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ace2space - Rules & Guidelines

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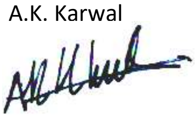
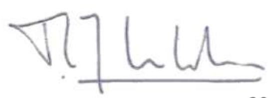
A.K. Karwal  Arun K. Karwal 2022.06.09 19:32:56 +02'00'	T.J. Mulder  2022.06.10	D. Eikelenboom eikelenboom Digitally signed by eikelenboom Date: 2022.06.10 13:18:31 +02'00'

Distribution:

AOFO, ASTC
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Summary

ace2space is the name under which Royal Netherlands Aerospace Centre (NLR) and TU Delft (TUD) perform low gravity flight services.

This document is a user's guide for ace2space Parabolic Flight Campaigns (PFC) with the Cessna Citation II (PH-LAB), aimed on the one hand at giving the users the requirements for parabolic flight experiments and, on the other hand, at supporting them in designing an experiment ready to fly aboard the Cessna Citation II.

This document presents:

- The reviewing and acceptance process of an experiment.
- The safety policy for designing, building and operating a parabolic flight campaign experiment using hazard analysis.
- A description of the Cessna Citation II interfaces.
- Requirements and guidance for designing, building and operating experiments.

Appendix A provides the ace2space Experiment Plan that needs to be filled in by the prospective customer. The Experiment Plan will be used in subsequent discussion between ace2space and the customer to clear the experiment design for flight and to prepare for a successful campaign.

Contents

1 Introduction 6
1.1 Background 6
1.2 Purpose 6
1.3 List of acronyms 7

2 Acceptance Process for PFC Experiments 8
2.1 Introduction 8
2.2 Acceptance process for flight operations 8
2.3 Deviations from requirements 8

3 Safety Policy 9
3.1 Introduction 9
3.2 Experiment design considerations 10
3.3 Experiment Plan 10

4 Cessna Citation II Interface Description 11
4.1 Aircraft dimensions and axis 11
4.2 Cabin layout and dimensions 12
4.2.1 Storage, cabin installation racks and platforms 12
4.3 Cabin environment 14
4.3.1 Cabin pressure 14
4.3.2 Cabin temperature 14
4.3.3 Cabin lighting 15
4.4 Electrical power interface 15
4.4.1 Aircraft Data Interface 15
4.5 Experiments loading into the aircraft 15

5 Requirements and Guidelines 17
5.1 Introduction 17
5.2 Loss of aircraft services 17
5.3 Mechanical design requirements and guidelines 17
5.3.1 Definitions and terminology 17
5.3.2 Load requirements 19
5.3.3 Fixation to aircraft structure 19
5.3.4 Specific equipment attachment 19
5.3.5 Prohibited and accepted materials 20
5.3.6 Pressurization for sealed experiment 21
5.4 Electrical design requirements and guidelines 21
5.4.1 Introduction to electrical design 21
5.4.2 Limitations and requirements related to experiment connection to aircraft power supply 21
5.4.3 Electro-Magnetic Compatibility (EMC) 22
5.4.4 Electrical installation 22

5.4.5 High voltage equipment 24
5.4.6 Batteries 24
5.5 Additional system requirements 24
5.5.1 Laser 24
5.5.2 Harmful light intensity and wavelength 26
5.5.3 Pressurized systems 26
5.5.4 Free-floating experiments 27
5.5.5 Contact temperature 28
5.5.6 Heating systems 28
5.5.7 Test equipment noise levels 29
5.5.8 Pumps 29
5.5.9 Computers and tablets 29
5.5.10 Ionizing radiation, x-rays 29
5.6 Products and materials requirements 29
5.6.1 Liquids and biological preparation 29
5.6.2 Genetically Modified Organisms (GMO) 30
5.6.3 Smoke 30
5.6.4 Handling of powder or small particles 31
5.6.5 Hazardous materials 31
5.6.6 Cabin environment preservation 31
5.6.7 Flammable and explosive gases 31
5.6.8 Dry ice 31
5.7 Flight and "safe-mode" procedures 32
5.8 Life-sciences experiments involving test subjects or animals 32

Appendix A Ace2space Experiment Plan 33

(34 pages in total)

1 Introduction

1.1 Background

ace2space is the name under which Royal Netherlands Aerospace Centre (NLR) and TU Delft (TUD) perform low gravity flight services. NLR and TUD already operated together a flight test facility, when in 2019 they both decided to combine their efforts and experience in the low gravity field. To mark this co-operation, the name *ace2space* was launched. NLR and TUD have been performing Parabolic Flights with the Cessna Citation II for many years.

Parabolic Flights are an essential way of achieving weightlessness. Initially used for training astronauts, parabolic flights are now mostly dedicated to scientific experiments and technological tests of space systems and hardware. Simplicity of preparation and of operations, reduced costs, repeated weightlessness phases and opportunity for researchers present on board to directly work on their experiment are key points not offered by any other available means.

1.2 Purpose

This document is a user's guide for ace2space Parabolic Flight Campaigns (PFC) with the Cessna Citation II (PH-LAB), aimed on the one hand at giving the users the requirements for parabolic flight experiments and, on the other hand, at supporting them in designing an experiment ready to fly aboard the Cessna Citation II. Designing and building an experiment to fly under microgravity conditions implies taking into account the several different environments including the aircraft. Safety rules and related issues are different from those of a standard laboratory.

This document presents:

- The reviewing and acceptance process of an experiment.
- The safety policy for designing, building and operating a parabolic flight campaign experiment using hazard analysis.
- A description of the Cessna Citation II interfaces.
- Requirements and guidance for designing, building and operating experiments.

1.3 List of acronyms

°C	Degree Celsius
A	Amps
A/C	Aircraft
AC	Alternating Current
DC	Direct Current
ESDP	Experiment Safety Data Package
FF	Free-Floating
g	Acceleration constant equal to $9.81 m/s^2$
HAZOP	Hazard & Operability analysis
hPa	hectoPascal
m	meter
MAWP	Maximum Allowable Working Pressure
mb	millibar
mm	millimeter
MSDS	Material Safety Data Sheet
N/A	Not Applicable
PFC	Parabolic Flight Campaign
PHA	Preliminary Hazard Analysis
SF	Safety Factor
V	Volt
W	Watt

2 Acceptance Process for PFC Experiments

2.1 Introduction

The experiment participation to an ace2space Parabolic Flight Campaign (PFC) is subjected to the completion of several technical documents. Before the beginning of the PFC, you will be asked to fill in the ace2space Experiment Plan (see Appendix A) that will be used for the technical description and hazard analysis of the experiment in-flight and on ground. This includes procedures, equipment and all materials (solids, liquids and gas) used in-flight and on ground. Based on this document, the ace2space personnel, together with you, will analyse and evaluate your experiment design. The Experiment Plan will be the document supporting the hazard-related communication between you and the ace2space personnel.

2.2 Acceptance process for flight operations

Compliance with requirements from this document does not mean automatic acceptance, which – in any event – is granted only by ace2space personnel after an inspection of the experiment and hardware. Based on the information provided in the Experiment Plan, and subsequent discussions through follow-up communications, ace2space will already have a very good understanding of the experiment submitted for parabolic flight.

