ESRANGE USER'S HANDBOOK

Volume II
Safety

CHANGE LOG

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APPROVAL

This version was approved by Mr Lennart Poromaa, Head of Esrange Space Center, on the date of issue.

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PREFACE

Swedish Space Corporation (SSC) owns and operates Esrange Space Center (ESC) located in the north of Sweden, where a multitude of activities are performed in support of space and Earth science research, satellite communications, aerospace technology development and orbital launches. SSC also maintains capabilities to conduct mobile launch activities for stratospheric balloons at Esrange.

Users of Esrange include space agencies, scientific and research organizations, universities, and commercial customers from all over the world.

This Esrange User's Handbook summarizes policies and procedures for facility use and provides a description of the range capabilities to users.

The handbook is divided into 11 volumes, with the three first addressing general information related to the range, safety and range instrumentation, while the next seven address specific facilities, processes and operations related to individual types of activities (e.g., sounding rockets or orbital launch).

Abbreviations and acronyms used throughout the handbook, as well as identified references, are included in Volume A.

Each new version of an individual volume of the Esrange User's Handbook replaces all previous versions of that particular document (but not any of the other volumes).

The most current version of the complete/consolidated Esrange User's Handbook, and other documents referenced within it, can be found at http://www.sscspace.com.

Volumes in Esrange User's Handbook

Vol. I - General Information	Vol. II - Safety
Vol. III - Launch Range Instrumentation	Vol. A - Abbreviations and References
Vol. IV - Scientific Ground Instruments	
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1 GENERAL

Safety should be the focus of all personnel - SSC staff, contractors and range users alike - while conducting operations at Esrange Space Center (ESC), or other off-range locations where Esrange Space Center has operational responsibility.

To facilitate this, Esrange has a dedicated Safety Team that is responsible for coordinating and compliance of Range Safety.

1.1 ESC Safety Responsibilities

In accordance with Swedish law, SSC has ultimate responsibility for the safety of all activities at ESC, in conformance with regulations from various Swedish governmental agencies.

Before any activity is performed at Esrange it must first be approved by the Esrange Safety Board. SSC will define the information required to be submitted by each range user. The range user will be responsible for ensuring that all submissions delivered to SSC are complete and correct, that all operations are performed according to pre-defined/approved procedures and that all hardware is designed and used in accordance with applicable standards. SSC will then ensure that all operations are performed in accordance with the Esrange Safety Manual and other complementary safety policies and regulations, as applicable.

2 SSC SAFETY POLICY

All Esrange operations must be performed in accordance with Swedish law, ordinances and provisions and within acceptable risk levels.

Safety considerations early in the planning stages of a project will reduce the possibility of costly engineering changes and/or scheduling delays. Therefore, coordination with Esrange safety personnel should be established through the SSC Project Manager as early as possible in the planning stages of each project.

Esrange safety personnel should be notified of and represented during technical interchange meetings, system design reviews and flight readiness reviews where Ground and Flight Safety issues are addressed.

2.1 Esrange Safety Manual

The Esrange Safety Manual (ESM) defines the specific requirements which shall be met to implement SSC's Safety Policy. The ESM is available at http://www.sscspace.com. It is the responsibility of all range users to acquaint themselves with the requirements identified in the ESM.

The possibility of more stringent safety requirements being necessary for individual projects and/or operations will also be considered by SSC on a case-by-case basis.

2.2 Esrange Safety Board

Before any operation can proceed it must first be approved by the Esrange Safety Board (ESB), which is the overarching approval authority for all activities performed under the operational responsibility of Esrange Space Center.

3 APPLICABLE LEGISLATION

Swedish law, and associated safety and security regulations, apply to all activities at ESC.

The Work Environment Act (Arbetsmiljölagen) is the basic law which defines the framework for regulations concerning occupational safety and health in Sweden. The Swedish Work Environment Authority (Arbetsmiljöverket) is the administrative agency responsible for matters relating to occupational environments.

Provisions based on the Work Environment Act, and other applicable laws addressing occupational safety and health, contain detailed stipulations and requirements for a multitude of different topics, including explosives, flammable materials, toxic materials, electrical facilities, crane and lifting operations etc.

