**Identified route of exposure**	**Description of how exposure is controlled**
Weighing		
Pipetting		
Filtering		
Elevated temperature		
Shaking / Mixing		
Centrifugation		
Use of Sharps		

High Pressure	In	PPE (face shield, boiler suit), easy-to-use and labelled shutoff valves
Other		

2.3 EMERGENCY PROCEDURES

Note: Do not cut and paste information on emergency procedures and first aid from the MSDS – it must reflect procedures that are available within the local area (laboratory, building or campus concerned) and be proportional to the extent of exposure anticipated.

2.3.1 Spillage or release

If the spillage involves an unidentified chemical, evacuate the area and contact safety personnel.

Describe the procedures in place for a spillage / release:

Within the laboratory but outside any primary containment facility such as a fume cupboard:

Testing facility is open-air; hence, all personnel will retreat to a safe distance, clear of nitrous oxide gas.

Within a fume cupboard (if relevant):

Outside the laboratory e.g. en route to another part of the building / site:

Evacuation of the exclusion zone.

2.3.2 First aid

Describe the local first aid arrangements that are in place for accidental exposure to any of these substances.

In the event of extreme inhalation, the affected person(s) should be moved to a well-ventilated area. They should lie down in the recovery position and be covered with a first aid foil blanket.

☐	Mains fed eyewash / shower available	First Aid emergency eyewash station	Alternative eyewash facilities (describe)

Chemical Weapons Act: http://www.opsi.gov.uk/Acts/acts1996/ukpga_19960006_en_1

Anti-terrorism, Crime and Security Act: http://www.legislation.gov.uk/ukpga/2001/24/contents

Drug Precursors: https://www.imperial.ac.uk/safety/safety-by-topic/laboratory-safety/drug-precursors/

Imperial College
London

GENERAL RISK ASSESSMENT

SUBJECT OR ACTIVITY:- ICL Rocketry Hot Fire Testing

1. PERSONS CARRYING OUT, APPROVING AND CHECKING THIS ASSESSMENT. (MUST HAVE SUCCESSFULLY COMPLETED RAFT OR OTHER APPROVED TRAINING)

Assessor	[redacted]	**Position**	ICLR Propulsion Technical Lead	**Date**	09/11/2022	**Confirm Training in Risk Assessment Yes ☒**
Approved by		**Position**		**Date**		**Confirm Training in Risk Assessment Yes ☐**
Checked by		**Position**		**Date**		**Confirm Training in Risk Assessment Yes ☐**

2. DETAILED DESCRIPTION OF THE STEPS INVOLVED IN THE ACTIVITY (include storage, transport and disposal if relevant, and how often it is carried out)

The activity is undertaken by Imperial College London Rocketry at the Silwood Park campus, and entails the ground testing of student-developed hybrid and liquid rocket engines on a bespoke test stand, specifically designed to facilitate testing at this scale. This activity is scheduled to start during February 2023 - September 2023, and further tests will be planned, provided their initial success and the ultimate suitability of the testing site. In addition, this is to be a multi-event series of tests, as research goals may require that multiple tests be conducted in a day - a more detailed overview of the relevant procedures is provided below.

The testing consists of hot-fire testing of a 3kN liquid rocket engine which uses nitrous oxide as an oxidiser and methanol as a fuel. The test setup consists of a static testing rig to contain the engine, load cell mounting bracket, exhaust plume diverter, fluid system with nitrous oxide run tank, methanol fuel tank, BOC Nitrogen cylinder for system's pressurisation and a BOC nitrous oxide cylinder on a tank inverter rig. See Figure 1 and Figure 2 for further details.

Cold flow testing shall test the fluid system connections for leaks, and will only be conducted once per testing session. Hot fire testing shall be performed up to 10 times per test date. During the first hot fire testing campaign, tests shall last a maximum of 15 seconds. The maximum testing frequency is once per week.