At the latest 1 day before the flight, the experiment in its flight configuration (i.e. as it would be in flight) will be reviewed thoroughly by ace2space personnel. This review is called the *Safety Visit*.

2.3 Deviations from requirements

Ace2space can decide to accept on a case by case basis that an aspect of an experiment does not meet a requirement. The acceptance is granted for one flight OR one campaign only. Before the acceptance, it must be demonstrated that the setup has been developed so as to reach an equivalent or higher level of safety. A deviation request, including substantiation of safety, must be issued and submitted to ace2space.

3 Safety Policy

3.1 Introduction

Flight safety is our primary concern, ace2space is responsible for the safe planning and execution of a parabolic flight. Flights are operated in accordance with stringent safety procedures, both for the planning and execution of the parabolic flights, as well as design procedures regarding the experiment in the cabin. A generic safety assessment has been developed that addresses flight operations and maintenance issues, this generic safety assessment is valid for all ace2space parabolic flights. In addition a specific assessment for the particular flight, focussed on the experiment that will be carried, is made for each flight. The customer is required to provide necessary safety-related information for this assessment when requested. If required, a Non-Disclosure Agreement (NDA) can be drafted if this safety-related information is sensitive to the customer.

For the generic part, planning and execution of the actual (parabolic) flights, ace2space Flight Operations through the in-house Part 21 organisation has developed flight conditions, flight- and additional maintenance-procedures as well as instructions for continued airworthiness that are supported by statements of the OEM of the airframe and engines. This package was submitted for approval to the competent authority CAA-NL. Based on the documentation a Permit to Fly (PTF) has been issued for flights in The Netherlands airspace. For flights in other countries this Dutch Permit must be validated by the competent authority of the relevant State, ace2space is will organise but is dependent on the cooperation of that relevant CAA. to obtain such a validation should that be required. Safety of the flight is covered by the Safety Assessment as described in the Flight Test Plan which is part of the underlying documentation of the Approved PTF. The risk of performing parabolic manoeuvres is assessed as LOW RISK. This FTP is available on request for customers.

For the specific part, the experiment in the cabin, the customer must submit relevant information on the design and content of the equipment carried on board to ace2space, including the experiment description and information required to perform a safety analysis. The degree of detail, rigor, and formality required in the development and conduct of a reduced gravity test depends on the complexity, hazards, and uniqueness of a test. It ranges from very simple for basic science experiments, to quite elaborate for more advanced setups. Simple experiment set-ups may be cleared based on generic data without further involvement of the Design Organization. More elaborate experiments need to go through a more thorough process called an *Engineering Assessment* by the Part 21 organization. In the unlikely case where special requirements exist that require an extensive engineering effort to accommodate the experiment in the aircraft cabin, for example a special mounting is required or non-standard electrical requirements exist, a full certification effort may be required.

Information exchange with ace2space is required both at an early stage and frequently throughout the process to preclude any last minute surprises at the *Safety Visit* which might cause delays. The relevant personnel will review and comment on preliminary drawings (if available) and plans at all stages of development. It should be noted that a flight will only be conducted after ace2space has been assured that a safe, well organized, and productive flight can be achieved.

3.2 Experiment design considerations

Flight safety starts in the design phase. When designing an experiment, the customer must be aware that their experiments will be performed in an aircraft. This environment should be taken into account from the beginning of the experiment design activities in order to assess and minimize all risks beforehand. There are many differences between an aircraft environment and a usual laboratory environment, for example:

- During a parabolic manoeuvre the experiment will be subjected to a cycle of hyper-g (~2.5g), micro-g (0-g or another micro-g target) and a pull-out with hyper-g. High g-loads can generate a hazard for an experiment which would have been safe in a 1g environment (e.g. spillage of hazardous substances, mechanical design, etc);
- The cabin is a closed door compartment. When the aircraft is flying the experimenters cannot escape from a hazard. Running away from a spill is not an option inside an aircraft;
- A relative benign hazard in a laboratory can become more serious in an aircraft environment as soon as it threatens the integrity of the aircraft structure, or incapacitates the flight crew. For example, a small fire or development of fumes is typically not a very dangerous situation in a laboratory, but is very dangerous inside an aircraft cabin;
- Anxiety, motion sickness and time pressure may degrade human performance of the experimenter during the flight. The micro-g phase of the parabolic manoeuvre follows immediately after the hyper-g phase, and lasts somewhere between 10 and 15 seconds which is the timeframe that the experiment has to be performed. When designing the experiment, the task of the experimenter should be a simple task, ideally automated or initiated by e.g. a single button press;
- The aircraft cabin is restricted in size. Chapters 4 and 5 describe the mechanical and electrical interfaces between experiment and aircraft, but realize that space for the operator is limited. A task that is easy to perform in a laboratory environment with the experiment on a table may be more difficult;
- Substances that may seem harmless may classify as “dangerous good” for the carriage on board of aircraft because they are toxic, explosive, flammable, oxidizing, infectious, radioactive or corrosive. Special rules may apply to carry such materials on board of an aircraft, even in small quantities. This also applies to compressed gas, or for example laptop batteries or power banks to power an experiment.

It is recommended that (potential) customers involve ace2space early on in the experiment design phase to address these potential safety issues and amend the experiment design if required.

3.3 Experiment Plan

Customers are required to provide an *ace2space Experiment Plan* according to the outline given in Appendix A as soon as feasible, to initiate the process of clearing the experiment for flight.

4 Cessna Citation II Interface Description

This chapter describes the cabin area and (electrical) interfaces of the Cessna Citation II. It provides information on electrical power supply, attachment of experiments to aircraft floor and a description of the other interfaces.