4 RANGE SAFETY

The main objectives of Range Safety are to minimize the risk of injuries to persons and damage to property on and outside the range.

SSC's definition of Range Safety is the "application of safety policies, principles and techniques to protect the public, workforce and property from hazards associated with range operations".

As such, both Ground Safety and Flight Safety are key parts of Range Safety.

4.1 Ground Safety

The fundamental philosophy for Ground Safety is that all risks to personnel shall be minimized as much as is reasonably achievable, and all systems shall be designed in such a way as to require a minimum of two unrelated failures before personnel are exposed to a hazard. Only task-essential personnel are allowed to be present when a hazardous operation is conducted and the number of people should always be kept to a minimum.

4.1.1 Ground Safety Process

The Esrange Ground Safety Officer (GSO) is responsible for Ground Safety during all approved operations, and will prepare a Ground Safety Plan for presentation to and approval by the Esrange Safety Board. The purpose of the Ground Safety Plan is to identify all hazardous systems and minimize risks to infrastructure and personnel by the means of hardware and procedures.

4.1.2 Explosives

All explosives shipped to Sweden will require an import license issued by the Swedish authorities. It is the responsibility of Esrange to prepare the application for such a license with input from the range user. The process of obtaining an approved license can take 6-12 weeks, depending on the planned method of transportation.

4.1.3 Hazardous Systems

Hazardous systems can include anything that involves chemicals, cryogenics, ionizing radiation or strong non-ionizing radiation, lasers, mechanical systems, poisonous substances, pressure, pyrotechnics, etc. All of the aforementioned systems are regulated by the Esrange Safety Manual. The Ground Safety Officer has the unilateral right to continue requesting additional information regarding any potentially hazardous systems until convinced of their sound design and safe operation.

4.1.4 Cryogenic Systems

Cryogenic systems (which are considered and treated as hazardous systems) are regulated by the Esrange Safety Manual, section 5.3.11, and the document "Cryogenic Safety at Esrange Space Center" (SCIENCE-878286732-26684). Additionally, all rules related to both pressurized systems and chemical systems are also applicable to cryogenic systems. Each individual cryogenic system must be reviewed and approved by the Cryogenic Safety Board (ESM section 3.1) before it can become operational.

4.2 Flight Safety

Flight Safety addresses the time from vehicle lift-off until all vehicle components have either impacted the surface of the Earth or been injected into orbit.

4.2.1 Flight Safety Process

SSC is responsible for Flight Safety at Esrange and has defined processes and requirements for the safe operation of UAVs, stratospheric balloons, sub-orbital rockets and orbital launch vehicles. All range users must supply SSC with information regarding trajectories, dispersions, failure modes and debris catalogs in sufficient detail for SSC to perform a pre-requisite Flight Safety analysis.

After sufficient documentation has been provided, the Esrange Flight Safety Officer (FSO) will prepare a Flight Safety Plan for presentation to and approval by the Esrange Safety Board. The purpose of the Flight Safety Plan is to prove that the mission complies with the Esrange Safety Manual, and any other applicable regulations. As such, each mission-specific Flight Safety Plan will contain all relevant documentation and analysis needed to convince the Esrange Safety Board.

Additional information regarding specific regulations governing Flight Safety can be found in the Esrange Safety Manual.

4.2.2 Flight Safety Systems

The inclusion of a Flight Safety System is mandatory on all non-inherently safe launch vehicles capable of reaching population centers or other protected areas.

The definition of an "inherently safe vehicle" can be found in the Esrange Safety Manual.

4.2.3 Quantitative Safety Requirements for Flight Safety

SSC employs quantitative safety limits to determine acceptable risk levels for missions. These levels are typically in line with internationally recognized standards for safety.

5 METEOROLOGY

5.1 Weather Forecasting

SSC has substantial experience with weather forecasting for balloon and rocket missions.