These tests will be conducted in a remote area with little-to-no human activity, owing to the inherent risks of propulsion systems testing; however, there are two primary mechanisms in place to prevent large-scale accidents. The first is an over-pressurisation prevention system, which detaches the nozzle closure in the direction of the exhaust plume (a safe direction). This fail-safe design will ensure that a catastrophic explosion cannot take place. By virtue of their design, upon catastrophic failure (i.e. an explosion), combustion ceases for liquid engines, as there is no longer contact between the oxidiser and fuel, and neither is flammable on their own. The second major safety mechanism is an emergency shutoff system that will stop the flow of nitrous oxide and methanol if commanded, or in the event of a power failure. This will immediately shut down the engine. Furthermore, although the testing site will have a paved section, it is surrounded by grassland - therefore, a plume diverter will be used to direct the exhaust flames upwards, away from flammable materials.

Purpose of Testing

Rocket engine engineering is by nature quite difficult and somewhat empirical. As such, despite advanced modelling software, it is impossible to fully understand or predict the behaviour of bespoke engines. In order to understand how effective the design is and if it is suitable for flight, the engine must be thoroughly tested with a series of short & long duration firing tests. Additionally, the conditions must aptly resemble those of flight, as such using similar (or identical) fluid systems, maintaining the same procedure for filling and emptying. These tests will give the team experience and knowledge of the engine's behaviour, ensuring flight tests can be conducted safely, or the engine modified.

Outline of Procedures

The N2O and N2 tank will be moved from the storage area behind the Spars building to the test area. The N2O tank will be strapped to a trolley with the included chain.

At the test site, the N2O tank will be offloaded from the trolley to the tank inverter by five team members wearing steel toe shoes (see appendices for details and manual handling assessment). Ratchet straps and a hydraulic hoist will be used to assist with lifting. The tank will then be rotated 180 degrees in the tank inverter so that the outlet of the tank is at the bottom. The upstream plumbing will be connected to the tank outlet using a short flexible hose.

The trolley will be returned to the storage area and the Nitrogen cylinder will be transferred to it and chained in place. The Nitrogen cylinder will be wheeled to the test site and left upright on the trolley next to the N2O tank in the tank inverter. The high-pressure gas plumbing will be connected to the nitrogen tank via a long, high pressure, rubber hose.

Methanol will be stored at a concealed place with a lock at the South Kensington campus and it will be brought to the test sight whenever needed, in amounts no larger than 5 litres. The Methanol will be transferred from the storage container to the propellant tank by hand using a funnel. Protective gloves, eye protection and a lab coat are to be worn during this process (please refer to the Methanol COSHH form and SOP for further details).

The data acquisition electronics (DAQ) will be connected to the various sensors (e.g. pressure transducers, thermocouples etc.) and turned on. The main valves will be connected to the control box in the Silwood building with a ~30m cable, while running on separate power systems as a redundancy. The live feed camera will be started along with other recording cameras to provide visual analysis of tests.

The test stand box will be placed in an already dug pit in the ground. The engine will be bolted to the plate onto the test stand. The run tank stand will be placed on top of the test stand and clamped in place. A short 0.5m flexible hose will be used to connect the run tank to the engine and the longer 2m hose will connect to the N2O filling system. A separate set of hoses will connect the nitrogen tank to the N2O run tank and the methanol tank.

The majority of the test crew will exit the test area and move to the control room (kitchen) in the Spars building behind the polycarbonate shield. The CTO (Chief Test Operator) and PSO (Propulsion Safety Officer) will remain at the test area and must ensure they are carrying the arming key with them. The ESO will perform a check of surrounding areas and two team members wearing high visibility clothing will walk to the two site entrances to prevent perimeter breaches and put on warning signs. The west station keeper will also knock on the door of the nearby residents to ensure they are aware of imminent testing and loud noises. There will be a surveillance system covering all entrances and the test sight. The methanol tank filling cap will be removed, and methanol will be poured into the fuel tank using a funnel, with the vent valve open to allow air to exit the tank. The N2O tank will be carefully opened to allow nitrous into the plumbing section upstream of the main filling valve. The Nitrogen tank will also be carefully opened to allow nitrogen gas into the high pressure plumbing upstream on the main pressurant valve. The pressure gauges will be monitored to ensure the upstream and downstream pressures are correct.