4.1 Aircraft dimensions and axis

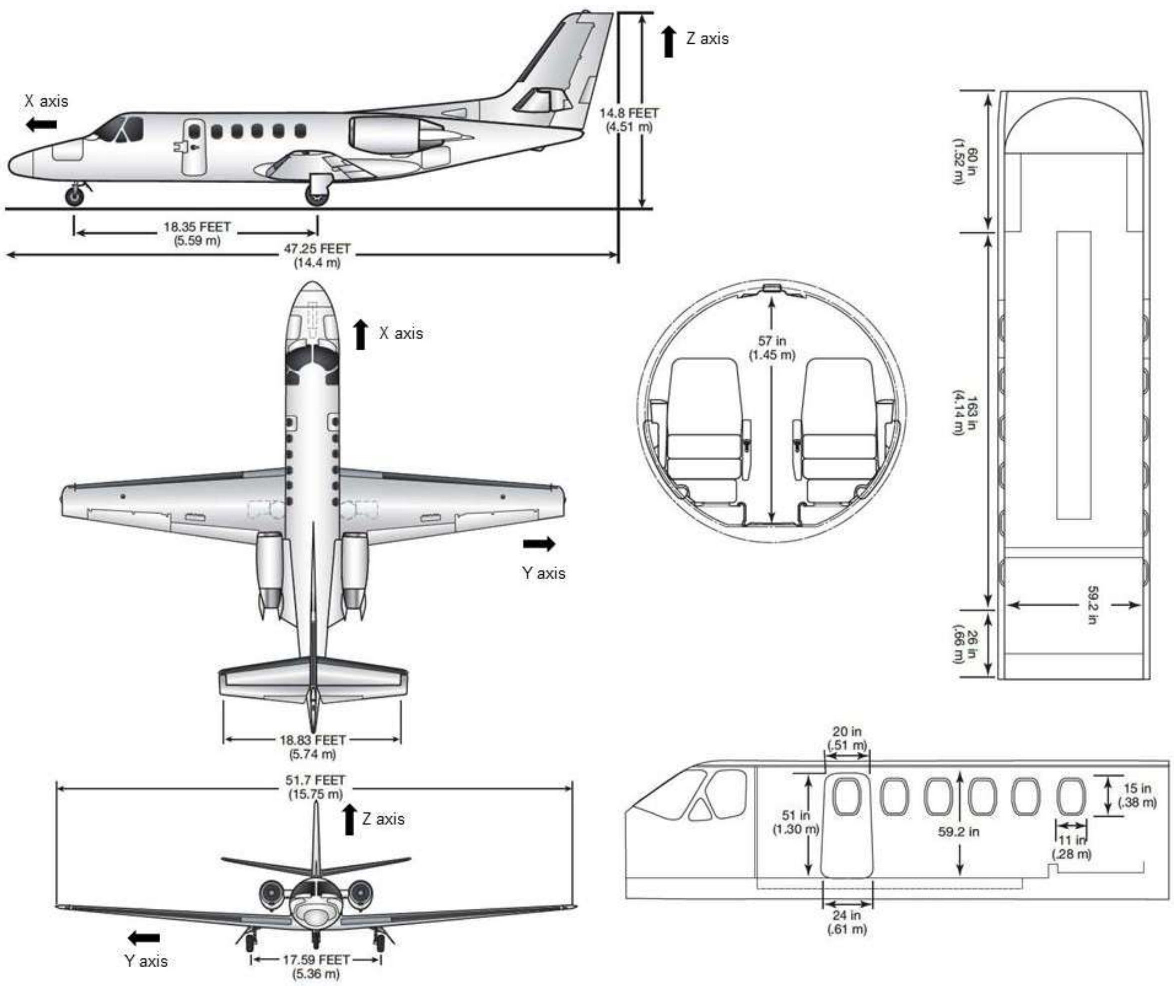

Figure 1: Aircraft dimensions and axis system

4.2 Cabin layout and dimensions

The following standard cabin configurations are available (see Figure 2):

1. Config #1 — Free float — empty cabin
2. Config #2 — Flying classroom — 8 seats, each equipped with personal work station (tablet with WiFi connection, real-time aircraft parameters)
3. Config #3 — Optimized for dedicated experiments — 19” racks or flat table for equipment, multiple seats for operators or subjects

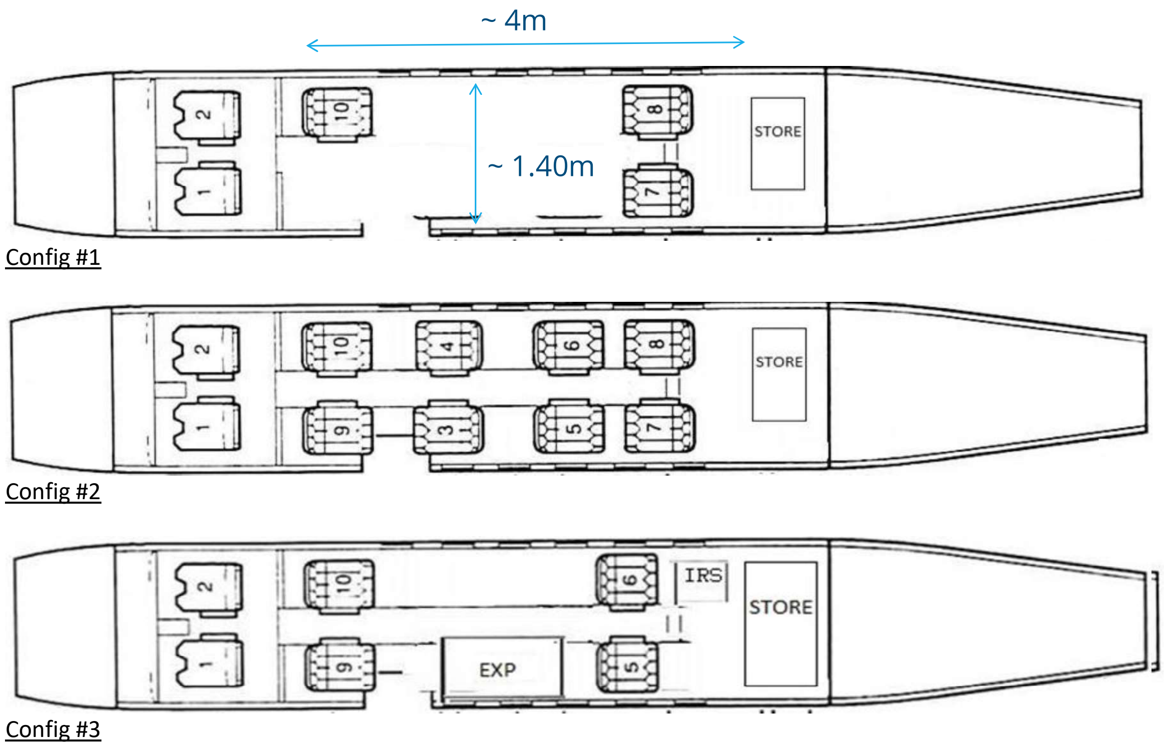

Figure 2: Cabin configurations

Combinations of configurations, or configuration changes in between flights are possible. Contact ace2space for further advise.

4.2.1 Storage, cabin installation racks and platforms

For storage of equipment during T/O and Landing and during experiments various boxes are available and described below. These boxes are neither air- nor water tight, and should therefore NOT be considered as containment vessels for either gases, liquids or solids.

- Metal (aluminium) instrumentation box installed inside a 17” instrumentation rack in the aft cabin
  EXTREME BRAVO (40 x 30 x 34 cm)
  The bottom of the instrumentation box will be reinforced on the inside with a Dural plate (thickness 1.2 mm). With an own weight of the individual racks of 9 kg and an own weight of the box of 2 Kg, there is a mass limit of max. 14 Kg for items stored in these boxes (per box).

- Metal (aluminium) instrumentation box installed on top of the 17” instrumentation rack construction in the aft cabin
  Defender KA74-003 (55 x 35 x 22 cm)
  The bottom of the instrumentation box will be reinforced on the inside with a Dural plate (thickness 1.2 mm). With an own weight of the top mounted box of 3 Kg, there is a mass limit of max. 22 Kg for items stored in this box.