SSC receives weather data from the Swedish Meteorological and Hydrological Institute (SMHI), which is also Sweden's participating agency within the European Center for Medium-Range Weather Forecast (ECMWF). For the Esrange area, two main meteorological models are produced: ECMWF and AROME.

ECMWF is a global forecast model produced by the organization with the same name. The model is considered to be one of the most accurate global models available. It produces 2 forecasts every day at 00:00 and 12:00 UTC, and the results are available about 10 hours later. Each forecast has an outlook of 120 hours. The model has a horizontal resolution of 9 km and contains 137 vertical levels in a hybrid sigma-pressure arrangement. Each run contains 32 time steps with a temporal resolution of 3 hours the first three days and 6 hours the last two days. ECMWF delivers all important parameters required to make an accurate prediction of the conditions for launch such as wind speed, wind direction, temperature and humidity for all vertical levels.

AROME is the high-resolution forecast available at Esrange. The model has been developed within a large European cooperation and is now run operationally by SMHI. It produces forecasts 4 times every day at 00:00, 06:00, 12:00 and 18:00 UTC, and the results are available less than 5 hours later. Each run contains 60 time steps with a temporal resolution of 1 hour. The model has a horizontal resolution of 2.5 km and contains 65 vertical levels concentrated in the lower levels of the atmosphere. AROME delivers all important parameters required to make an accurate prediction of the conditions for launch such as wind speed, wind direction, temperature and humidity for all vertical levels. Skew-T diagrams are also provided for easy analysis of atmospheric stability.

5.2 Wind Measurements at Launch

5.2.1 Current capability

Wind measurements during launch countdowns are currently performed by two means:

- Surface winds are measured by anemometers providing U, V and W vectors with a very high accuracy and frequency. These are placed on masts or tall buildings near the launch areas, providing data in real-time.
  - » At the stratospheric balloon pad there are anemometers placed at the north and west ends of the pad area, at around 10 m and 5 m height, respectively. One additional anemometer is also placed on a mast 45 m above the Satellite Station on the hill that overlooks the balloon pad.
  - » At the sounding rocket launch area there are six anemometers placed on a 100 m high wind tower, providing data for 10 m, 25 m, 45 m, 65 m, 85 m and 100 m height above ground.
- Winds at altitude are measured by balloons. This can be done in two ways:
  - » Pilot balloons (sometimes called "pibals") are released and tracked with a theodolite, thus providing wind speed and directions up to a few kilometers, depending on visibility. This is typically only done for large stratospheric balloon launches and the results have a slight delay as the data must be processed, normally being available 5-10 minutes after flight.
  - » Sounding balloons with a GPS-transmitter are launched and will send back its position. These balloons can measure winds up to 30 km altitude depending on what type of operations is supported. The data is available in real–time.

5.2.2 Future plans

Following the implementation of a planned upgrade, wind measurements will be obtained from two different sources:

- Surface winds will still be measured with anemometers placed on a mast, to provide U, V and W vectors with a very high accuracy and frequency.
- Higher altitude winds will be measured with LIDAR, to provide accurate representation of winds and clouds at higher altitudes. LIDAR measurements can be performed both immediately above the launch site as well as further downrange.

All measurement will be broadcast directly to customer control rooms and also stored on SSC servers for further analysis, if

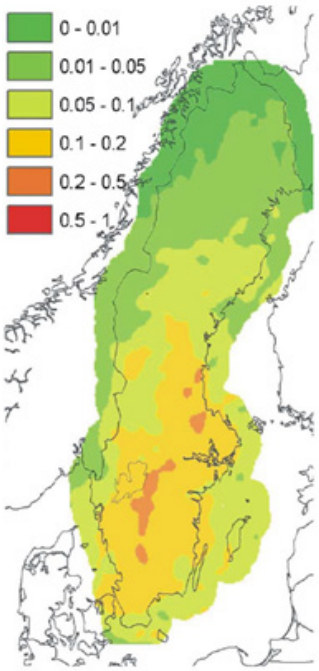
needed.

5.3 Annual Lightning Flash Density

Due to ESC's location above the Arctic Circle, the sun is relatively low in the sky (even in summer), leading to limited surface heating and a stable atmosphere.