The CTO and PSO will then also move to the control room. The front door of Spars building will be closed and PSO will check if all team members are inside. A megaphone will be used to warn of hazardous activity during filling as well as imminent testing. Station keepers will be radioed to inform that filling is commencing. Once go ahead is given by the PSO, the CTO will turn on power to the valves and arm the system. The filling valve will be opened to allow nitrous to flow into the run tank and the nitrogen to flow into the nitrogen tank simultaneously. The run tank and the N2O tank will be filled and the filling and vent valves will be closed. The pressurant valve will then be opened to pressurise the N2O and the methanol tank with pressurant gas regulated to approximately 50 bar by the pressure regulator. The CTO will then perform a clear 10 second countdown using the megaphone. At T = 0 seconds, the main valve(s) will be opened to the pre-stage (partly open) position and the ignitors triggered. At T+ 1 seconds, the main valve(s) will be fully opened and the engine will reach full throttle. After a predefined number of seconds (maximum 15) the main valve(s) will be shut off, finishing the burn. The vent valves will then be opened to fully safe the system.

If the live video shows no visible signs of issues, the ESO will notify the station keepers that the test is completed. The PSO will then open the door and walk over to the test area to visually inspect the setup from a distance. If everything looks fine, selected team members may enter the test area to collect data from the DAQ, turn off cameras and configure the setup for the next test.

Transportation and storage are split into three categories:

i) The Nitrous Oxide cylinder and Nitrogen Cylinder, to be delivered to Imperial College Silwood Park Campus by the supplier (BOC), and stored in a locked cylinder storage area behind the Spars building;

ii) The test-stand, to be manufactured at the South Kensington campus, and transported once (disassembled), then stored at Spars building;

iii) Consumables and engine parts/assemblies, which are to be either stored within the premises of the testing or transported between the two campuses before each test-fire.

There are few disposal concerns which pertain to the testing activity itself. Consumables such as spent graphite nozzles and paraffin fuel grains will be kept at South Kensington campus in a dedicated locker. These are very inert and will not require any special transport or storage. Nitrous oxide tanks are to be reclaimed by the supplier from the site.

3. LOCATION

Site	Field	**Building**	Field	**Room**	Spars Building Paddock

4. HAZARDS – WHAT ARE THEY, WHO IS AFFECTED, HOW ARE THEY CONTROLLED?

NOTES – PLEASE READ CAREFULLY!

List **all** the hazards associated with the work, decide who could be affected, give details of what could happen without any controls, and estimate the “raw” risk.

Then write down the control measures that are already in place to prevent any harm occurring, and estimate the “residual” risk using the matrix guide (Appendix1)

If the residual risk is not reduced to “LOW” (less than 4) then additional controls must be considered; however, aim to get the lowest risk score that is reasonably practicable.

HAZARD TYPE	**WHO DOES THE HAZARD AFFECT?**	**WHAT INCIDENT OR HARM COULD BE CAUSED WITHOUT ANY CONTROL MEASURES?**	**RAW RISK with no control measures.** **In your estimation, is it:-** **LOW, MEDIUM or HIGH?**	**EXISTING CONTROL MEASURES** **(E.g. PHYSICAL THINGS LIKE MACHINE INTERLOCKS; PROCEDURAL THINGS LIKE OPERATING PROCEDURES; TRAINING)**	**RESIDUAL RISK with existing controls (See appendix 1)**		
					Proba bility	**Seve rity**	**Risk (S x P)**

Explosion	Staff / Students/ Other	Uncontrolled explosion of pressurised components could cause serious injury through flying shrapnel, hot gas release or cold gas release, resulting in major hot or cold burns, broken limbs or other major injuries requiring medical attention	High	Physical distance and obstacles (Members taking shelter in building ~20m away behind 2 walls and a fence), engine (source of explosion) being placed into 0.5m deep pit, controlled failure mode (nozzle popping off), Windows in proximity of members are being covered with polycarbonate attached to existing steel bars to protect against broken glass. For members of the public, a thorough inspection and clearing of the surrounding area will be done. Air horns will be sounded to ensure people are aware of the danger. Nearby residents have been notified and signs shall be put up. All pressure containment devices must be hydrostatically proof tested to 1.5x the maximum operating pressure before use, and will not be pressurised until people are in safe positions (50+ m away or inside the Spars control room) and behind the polycarbonate shield. Propellant tanks and plumbing containing nitrous oxide feature Safety Pressure Relief Valves (SPRVs) calibrated to open at or above 70 bar. This prevents pressure rising to the point of plumbing or tank mechanical failure.	Unlikely	Serious	4
		Nitrogen gas is stored under high pressure (300 bar). In the case of severe cylinder damage, explosion could cause serious injury.					