- Metal instrumentation box installed on an installation frame inside the cabin
  Defender KA74-010 (75 x 55 x 38 cm)
  The bottom of the instrumentation box will be reinforced on the inside with a Dural plate (thickness 1.2 mm).
  Mass limit: 16 kg

To mount the experiment the following options can be used:

- Small cabin platform with base plate (Figure 3)
  Base plate: 49.5 x 59.5 x 0.6 cm
  Mass limit: 50 kg including box or cover (with C/G at or below 40 cm)

Figure 3: Small cabin platform (left) with empty and unlashed 19’’ flight case (right)

- Large cabin platform with base plate with or without 19’’ instrument racks
  Base plate: 41.8 x 60 x 0.6 cm
  Mass limit: 60 kg (C/G at or below 40 cm)


Figure 4: Large cabin platform (left) with 19'' rack installed (right)

Optional and **with** an Engineering assessment by ace2space:
One rack for installation of 19" equipment can be installed in the aft part of the cabin. See Figure 4 for a large cabin platform and 19" rack. In this rack equipment can be fitted on metal installation adapter plates, delivered by ace2space, with mounting. The maximum allowed load to these racks can be up to 75 Kg, but may be limited depending on the height of the centre of gravity.

4.3 Cabin environment

4.3.1 Cabin pressure

The pressure in the cabin depends on the aircraft flight altitude. Typically, on parabolic flights the cabin pressure is maintained at sea level value (1013 hPa) for flight altitudes not exceeding FL200, but may decrease to 900 hPa (3,000 ft cabin altitude) when parabolas must be flown at higher altitudes up to FL 300, for example if weather conditions or airspace restrictions require to do so. In case of a cabin depressurization event, the cabin pressure will drop to the atmospheric pressure at the current altitude.

4.3.2 Cabin temperature

In flight, cabin temperature is only roughly adjustable. Experiments sensitive to ambient temperature may need internal thermal control heaters or coolers before or during the flight.

Temperature variation in the cabin may be expected to be less than 2°C/min.

Note: Depending on the geographical position and the local weather, during overnight parking or parking into the sun, the temperature in the cabin may be well below 0°C or above 40°C prior to engine start (when the aircraft air conditioning system becomes available). It is advisable to use equipment that can withstand these temperatures or take procedural precautions to avoid damage to the equipment.

4.3.3 Cabin lighting

The Cessna Citation II is lit primarily through its windows. This means that lighting conditions may be poor under cloudy sky conditions. Experiments depending on proper illumination should therefore carry their own lighting apparatus (and associated power source). The use of LED strips (with small internal batteries) is recommended.

4.4 Electrical power interface

The aircraft is equipped with provisions for electrical power supply by means of a dedicated DC/AC system which is made available via the Power Junction Box in the back of the cabin.

115VAC/400Hz and 28VDC is available and can be connected to experimental equipment via circular MIL-connectors which can be provided by ace2space in advance. The two different type of receptacles are protected by a 5A- and 10A CB (Circuit Breaker).

Also a Static Inverter is available in the cabin which converts 28VDC to 220VAC/50Hz. Equipment can be connected both by MIL-connectors as well as standard 220V Euro-plug type outlet. The receptacles are protected by 5A CB.

Research equipment, PEDs and carry on test instruments like spectrum analysers , laptops etc. can be connected to the 28 VDC,115 VAC and 220VAC with a qualitative assessment on electrical load to the aircraft electrical system.

Total power consumption for all experiments is limited to approximately 1.2 kW.

4.4.1 Aircraft Data Interface

Various Aircraft Digital Avionics busses (GPS, FMS, DADC, AHRS) can be tapped during flight to provide Aircraft parameters such as accelerations, pitch, roll, yaw, airspeed and position. Also accurate GPS-time synchronisation formats/outputs are available.

4.5 Experiments loading into the aircraft

The access door used for loading the experiment is located at the left-hand side of the aircraft. The access door dimensions are 1.30 m tall by 0.61 m at the bottom of the door tapering to 0.51 m at the top of the door. See Figure 1 for the dimensions and Figure 5 for the actual doorway. Access to the door is through 2 steps.

Teams should design their experiments so that powering up the experiment can be carried out easily without dismounting the setup. They should also make sure that battery self-discharge is not an issue. Finally, it should be easy to check proper functioning of the experiment prior to take-off (without dismounting the experiment or perturbing possible other experiments).

Figure 5: Access Door Dimensions: 1.30 x 0.61 m

Also the emergency hatch on the right hand side of the aircraft (opposite the access door) can be used for loading equipment into the aircraft cabin. The dimensions of the emergency hatch are 0.57 x 0.95 m.

5 Requirements and Guidelines

5.1 Introduction

This chapter presents the general requirements related to the design of experiments. Guidance is also given for meeting these requirements. This guidance should obviously be adjusted on a case-by-case basis depending on your own test set-up. The design of an experiment should take into account the requirements described in this section, but should also take into account the risks relevant to your experiment. The design of an experiment should be driven by your own safety analysis and the rules described below. If the document presents some requirements interpretation which looks contradictory, the safer interpretation has to be taken. If needed, the customer can consult ace2space experts.

5.2 Loss of aircraft services

The experiment design should be such that the experiment should keep consistent safety margins and not induce any hazard in the unlikely case aircraft electrical power and/or cabin pressurization is lost during flight.

5.3 Mechanical design requirements and guidelines

Customers have to verify and document the structural integrity of each part of the experiment (including structural hardware and equipment) to be flown, in compliance with the structural requirements hereafter. All the bolts included in the experiments have to be secured by using thread locker, Nylon Insert Lock Nuts and/or lock washers.

5.3.1 Definitions and terminology

FIXED EXPERIMENT SET-UP RACK
A fixed set-up rack (containing of 6 individual racks) is available in the back of the cabin (see Figure 6). To hard mount the experiment an additional Engineering Assessment (or modification through certification) is required. As already described in section 4.2.1 for most experiments one or two cabin platform(s) are readily available for experiments which can be handled as carry-on equipment that do not require a certification process.