The Convective Available Potential Energy to make thunderstorms possible is only present during the summer months of May-July, and it is rare even then. As shown in Figure 19, the area around Esrange Space Center sees an average lightning flash rate density of 0.01 strikes/(year*km^2).

More information can be found in the Esrange Weather Report (SCIENCE-637804196-99), available through SSC Project Manager.



Annual lightning flash density per km^2 in Sweden

(Characterization and Modeling of Lightning Flashes in Sweden, Strandberg, 2003)

6 SAFETY POLICIES SPECIFIC TO UNMANNED AERIAL VEHICLES

6.1 Permits and Applications

6.1.1 New UAVs

Refer to ESM paragraph 6.3.3 (New UAVs and other similar vehicles).

As with every other activity performed at Esrange Space Center, all UAV operations must be approved by the Esrange Safety Board.

6.2 Requirements for UAVs

Refer to ESM paragraph 6.3 (Requirements for Rockets, UAVs and other similar vehicles).

6.2.1 Required Equipment

Additional information to be added in the next revision.

6.3 Operations

Refer to ESM paragraph 6.5 (Operational Procedures for Rockets, UAVs and other similar vehicles).

7 SAFETY POLICIES SPECIFIC TO STRATOSPHERIC BALLOONS

7.1 Permits and Applications

Refer to ESM paragraph 8.5 (Schedules for Providing Required Data).

As with every other activity performed at Esrange Space Center, all balloon operations must be approved by the Esrange Safety Board.

7.2 Requirements for Balloons

Refer to ESM paragraph 6.7 (Requirements for Balloons).

7.2.1 Required Equipment

Stratospheric balloons must carry all equipment necessary to fulfil Air Traffic Control and Esrange safety requirements.

Additional information can be found in ESM paragraph 6.7 (Requirements for Balloons).

7.3 Operations

Refer to ESM paragraph 6.8 (Operational Procedures for Balloons).

7.3.1 Vehicle Work

Assembly and preparation of stratospheric balloons is either:

- performed by Esrange personnel, with support from the Range User
- performed by the Range User, with support from Esrange personnel

In the event that the Range User desires to perform these operations, all work must be performed in accordance with the ESM regulations.

7.3.2 Payload Work

Assembly, preparation and checkout of balloon payloads by the range user must likewise adhere to the ESM regulations.

8 SAFETY POLICIES SPECIFIC TO SUB-ORBITAL ROCKETS

8.1 Permits and Applications

Refer to ESM paragraph 8.5 (Schedules for Providing Required Data).

As with every other activity performed at Esrange Space Center, all sub-orbital launch operations must be approved by the Esrange Safety Board.

8.2 Requirements for Sub-Orbital Rockets

Refer to ESM paragraph 6.3 (Requirements for Rockets, UAVs and other similar vehicles).

8.2.1 Acceptance

Refer to ESM paragraphs 6.3.1 (Flight-proven Rockets not previously launched from ESC) and 6.3.2 (New Rockets).

8.2.2 Launch Limitations

Refer to ESM paragraph 6.5.5 (Ground-launched Vehicles without a FTS or 6.5.6 (Vehicles with a FTS).

8.2.3 Required Equipment

If a vehicle is non-inherently safe (see ESM paragraph 6.3.4 - Inherently Safe Requirements) and has the capability to reach any population center, a Flight Termination System (FTS) is required.

Additional information regarding FTS requirements can be found in ESM paragraph 6.4 (Flight Termination System).

8.3 Operations

Refer to ESM paragraph 6.5 (Operational Procedures for Rockets, UAVs and other similar vehicles).

8.3.1 Launch Vehicle work

Assembly and preparation of sub-orbital rockets is normally performed by Esrange personnel, with support from the range user.

In the event that the range user desires to perform these operations, all work must be performed in accordance with the ESM regulations.

8.3.2 Payload work

Assembly, preparation and checkout of sub-orbital rocket payloads by the range user must likewise adhere to the ESM regulations.