				All gas cylinders shall be chained to a supporting structure or transport device (i.e. a trolley) when in an upright position, to prevent them falling and potentially becoming damaged.			
Noise	Staff / Students / Other	Sudden depressurisation or explosion could cause excessive noise which may cause alarm or injury to personnel if hearing protection is not worn.	Medium	Wearing ear protection, physical distance and being in an enclosed building. For members of the public, a thorough inspection and clearing of the surrounding area will be done. There will be a surveillance system with CCTVs covering entrances and the whole test sight. A megaphone will be used to notify anyone nearby of hazardous activities and when testing is imminent. Nearby residents will have been notified and signs shall be put up. Members of the public should be kept a safe distance from the hot fire by establishing a 100-meter radius exclusion zone.	Unlikely	Minor	2
		The engine firing itself will produce high noise levels which may cause alarm or injury to personnel if hearing protection is not worn within close proximity.			Likely	Minor	3

Manual Handling	Staff / Students	During offloading of N2O tank from trolley to tank inverter, students/staff will be lifting the tank physically. Potential risk of dropping tank causing severe injury if control measures are not taken. The Nitrogen cylinder will be always transported and used on a trolley and will not need to be transferred to any other equipment.	Medium	Wear PPE specifically steel toed shoes, additionally ensure there are other members onsite to help guide those lifting. Use a hydraulic hoist or other certified mechanical aid to support tank weight during lift and ensure members using it follow operating instructions correctly. Inspect equipment prior to use to ensure in good working condition. Tanks should always be chained or mechanically secured to a supporting structure (e.g. trolley, tank stand etc.) when stored in an upright position.	Unlikely	Minor	2
Heat	Staff / Students	Handling of the engine and sub-assemblies post-test without PPE can lead to skin burn (expected external temperatures around 100-150°C)	Medium	Using PPE (thermally insulating gloves) and IR Thermal sensor to ensure components have cooled sufficiently. Wait at least 30 minutes after a test before touching engine components. Hold hand above parts before touching them to check if they are still hot.	Very unlikely	Minor	1
Cold	Staff / Students	After testing, all plumbing components (tank, pipes, valve, injector) could reach very low temperatures (~-90°C) which could cause skin freezing if PPE is not worn during post-test handling	Medium	Using PPE (thermally insulating gloves) when handling any components after a cold flow or hot fire test.	Very unlikely	Minor	1

Procedures	Staff / Students	Low mechanical risk, incorrect use of tools or falling objects could cause injuries such as bruises or minor cuts.	Low	Wearing PPE such as safety shoes, and working gloves	Very unlikely	Minor	1
Chemicals	Staff / Students/ Other	Nitrous Oxide can be harmful if ingested in large amounts (a large tank will be present) in case of uncontrolled leak Nitrous oxide is stored at high pressure (40-60 bar), leaks may result in high velocity sprays which could cause injury without appropriate PPE. Nitrogen is stored at high pressure (300 bar), leaks could result in high speed, loud jets of gas. Large Nitrogen releases can displace air and potentially cause asphyxiation in enclosed areas. Methanol can be harmful if ingested or inhaled.	Medium	Prior to usage of system, all components will be hydrostatically tested, ensuring system seals properly and will not cause uncontrolled leaks. All containers with methanol shall be clearly marked to ensure they are not ingested by accident. All gases are stored and used outside and in well ventilated areas to prevent gas build up and asphyxiation. For members of the public, a thorough inspection and clearing of the surrounding area will be done. There will be a surveillance system with CCTVs covering entrances and the whole test sight. A megaphone will be used to notify anyone nearby of hazardous activities and when testing is imminent. Nearby residents will have been notified and signs shall be put up. Members of the public should be kept a safe distance from the hot fire by establishing a 100-meter radius exclusion zone.	Unlikely	Minor	2