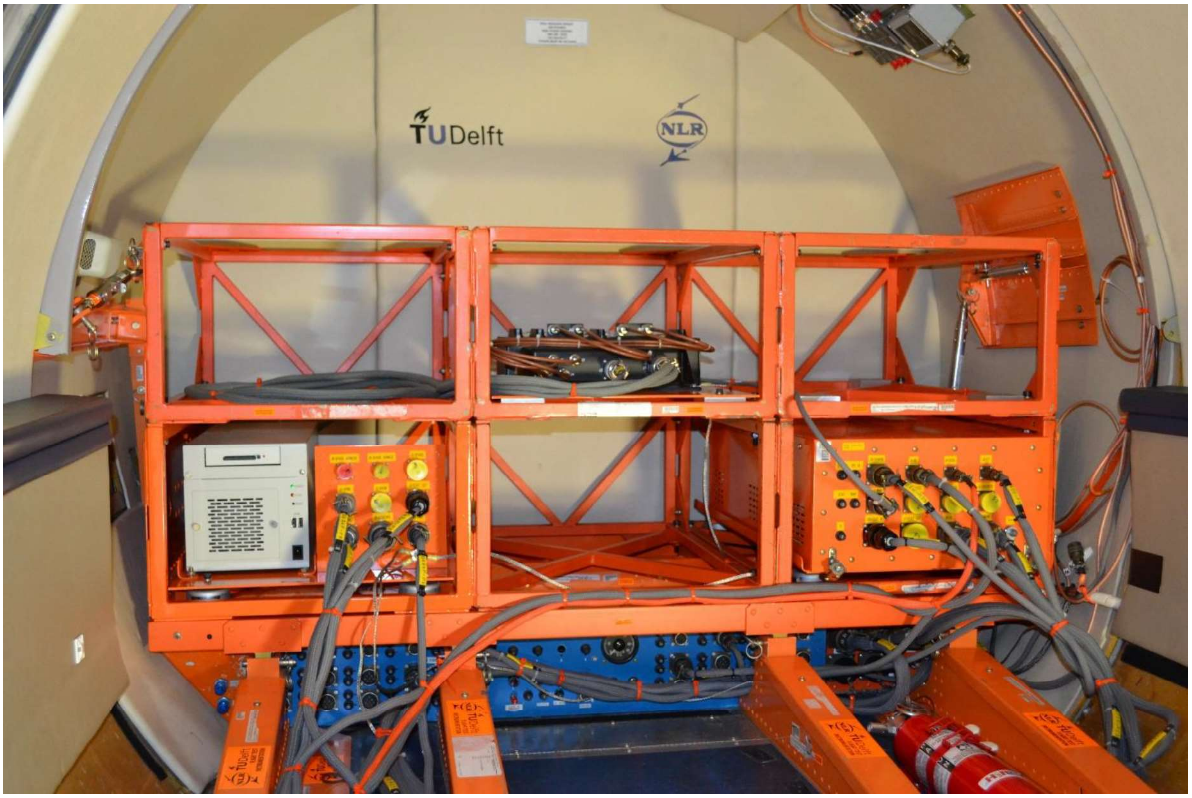

Figure 6: Setup rack in the rear of the Cessna Citation II

FREE-FLOATING (FF) SET-UP

Some experiments may require to let some test package free-float. Such stand-alone devices are also considered as a rack. Usually, such racks are linked to another rack for data recording or free-floating module control. The free-floating package must be covered with foam padding.

Figure 7: Padding for free-floating experiments

As a rule of thumb floating experiments should have maximum dimensions of 30 x 30 x 30 cm and weights not more than 3 kg and must have at least one gripe or lug which can be attached to a safety line.

5.3.2 Load requirements

Equipment installed on the ace2space research aircraft shall not detach from its mounting or separate in a manner that presents a hazard for the flight crew and observers as a result from vibrations during normal operational environments. The mechanical design of an experiment should consider in-flight cyclic loads cases varying from + 2.5G to -0.5G in the Z axis.

5.3.3 Fixation to aircraft structure

Carry-on equipment is taken on board and operated in the cabin at the responsibility of the Pilot in Command. The equipment is secured/stowed in the cabin during takeoff and landing and during the experiment as described in paragraph 4.2.1 and may also be electrically connected to one or more of the provisions mentioned below in paragraph 5.4.

All equipment needs to be fastened/tied-down to above provisions by means of lashing belts / straps in order to be able to qualify as carry-on equipment.

Figure 8: Example lashing belt / strap

Larger equipment which, in the opinion of ace2space, should be hard mounted using the fixed set-up rack configuration will be identified and treated as a modification to the aircraft. Such equipment is already identified in the experiment plan.

5.3.4 Specific equipment attachment

This section lists specific equipment and the according recommendations.

ATTACHMENT OF GAS CYLINDERS

Gas cylinders can be heavy. As shown in Figure 9, the principle is the same as for attaching any equipment: the gas cylinder should be locked in each direction. Two metallic rings clamp the cylinder to lock it in two directions. L-profiles are used to lock the cylinder in the remaining direction.

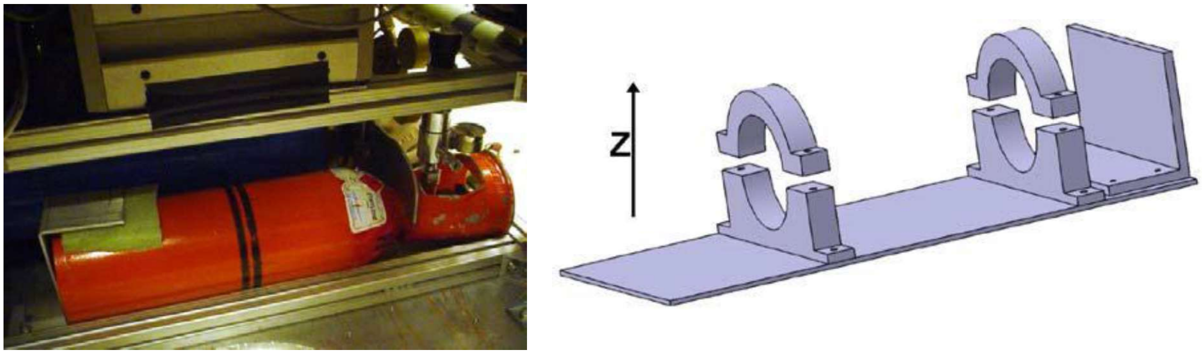

Figure 9: Gas Cylinder Attachment

The head of the cylinder should be shielded in order to protect it from shocks, and accessible to easily close the bottle. The gas cylinder will have to be removed from the aircraft and placed in the ace2space rack storage when not used. No gas cylinder shall stay aboard during night. Specific requirements for pressurized systems are given in further sections of this document.

VIBRATING EQUIPMENT ATTACHMENT

Vacuum pump or other rotating or vibrating equipment can induce vibration on your experiment or to other experiments. Note that in case an experiment induces high level vibration inside the aircraft, the experiment may be rejected. This could occur as late as during the preparation day, during the Safety Visit. This section describes ways to reduce these mechanical perturbations as much as possible. It is recommended to attach vibrating equipment on a plate fitted with mechanical dampers (e.g. Silentblocks or Shock mounts). However, such structures should be capable of withstanding loads in the take-off and landing phases. So, in addition to a damper device, during take-off and landing a mechanical device could be added to the structure for counteracting the potential hard landing loads. As this type of safety device could transmit vibrations, it shall be removed after take-off and put back in place before landing.

EXPERIMENTS WITH MOVING PARTS

Some experiments have moving parts. Depending on the speed and amplitude of the motion, and the weight of the moving parts, it may induce hazards to customers and crew, on the one hand, and people on board or unexpected free floating objects could interfere with the moving part and generate other issues, on the other. The moving part should be contained inside a protective housing. In case there is an access door on the housing, the access door shall have an interlock safety switch to automatically stop the motion of the moving parts when the door is open.

5.3.5 Prohibited and accepted materials

All flammable and/or breakable materials (e.g. wood, Plexiglas, glass) should be avoided in an experiment setup. Aluminium should be used instead of wood, and LEXAN® (non-flammable polycarbonate, for non-structural parts) instead of glass or normal Plexiglas.