9 SAFETY POLICIES SPECIFIC TO STATIC TESTS

9.1 Permits and Applications

Refer to ESM paragraph 8.5 (Schedules for Providing Required Data).

As with every other activity performed at Esrange Space Center, all test operations must be approved by the Esrange Safety Board.

9.2 Requirements for Test Items

9.2.1 Acceptance

Additional information to be added in the next revision.

9.2.2 Required Equipment

Additional information to be added in the next revision.

9.3 Operations

Refer to ESM paragraph 6.6 (Operational Procedures for Static Tests).

10 SAFETY POLICIES SPECIFIC TO ORBITAL LAUNCH

Orbital launches represent the most complex safety case at Esrange. For each orbital mission to be conducted at Esrange, SSC will perform a full safety analysis (including both Ground Safety and Flight Safety) which will require significant input from the Launch Service Provider.

10.1 Permits and Applications

All orbital launches from Sweden will require authorization by Swedish Authorities. In order to obtain approval for an orbital launch, SSC (as the launch site operator) will need to apply for a launch license, together with the Launch Service Provider. A part of the license application, a safety analysis will need to be included. Additional information regarding launch licensing can be found in Esrange User's Handbook Volume IX (Spaceport).

As with every other activity performed at Esrange Space Center, all orbital launch operations must be approved by the Esrange Safety Board.

10.2 Safety Review Documentation

The range user must submit all required safety review documentation to the SSC Range Safety Office no later than 6 months before the anticipated launch date.

The safety review documentation must include, but is not limited to, the top-level information described below. Additional details will be provided by the relevant SSC Project Manager.

10.2.1 Launch Description

A description of the launch vehicle and payload(s). Description of the nominal flight trajectory (including all dispersions) and all key events along the trajectory. Vehicle performance graphs.

10.2.2 Launch Personnel Certification

A description of the process used to ensure that range user personnel are qualified to perform the planned activities. A list of controlled tasks and who can perform them.

10.2.3 Flight Safety

Complete vehicle Flight Safety data package (including information such as description and probability of failure cases, debris catalog for all failure cases, description of blast during intact impacts, etc.). Description of any risk for toxic release. Proposed flight safety rules.

10.2.4 Ground Safety

All required Ground Safety information, as requested by the Ground Safety Officer.

10.2.5 Flight Termination System

Flight Termination System report, according to the Esrange FTS approval process (final version 4 months prior to launch).

Any independent safety analysis can also be shared with SSC as part of the review documentation.

10.3 Analysis

Both Ground Safety and Flight Safety analyses must be performed by SSC to ensure that the mission fulfills the requirements in the Esrange Safety Manual and other applicable regulations.

Additional analyses can also be requested by the range user.

10.3.1 Ground Safety Analysis

SSC will perform a Ground Safety analysis based on the range user's input regarding hazardous systems and procedures.

A Ground Safety Plan (as described in paragraph 4.1.1) will be written for each orbital launch campaign, based on the Ground Safety analysis. The Ground Safety Plan aims to minimize risks to personnel and infrastructure by requiring the implementation

of protective systems and/or procedures. The Ground Safety Plan must be approved by the Esrange Safety Board.

10.3.2 Flight Safety Analysis

SSC will perform a Flight Safety analysis based on the range user's input. This analysis will be based on Swedish Flight Safety Authority methodology. The result of the Flight Safety analysis will then be compared to the risk limits defined in the Esrange Safety Manual.

A Flight Safety Plan (as described in paragraph 4.2.1) will be written for each orbital launch, based on the Flight Safety analysis. The Flight Safety Plan must be approved by the Esrange Safety Board.

Additional information regarding some specific trajectory-related considerations that are evaluated as part of the Flight Safety analysis (including azimuth, altitude, jettison and risk constraints) can be found in Esrange User's Handbook Volume IX (Spaceport).

10.3.3 Launch Collision Avoidance Analysis

A collision avoidance (COLA) analysis will be performed in accordance with the licensing requirements of the Swedish Authorities. It is expected that these requirements will be in line with the requirements made by the FAA.