5. WHAT ADDITIONAL CONTROL MEASURES ARE NEEDED? **If none, please tick box and move on to next section** ☐

Please describe:-	Responsible Person(s)?	By what date?	Completed? (Date)
Silwood staff and local residents will be notified at least 2 days in advance, specifying the date & approximate time of tests, via email	[redacted]	2+ days prior to hot fire (fill in after date confirmed)	(fill in after date confirmed)

6. LONE WORKING (This can increase the risk from other hazards, and must always be considered.)

NOTE – READ CAREFULLY! USE THESE LINKS FOR THE COLLEGE GUIDANCE, THE COLLEGE CODE OF PRACTICE AND THE LONE WORKING CONSENT FORM

Lone working is not a hazard in itself, but will increase the risk of harm occurring from other hazards.

Record *why* Lone working will or won't take place, state *who* will be lone working and *what* controls and permissions are in place.

WHY WILL (OR WON'T) IT TAKE PLACE?	WHO MIGHT BE WORKING ALONE?	WHAT ARE THE CONTROLS / PERMISSIONS?
Due to the testing conditions and procedure, it is physically impossible to conduct this operation alone, hence lone working is not possible and will not take place.		

7. EMERGENCY ACTIONS

INCLUDE:-

- Dangerous failure of equipment or experiment;
- Evacuation procedures if the (Fire) Alarm sounds (Evacuation route and muster point);
- How to raise the alarm;
- What to do and who to call in the event of an Injury or accident.

All emergency response procedures can be found in the dedicated document that is attached alongside this risk assessment.

8. Monitor and review

This risk assessment should be reviewed monthly until the extra controls are fully implemented, and annually thereafter.

It should also be reviewed Immediately in the event of process / location change or incident or accident.

REVIEW DATES	10/02/2023	10/02/2024				

9. Other Specialised Risk Assessments

Some of your hazards may require additional risk assessments - ask your safety officer for guidance or visit the Central Safety forms web pages. For example:-

Chemical and Hazardous Substances – needs a COSHH assessment.

Biological Hazards – visit the Biological Safety web pages – may need a College Bio1 risk assessment

Off-site Work and Fieldwork – there are specific forms for Fieldwork, Hosted Research and Conferences etc.

Ionising Radiation, inc. X-rays – the College Radiological Protection Team will help, but you need to register the work.

Lasers - need to be registered and risk assessed

Significant Manual Handling – Speak to your departmental manual handling advisor

Compressed Gases and Cryogenics – need separate risk assessments.

PLEASE LIST BELOW ANY SPECIALISED RISK ASSESSMENTS THAT ACCOMPANY THIS ONE.

Type of Risk Assessment:	Title (and reference number if applicable):	Name of Assessor:	Date:
COSHH	**N2O COSHH Form.docx**	[redacted]	**03/11/2021**
Fieldwork Risk Assessment	**Hotfire_FW1.docx**	[redacted]	**03/11/2021**
Manual Handling Assessment	**N2O Cylinder Manual Handling Assessment.pptx**	[redacted]	**28/03/2022**
COSHH	**Nitrogen COSHH Form**	[redacted]	09/11/2022
COSHH	**Methanol COSHH Form**	[redacted]	28/01/2023