Prohibited are:
- Firearms, ammunition, explosives etc.
- LiPo batteries

5.3.6 Pressurization for sealed experiment

As explained in chapter 4, the cabin pressure may slightly decrease as altitude increases. Accordingly, sealed containers, especially those made of polycarbonate, should be able to withstand the load induced by the pressure difference between ground conditions and flight level cabin conditions (worst case 900 hPa/3,000 ft cabin altitude, FL300 flight altitude) by means of a pressure relieve valve. Other relevant limitations related to pressurized vessels on ground are defined in section 5.5.3.

5.4 Electrical design requirements and guidelines

5.4.1 Introduction to electrical design

This chapter introduces the requirements for electrical circuits taking into account the following risks or issues:
- Electric shock
- Electrical fire
- Damages to aircraft power distribution system, caused by excessive electrical consumption of experiments
- Interferences with other experiments and the aircraft systems

All electrical systems have to be designed and built by professional electricians.

As a baseline, all equipment used for experiment purposes shall be compliant with EU regulations and be CE marked. It is highly recommended to use commercial off the shelf (COTS) components. User's manuals of all equipment included in the experiments have to be made available to ace2space on request.

5.4.2 Limitations and requirements related to experiment connection to aircraft power supply

Connection the Aircraft Electrical power interface will always be in consultation and with permission by ace2space

EMERGENCY STOP SWITCH
Ace2space will provide an Emergency Stop Switch when applicable. In the event of an emergency, the use of a single stop switch will shut down all AC and DC powered equipment to a safe state. The switch will be easily accessible to

customers and the safety crew. A second Power Shut down switch is available in the cockpit which will be operated by the flight crew in case of an emergency.

5.4.3 Electro-Magnetic Compatibility (EMC)

ELECTROMAGNETIC INTERFERENCE (EMI)
Experiment payload emissions shall be limited to those levels identified in EU or national norms. For non-EC equipment, field measurements have to be performed and provided to ace2space.

RADIO FREQUENCY INTERFERENCE (RFI)
In addition to the above, it should be checked that radio devices are not going to interfere with aircraft or safety personnel radio communication devices. Radio frequencies and power have to be provided to ace2space.

5.4.4 Electrical installation

- In general all interconnecting wiring between the aircraft power and between various experimental equipment shall be of the aircraft approved type. Exceptions are made for standard PC-cabling like USB and ethernet cables. Ace2space will advise if such conditions cannot be met.
- Electrical wires: All experiment wiring (experiment cables and power cords) must be sized at a current superior or equal to the fuse value.
- The stranded wires must not be used when it is requested to tighten these wires by means of screws.
- Light transformers or converters weighing less than 1 kg, may be attached to the experiment framework with cable ties (e.g. Tie wraps or single-cord lacing). It is forbidden to attach them with tape.
- The voltage converters must be installed in safe areas, i.e. away from flammable materials.
- Experiment grounding: experiments shall be adequately grounded to prevent electric shocks. The grounding of the experiment has to be tested with an ohmmeter, prior to the PFC.
- High inrush current equipment (e.g. motors, heating systems,…), either AC or DC powered, should be protected by a fuse. The intent of the fuse is to limit the max. current in compliance with the wiring section at the power supply output.
- All DC–powered commercial equipment not used with their own power supply (provided by the equipment manufacturer) must also be protected by a fuse at the power supply output.
- All electrical connections shall be covered, protected and clamped.
- Wire securing: all experiment wiring (including power cords) shall be properly restrained and clamped to the experiment so as to prevent it from floating during micro gravity phases. Cable ties and adhesive backed mounts may be used for this purpose.

Figure 10: Cable Tie Mount (left) and Insulated Crimp Terminals (right)

Direct skin contact with a stripped wire end should not be possible. Stripped ends shall be wrapped by using insulated crimp terminals.

- Multiple outlet power strips should be connected individually to the AC-Inverter junction box and cannot be connected in series (plug one to the other).
- The power distribution socket used must be C.E. marked and must include a signal lamp.

Figure 11: Power distribution sockets

5.4.5 High voltage equipment

High voltages are permitted as far as they pertain to low power set-ups and are properly guarded against (accidental) contact with either people or conductors. The hazard of fire shall be considered by ace2space in the hazard analysis.

5.4.6 Batteries

The use of all the rechargeable batteries and primary cells has to be declared to ace2space. In addition, the chemistry, the voltage, the capacity and the number of the batteries must be mentioned. All the batteries must have been charged before each flight. The use of liquid electrolyte batteries is forbidden. Batteries must not be installed close to liquids, fuels or heat sources.

BATTERIES IN COMMERCIAL EQUIPMENT
This paragraph deals with batteries already integrated in "COTS" devices, i.e. all the internal electrical wiring are already performed according to CE rules, most of the time with embedded safety systems. Batteries must be CE marked and not be older than 3 years. Batteries have to be fully charged on ground before each flight. In addition, laptop batteries have to be checked so as to ensure they are not recalled by the manufacturer.

BATTERIES POWERING THE EXPERIMENTAL SETUP
This paragraph is dedicated to batteries used for powering an experiment set-up or some specific equipment where the wiring has to be performed by the customer. Batteries integrated in commercial equipment are not addressed in this paragraph. Batteries must be CE marked and not be older than 3 years. Experiments using this kind of batteries should be equipped with an additional emergency cut-off (connector) or switch de-energizing all components in the system to a safe state. They must also include a fuse at the battery output chosen at a convenient value (not more than 30% above the experiment consumption measurement and compliant with the battery specifications). It is not allowed to charge or to maintain the charge of these batteries on board the Cessna Citation II, whether in-flight or on ground, if required **one** additional (spare) battery per equipment is allowed. The use of Lithium Polymer batteries is not allowed aboard the aircraft. All requirements and limitations dealing with the implementation of fuses and emergency switches from previous sections are also applicable in this section.

5.5 Additional system requirements

All equipment used for experiment purposes have to be compliant with EU regulation and be CE marked. Non compliance with this requirement shall be stated to ace2space. Serviceable equipment should be serviced according to the manufacturer recommendations and in compliance with its user manual.

5.5.1 Laser

The use of laser can induce some major risks, including medical hazards related to the laser technology.

Laser level	Laser warning sign	Warning	Personal protective equipment
Class 1	LASER 1	Class 1 laser products	No need
Class 1M	CAUTION LASER 1M	Laser radiation, do not use a telescope to watch the beam 1M laser products	No need
Class 1C	CAUTION LASER 1C	Laser radiation Reference guide IC laser products	Reference guide
Class 2	LASER 2	Laser radiation Do not look at the beam Class 2 laser products	No need
Class 2M	CAUTION LASER 2M	Laser radiation Do not look at the beam or use a telescope to watch the laser beam Class 2 laser products	No need

Table 1: Table of Laser Classes

The use of laser must comply with the applicable European Directives.

Experiment set-ups with class 3A, 3B and 4 are **prohibited**. Setups with class 2 or 2M lasers must comply with the following requirements.