10.4 Required Equipment

10.4.1 Flight Safety System

A Flight Safety System (FSS) is any system that provides a means of control during flight for preventing a hazard from a launch vehicle, including any payload hazard, from reaching any populated or other protected areas in the event of a vehicle failure. A Flight Safety System consists of all hardware and software used to protect the public in the event of a vehicle failure, and the functions of any Flight Safety crew.

The range user is responsible for providing the on-board Flight Termination System for their launch vehicle. Esrange is responsible for providing the infrastructure needed to support the Range Safety decision process, which includes the ground-based instrumentation and support systems.

The on-board Flight Termination System must be compatible with the Esrange ground systems and meet the requirements stated in RCC 319-14 for design, performance, testing, analysis and documentation of the FTS.

The range user shall coordinate with the ESC Range Safety Office to determine the flight termination criteria during flight. The flight termination criteria shall address the following:

1 Valid data shows the vehicle violating a defined Flight Safety limit
2 Vehicle performance or location is unknown, the vehicle is capable of violating a defined Flight Safety limit, and terminating flight would mitigate the risk
3 Orbital launch vehicles not capable of achieving a minimum acceptable orbit
4 Gross trajectory deviation or obvious erratic flight rendering the vehicle uncontrollable
5 Other mission-specific conditions, as defined by the ESC Range Safety Office

For vehicles flown with a FTS, the ESC Range Safety Office shall ensure at least two independent and adequate tracking sources are operational to track the vehicle for the entirety of the planned flight path.

The ESC Range Safety Office shall also ensure each independent tracking source, and the associated tracking plans, are designed such that no single order failure mode (either on the flight vehicle or in any ground-based instrumentation) could cause the loss of both tracking sources to the Range Safety Display System.

10.5 Operational Support

10.5.1 Launch Vehicle Work

For orbital missions where SSC is acting solely as the launch site operator, the range user will be responsible for performing all of the work related to integrating and preparing the launch vehicle for flight.

The Esrange Safety Manual applies for all work performed at Esrange, but the range user is free to follow other regulations (in the event they are more stringent). The Ground Safety Officer can always choose to be present during hazardous operations.

Additional information regarding ground operations, including activities related to LV assembly and subsequent preparations for launch operations, is provided in Volume IX (Spaceport).

10.5.2 Payload Work

For orbital missions where SSC is acting solely as the launch site operator, the range user will be responsible for performing all of the work related to preparing payloads for flight and integrating them with the launch vehicle.

The Esrange Safety Manual applies for all work performed at Esrange. Any hazardous materials on-board a payload must be approved in advance. The Ground Safety Officer can always choose to be present during hazardous operations.

Additional information regarding payload operations, including satellite processing and fueling, is provided in Volume IX (Spaceport).

10.5.3 Launch and Flight

The ESC Range Safety Office will be responsible for Ground Safety during countdown operations and Flight Safety from lift-off until all vehicle components have either impacted the surface of the Earth or been injected into orbit.

Range Safety system hardware can only be operated by qualified ESC safety personnel, including the Range Safety Officer and Flight Control Officer.

10.5.4 Post-launch

Additional information to be added in the next revision.

10.6 Restricted Areas

Orbital launches from Esrange Space Center will result in restricted access to certain areas, both for personnel working inside the (fenced) Base Area as well as the general public in various areas around the base.

10.6.1 Base Area

The Ground Safety philosophy is to minimize the number of people present during each hazardous operation, and the time such personnel are exposed to risks.

Only mission-essential personnel will be permitted to access any dangerous areas during hazardous operations, and activities will be limited to ESB-approved procedures.

The Ground Safety Officer can always choose to be present during hazardous operations.

10.6.2 Downrange

SSC is responsible for range clearance prior to a launch. This involves restricting public air, land and sea traffic.

During orbital launches a part of the Esrange downrange impact area will be closed to the public and the large airspace around Esrange will be closed off to all unauthorized traffic. SSC also will issue any necessary NOTAMs and NOTMARs, as appropriate.

Additional information regarding the restricted groundspace and airspace around Esrange is provided in Volume I (General).

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Esrange Space Center - The most versatile space center in the world !

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