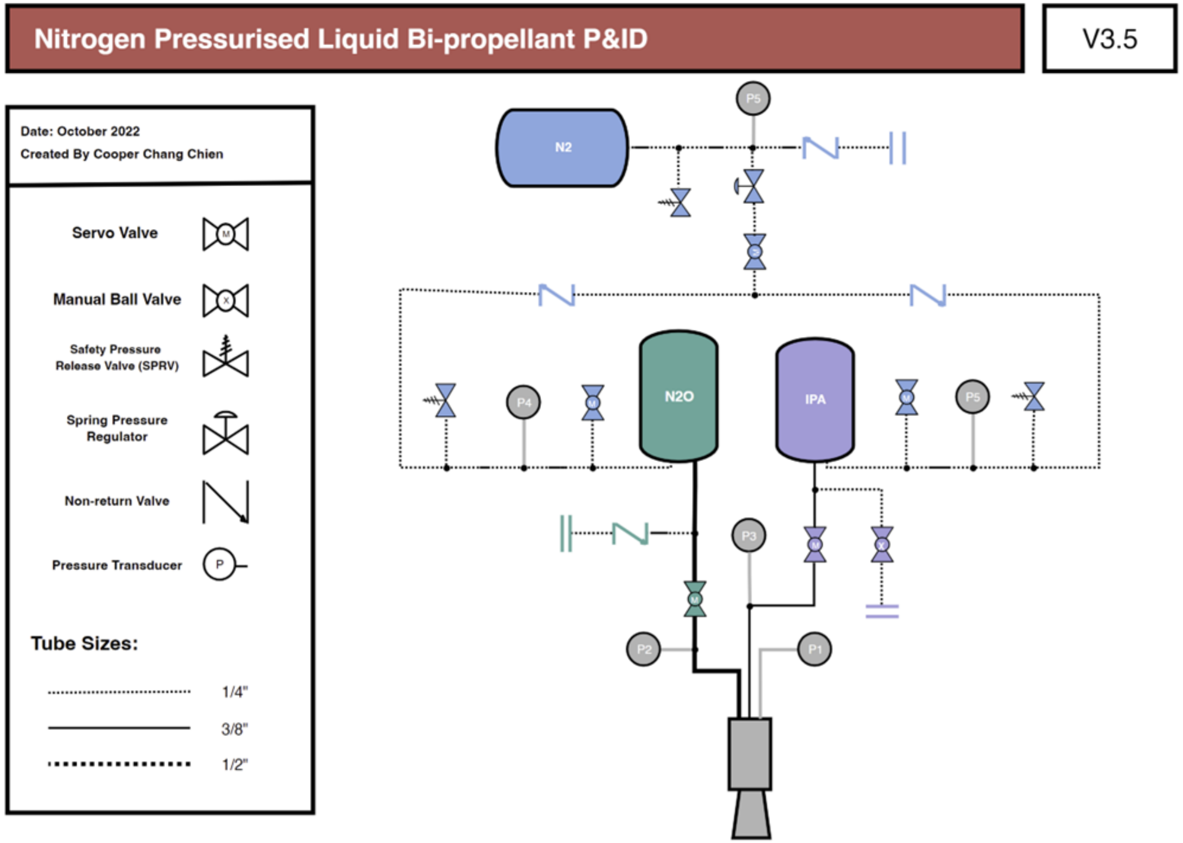


Figure 1: Simplified nitrogen pressurised liquid Bi-propellant P&ID.

Note that all closed volumes include a Safety Pressure Release Valve (SPRV) calibrated to open at or above 70 bar to eliminate the risk of overpressure events.