PROTECTIVE HOUSING

The path of the laser beam should be fully contained. Interlock switches should be installed on the protective housing in order to prevent operation of the laser when the housing is either opened (through an access door) or removed. Several interlock switches have to be installed in order to avoid a single interlock switch failure. Viewing portals and collecting optics (lenses, telescopes, microscopes, etc.), intended for viewing use on all lasers, must incorporate a means (interlocks, filters, attenuators, etc.) of maintaining a level of laser radiation at or below the Maximum Permissible Exposure limit at all times.

Note: If convergent lenses are used, the laser class must be determined taking them into account. All the inner surfaces of the housing should be laser absorbent to limit the beam reflection.

GENERAL REQUIREMENTS

- Material inside the protective housing should not be flammable and should be compatible with laser beam in order to avoid fire or toxic smoke.
- The laser operator must be qualified and familiarized with risks related to laser usage.
- Some lasers use water cooling. Such system shall be compliant with requirements related to liquid containment.
- Customers should define a clear procedure stating what to do in case of smoke emission or emergency.

- Even when the laser protective housing is open, the laser beam should be as much as possible not in direct view from operator's eyes.
- Alignment of lenses and calibration operation can be done with a class 1 or 2 laser, in compliance with European directives.

LASER WARNING LABELS
All lasers shall have appropriate warning labels (see Table 1). The label shall be affixed on the laser housing so as to be easily visible
from everywhere.

WARNING LIGHT
A red continuous warning light should automatically indicate the laser status: light is on when the laser is in use and light is off when the laser is off.

Figure 12: Laser Warning Label and Light

5.5.2 Harmful light intensity and wavelength

Lighting and optical instruments shall not allow harmful light intensities and wavelengths from being viewed by experiment operators or any other party. Depending on experiment light hazard, laser intensity limiting measures must be considered for preventing optical risks.

5.5.3 Pressurized systems

Seamless welded gas cylinders for compressed and liquefied gases (excluding acetylene) may be carried on board if compliance with ISO 7866 (aluminium alloy gas cylinders) 9809 (steel gas cylinders) or 11119 (composite gas cylinders) can be shown, and the installation and handling requirements of section 5.3.4. can be complied with.

The content of the cylinder may qualify as hazardous, see sections 5.6.5. and 5.6.7.

For the purposes of this section, 'Pressurized Systems' means vessels, piping, safety accessories and pressure Accessories beyond the gas cylinder. Any and all such equipment is only allowed after a design review by ace2space.

Remark: DEWARS
Dewar/cryostat systems are a special category of pressurized vessels because of unique structural design and

performance requirements. They are NOT considered as pressure vessels by themselves and are therefore allowed.

5.5.4 Free-floating experiments

Free-floating experiments may be performed in the Cessna Citation II. The design of a free-floating unit should take into account the risks associated with this type of set-up (customers, experiment operators and crew injured by the free-float package, free floating items in case of damage to the test package, etc). Note: aerodynamic disturbances undergone by the aircraft might induce some small variations of g-levels during the parabola. This residual acceleration results in the drifting of the free-floating test package toward the walls, ceiling or floor of the aircraft. In order to maximize the free-floating time, the test package should be designed as compact as possible.

There are two types of possible free-floating experiments:

FREE-FLOAT PACKAGE IN THE CABIN
There is no maximum allowable free-float package weight, but it may not impose hazards to the crew or cabin occupants. It will be assessed on a case to case basis. Often, a free-float unit is connected to an acquisition unit on the customer's lap or secured to the ground by means of data wires. These wires should not be used to restrain the movement of the free-floating unit. It is recommended that the wires be reinforced in order to avoid inadvertent disconnection. If possible, the unit should be protected with foam so as to avoid injuring crew and customers. During take-off and landing, the free-float package should be held onto the lap of the customer or stowed in one of the metal boxes as described in paragraph 4.2.1.

FREE-FLOAT PACKAGE IN A PROTECTIVE CAGE
In this configuration, the experiment is fully free-floating within a protective cage. Based on the resistance of the cage, the test cell should be strapped or stowed in an aluminium case for take-off and landing. In all test configurations, the free-float package and any handling aids should be capable of withstanding the two 2.5 g phases at the beginning (pull-in phase) and at the end (pull-out phase) of each parabola. At the parabola exit manoeuvre, the test object should withstand the shock induced by its fall on the floor (equivalent to a drop of 4 m at 1 g).

FREE-FLOATING PEOPLE
There is a possibility for cabin occupants to free-float at own risk and carry out experiments at the same time. Provisions should be made to reduce risks during the (transitions between) micro-g and hyper-g fases.

Figure 13: Example Free-Float Package

5.5.5 Contact temperature

Hot or cold hardware must be unexposed to the cabin, so as to avoid injuring crew and customers. The inadvertent touch temperature of any potentially exposed surface should be maintained between –2°C and 45°C.

5.5.6 Heating systems

Heating systems can be powerful systems that can embody a risk of fire onboard the Cessna Citation II. All the heating systems that can reach high temperatures have to be designed following these rules:

- The overheating scenario must be prevented by convenient safety barriers (thermo-switches, thermal fuses, etc) and addressed by means of a hazard report. (The temperature set for during the experiment and the maximum heating capacity, i.e. max temperature, must be mentioned.)
- Temperature sensors or thermocouples used for the regulation must be located in direct proximity of the heated area.
- The heaters must not be installed close to flammable products or materials.

Figure 14: Thermal fuse

5.5.7 Test equipment noise levels

Ace2space shall be informed about any noise-generating equipment. Noise levels above 90db requires active or passive protective hearing for experimenters and crew.

5.5.8 Pumps

The use of vibration-damping devices for mounting a pump is strongly requested in order to minimize the transmission of vibrations to the aircraft.

5.5.9 Computers and tablets

Modern standard computers (laptop, desktop) and tablets work properly in flight even during hyper gravity phases. Nevertheless, within some laptops, handheld computers and other devices containing a hard drive, a gravity detecting protection device might be implemented. Such device could switch off the computer during hyper gravity or zero-gravity phases.
Researchers are advised to work either with standard laptops (without gravity-detecting device), or to check the proper functioning of their laptop in the upside-down position and during (gentle) drop tests.

5.5.10 Ionizing radiation, x-rays

- The use of radioactive material is **forbidden**
- The use of radioactive equipment **forbidden**

Exception could be granted on a case by case basis. The customer should in any case inform ace2space as soon as possible. The experiment, the operators and the related procedure should be compliant with the Dutch radioprotection regulation which may be more stringent than European regulation.

5.6 Products and materials requirements

5.6.1 Liquids and biological preparation

For experiment using liquids the following requirements apply:

- All biological agents should be stated to ace2space, an MSDS should be provided for each.
- Containment: All liquids other than water, and water quantities exceeding 1 liter must be enclosed in a liquid proof sealed containment. It is mandatory to perform a waterproofness test of the containments before coming in the ace2space facilities. Cryogenic liquids are **prohibited**.