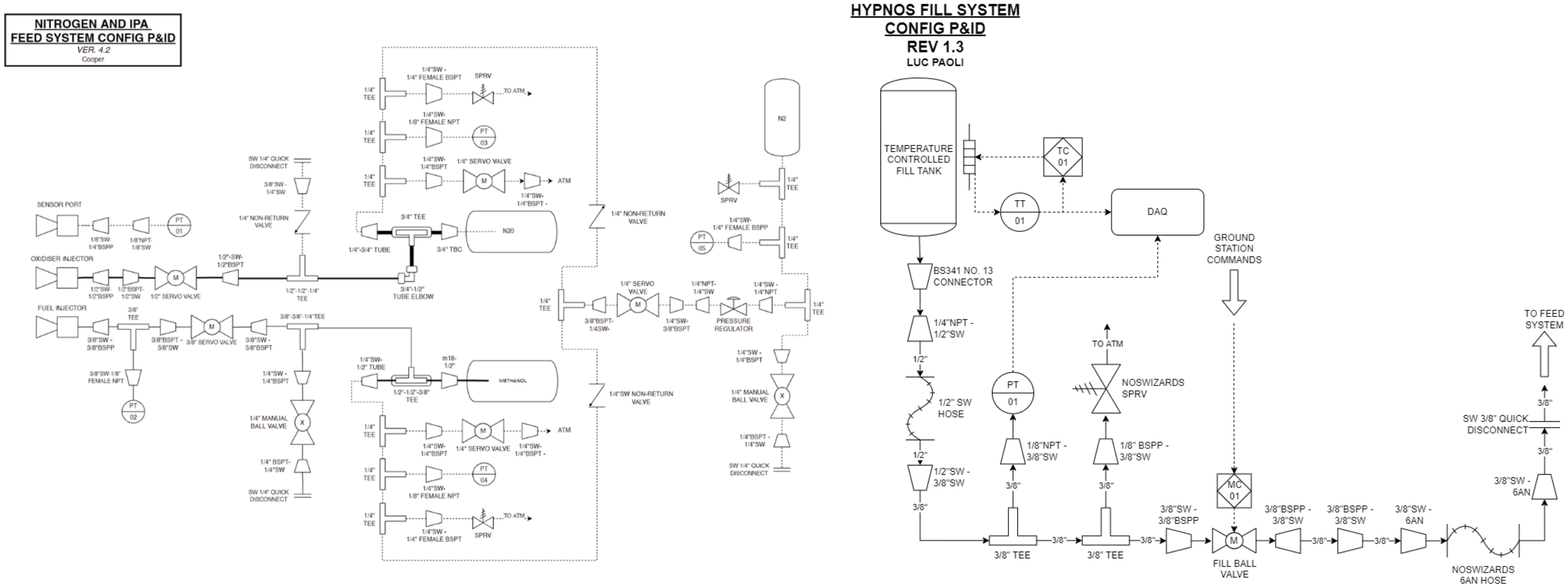


Figure 2: (left) Detailed P&ID of the plumbing components used to create the setup shown in Figure 1. (right) nitrous oxide remote filling system, as used in previous hot fire tests. Not shown is the high-pressure hose and adapter from the nitrogen cylinder. This will connect to the N2 quick disconnect port.