- Material Safety Data Sheets (MSDS): For all liquids other than water and vegetable oil, an MSDS form written in English from the liquid provider shall be submitted to ace2space. An MSDS shall also be provided for mixes of liquid and biological solutions.
- All liquid containers shall be labelled with the name of the chemical and of its owner, as well as the appropriate hazard warning signs.
- For each liquid used in flight, the quantity shall be justified and minimized as much as possible for experimental purposes.
- So as to have a backup solution in case of spill, the customer has to foresee the convenient absorbent material related to the products they handle.

Some experiments require access inside the containment during microgravity phases, e.g. for handling test cell with liquids. In this case it is advised to design and use a glove box for mounting at one of the ace2space cabin platforms. If required ace2space can assist in the selection of a suitable glove box.

Figure 15: DIY – Glove box

5.6.2 Genetically Modified Organisms (GMO)

Various definitions for GMO exist in Europe, leading to various classification of biologic material. In any case, the Dutch definition is applicable. All organisms falling under this definition are **forbidden**.

5.6.3 Smoke

Experiments generating smoke should confine the smoke within airproof containment, and keep its volumes small. Large volumes of smoke, as well as smoke based on toxic substances, are **prohibited**. The customer should send to ace2space the MSDS forms written in English for the products used to create the smoke. Based on the MSDS, a double containment might be requested.

5.6.4 Handling of powder or small particles

Based on the risk to scatter small particles inside the cabin and to hurt flight attendees, the requirements for liquids apply. Large quantities of powder, as well as powders based on toxic substances, are **prohibited**.

5.6.5 Hazardous materials

As far as possible, avoid the use of hazardous materials, including toxic and corrosive materials. The use of hazardous material shall be justified and it should be demonstrated that it cannot be replaced by any other safer materials. If such materials are required for purposes of the experiment, proper use, safety devices and proper containment must be implemented. A hazard analysis, including a list with all experimental products to be used and related Material Safety Data Sheets (MSDS) written in English must be provided. The customers must read the MSDS and understand the hazards relative to their products. The hazard analysis must address any potential risk and related control method.

Hazardous material quantities shall be justified and minimized as much as possible for experimental purposes.

5.6.6 Cabin environment preservation

No gas, liquid or material, even known as not toxic, may be released from an experiment into the aircraft cabin except air and water. Water quantity should be limited to 1 liter per flight.

5.6.7 Flammable and explosive gases

Flammable and explosive gases are only allowed in accepted small quantities in the plane or in ace2space’s premises at any moment, and must be accompanied by adequate safety provisions.

5.6.8 Dry ice

Dry ice (solid carbon dioxide CO_2), undergoes the process of sublimation, transitioning directly from solid to gaseous form. In solid form, its temperature is around -80°C. Precautions have to be taken to avoid direct skin contact with dry ice. Its handling must be performed only with cryogenic gloves. Dry ice should be used under a well ventilated environment as CO_2 is heavier than air: avoid high CO_2 concentrations. In addition, it should not be stored in a completely sealed container as overpressure could build up inside the container. Quantities shall be kept to a minimum.

5.7 Flight and "safe-mode" procedures

All procedures to operate the experiment shall be provided to ace2space on request. Procedures have to be detailed and updated. All procedure changes have to be reported to ace2space. Procedures should remain as simple as possible and always available in flight. It is strongly recommended to perform the maximum number of tasks during 1 g flight phases and not to work during 2 g phases. During microgravity phases the tasks have to be easy to perform. For safety and operational reasons, each customer shall use checklists and each task performed shall be cross-checked. In the event of a researcher becoming unfit, the ace2space personnel aboard should be able to safely and efficiently initiate emergency procedures to turn the experiment into a safe-mode. A single action "pushbutton" is the preferred means of securing research equipment in the event of an emergency. Emergency procedures for experiments must be meticulously derived and easy to accomplish. Customers must fully comprehend their experiment/hardware, and be ready at all times to initiate these procedures without delay. Emergency procedures must be visible on equipment by means of a placard, using easy to understand instructions placed at a highly visible location.

5.8 Life-sciences experiments involving test subjects or animals

Experiments may involve human test subjects. These experiments must be either non-invasive or be subjected to approval by the subject, his or her parents or legal guardians AND the subjects physician. ace2space maintains the right to refuse any experiment on human subjects.

The same applies to experiments that involve animals: ace2space maintains the right to refuse any experiment that includes animals.

Appendix A Ace2space Experiment Plan

1. Project Title:

Acronym:

2. Point of Contact

2.1. Principal Investigator (Name / Address / email / cell phone)

2.2. Technical Point of Contact (Name / Address / email / cell phone)

3. Document history

Version	Revision Date	Description of changes
1		

4. Project summary

(Provide a brief summary of the project that allows us to understand the scientific, technical and operational context, 1/2 page max)

5. Test matrix

(Provide the required type (zero-g, Lunar- or Mars-parabolas) and number of parabolas, and time between parabolas).

6. Required experiment crew

(Minimum number of operators required to run the experiment. This determines the required cabin lay-out)

7. Equipment description

(Please provide an overview of the overall system used on board and on the ground, its system elements / components and how they work together in terms of time and space. This section should enable us to understand the basic technical /operational structure.)

8. Aircraft installation requirements

8.1. Proposed location in the cabin (fixed in a rack, strapped to a table, or carry-on free-float)

8.2. Hardware weight and dimensions

8.3. Power supply (battery powered? Aircraft power required?)

8.4. Emissions (e.g. noise, odours, light, vibrations, electromagnetic fields, wireless communication system etc.)

8.5. Aircraft data required (e.g. altitude, heading, speed, g-level etc).

9. Experiment operational procedures (if applicable)

(Provide both normal procedures (e.g. once established in a parabola, a valve will be opened) and contingency procedures for the experiment (e.g. what to do if a liquid leaks, or a valve does not open when required)

10. Preliminary risk assessment checklist

List of simple Y/N questions to identify potential safety hazards. This checklist will be used in further discussions to determine any relevant safety related information for ace2space to perform a safety assessment and clear the experiment for flight

A. General	Yes	No
> 500W electrical power required?		
Contact temperature < -2°C or > +45° ?		
Weight (fixed experiment) > 50 kg?		
Weight (free floating) > 10 kg?		
Moving parts?		
Sharp corners?		
Laser?		
RF of EM radiation emitted? (WiFi, Bluetooth, other)		
Batteries? (experiment or data logging equipment such as laptops or tablets)		
Fire, or smoke or fumes generated by the experiment?		
B. Potential Hazardous Materials (See NOTE below) Does the experiment contain		
• Explosive materials?		
• Powders?		
• (Pressurized) gas?		
• Liquids?		
• Flammables?		
• Oxidizing substances?		
• Toxic substances?		
• Biological substances?		
• Radioactive material?		
• Dry ice?		

NOTE: If any question in section B (Hazardous Materials) is answered with "YES", please provide information on quantity to be carried, proposed containment, and a Material Safety Data Sheet (MSDS) or other similar format providing potential hazards associated with the particular material or product, along with spill-handling procedures.