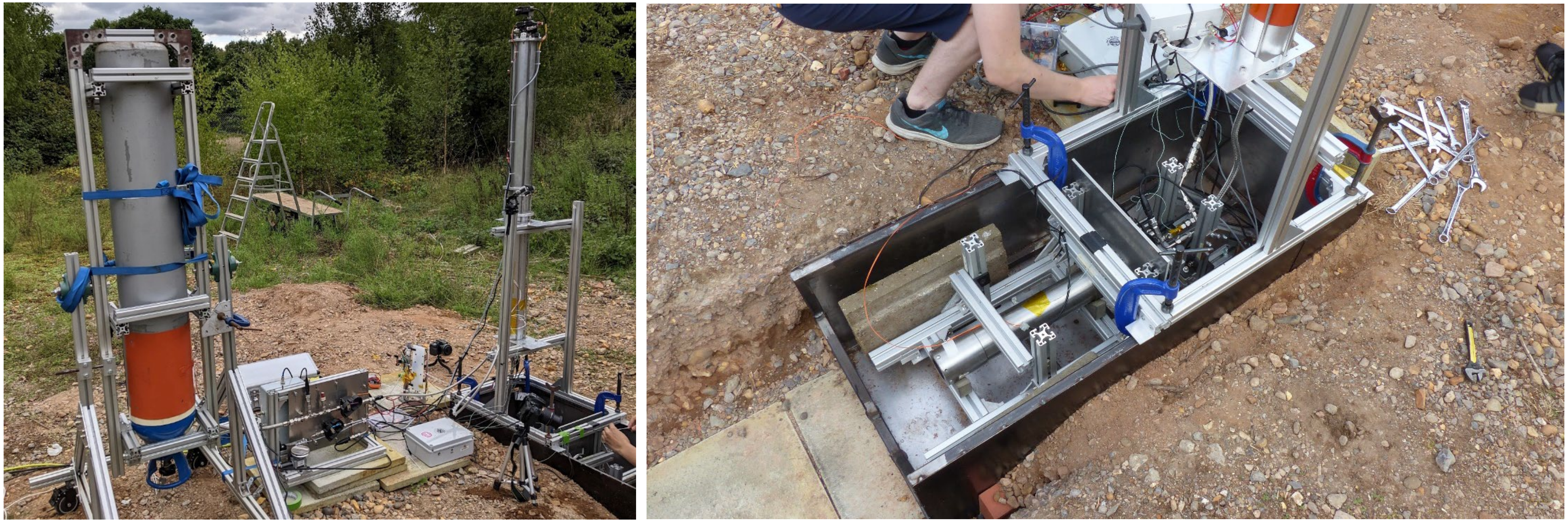


Figure 3: Images showing actual components to be used for hot fires. (left to right) The Tank Inverter with N2O cylinder, the Test Fire Box (with engine mounted) and the Run Tank. Not shown are the Nitrogen Cylinder (to be secured to a trolley) and the Methanol fuel tank stand (to be stood next to the test fire box).

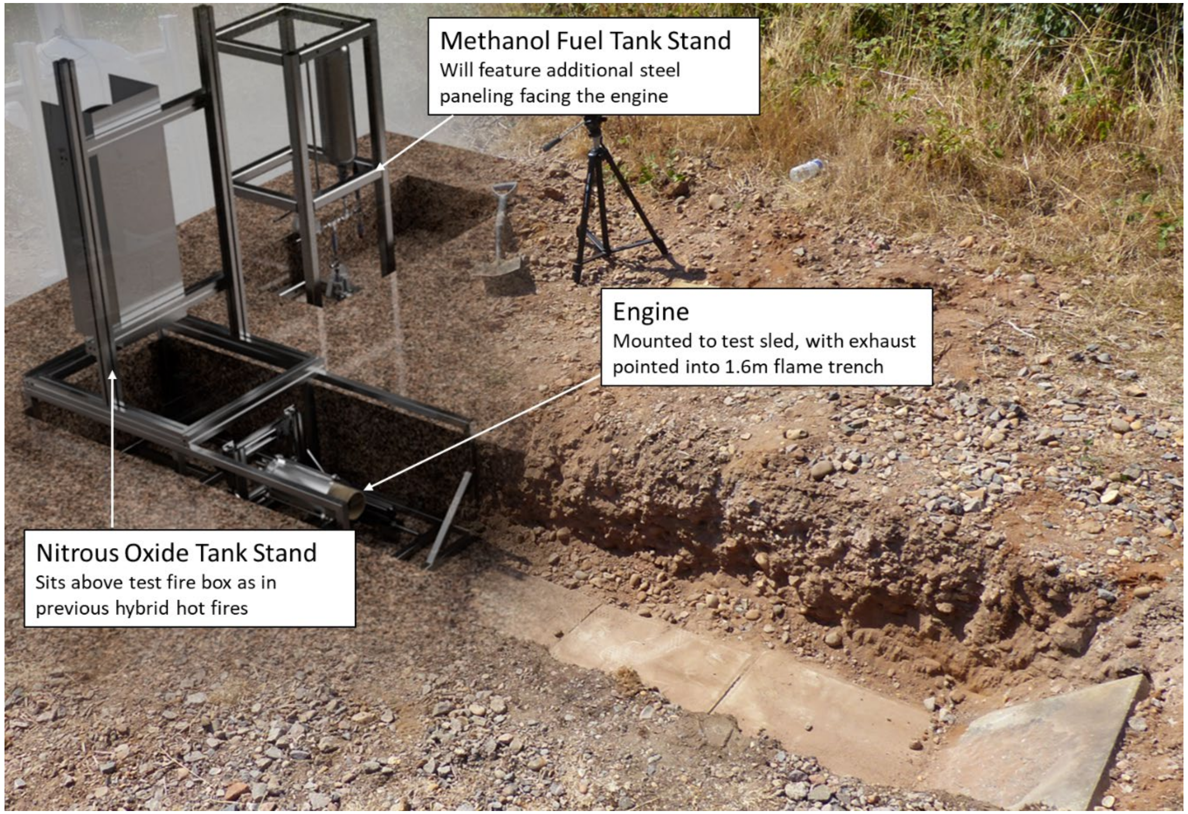


Figure 4: Approximate render showing the new propellant tank layout. Note that additional steel plates will be added to the methanol stand to shield it from any potential debris created by an engine anomaly.