SAFETY ASSESSMENT DOCUMENT

The Physics Division ATLAS Accelerator

2014
Rev. 1

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3/20/2014
Date

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1. INTRODUCTION

1.1. ATLAS Facility

The ATLAS (Argonne Tandem-Linac Accelerator System) facility is one of the leading facilities for nuclear structure research in the United States. It provides a wide range of stable and radioactive ion beams for research by a large international community of scientists exploring areas of atomic physics, nuclear physics, and astrophysics. In addition, ATLAS provides a facility for the development and testing of components and experimental equipment for the next generation of particle accelerators.

Since its inception in 1985, the ATLAS facility has continually been upgraded in order to be at the forefront of nuclear research. These upgrades have served to increase the capabilities of the accelerator system, improve the performance of the control system and radiation interlock system, reduce system maintenance requirements, and provide advanced research capabilities and instrumentation. Presently, the ATLAS facility is being upgraded to study the nuclear reactions and structures relevant to the astrophysical processes responsible for the production of heavy elements in the universe by developing the capability to accelerate neutron-rich fission fragments (the Cf Rare Ion Breeder Upgrade, CARIBU) and by measuring their masses (Canadian Penning Trap) and using them as projectiles for nuclear structure experiments (HELIOS, Gretina/Gammasphere). The facility changes described in this revision of the Safety Assessment Document (SAD) will result in increased accelerator beam current. This increased current can be immediately utilized for medium and heavy projectiles while remaining within the present Accelerator Safety Envelope (ASE).

The ATLAS facility is located at Argonne National Laboratory (ANL). ANL is a facility owned by the U. S. Department of Energy (DOE) and operated by UChicago Argonne, LLC, a consortium formed by the University of Chicago with industrial partners Jacobs Engineering Group Inc. and BWX Technologies, Inc.

1.2. Protection of Workers, Public, and Environment

The requirements imposed on the ATLAS facility for the protection of the health and safety of workers and the public, and the protection of the environment are established by DOE and ANL. These requirements cover all aspects of ATLAS activities and assure that those activities are conducted in accordance with the applicable rules and regulations established by other federal organizations such as the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA).

For the ATLAS facility, there is a set of documents that is particularly applicable to accelerator facilities, and there is an established hierarchy in the set of documents that specify the health, safety, and environmental requirements. In this hierarchy, the highest authorities are: Title 10, Code of Federal Regulations, Part 820 “Procedural Rules for DOE Nuclear Activities” (Reference 1-1), Title 10, Code of Federal Regulations, Part 835 “Occupational Radiation Protection” (Reference 1-2) and Title 10, Code of Federal Regulations, Part 851 “Worker Safety and Health Programs” (Reference 1-3). The next set of controlling documents are various DOE Orders, including DOE Order 420.1C “Facility Safety” (Reference 1-4) and DOE Order 420.2C “Safety of Accelerator Facilities” (Reference 1-5). The implementation of the DOE rules and regulations for activities at ANL is provided by various policies and procedures including the ANL Environment, Safety, and Health Manual (Reference 1-6) and Accelerator Safety Procedure LMS-PROC-188 (Reference 1-7).

1.3. Safety Assessment Document

The purpose of this Safety Assessment Document (SAD) for the ATLAS facility is to describe in sufficient detail all significant hazards presented by the facility and its operation and the controls by which these hazards will be managed to an acceptable level of risk. The SAD is written in compliance with DOE Order 420.2C “Safety of Accelerator Facilities” and ANL Accelerator Safety Procedure LMS-PROC-188.

The topics addressed in the remaining chapters of the SAD are described below:

- Chapter 2 of this SAD provides an overview of the results and conclusions of the analyses provided in this SAD.

- Chapter 3 addresses the characteristics of the Argonne site with attention being given to natural phenomena and nearby activities which could impact the safety of the ATLAS facility. The chapter also provides descriptive information on the ATLAS facility itself, including those facility features that are important for maintaining the safety of the facility. Finally, the chapter discusses the operational aspects of the facility which are relevant to safety.

- Chapter 4 identifies the variety of hazards that the ATLAS facility presents to workers, the public, and the environment, and specifies those hazards which are deemed to be most significant in terms of health, safety, and environmental concerns. Credible accidents due to operational, natural, and man-made events that could cause the significant hazards to be realized are postulated.

- Chapter 5 provides the basis for the ATLAS facility’s Accelerator Safety Envelope (ASE); the set of administrative and physical conditions that define the bounding conditions for the safe operation of the facility. The chapter also addresses the facility’s Operations Envelope; a set of conditions, more restrictive than those specified in the ASE, which facility management imposes to assure that the ASE conditions are unlikely to be exceeded.

- Chapter 6 discusses the quality assurance program which is applicable to the ATLAS facility.

- Chapter 7 discusses post-operations planning for the ATLAS facility. The chapter identifies features of the facility and on-going activities which will facilitate the future decommissioning, decontamination, and dismantlement of the facility, and discusses planning for the post-operations phases.

- Chapter 8 provides the references cited elsewhere in the SAD.

- Chapter 9 identifies the acronyms and defines the technical terms used in this SAD.

- The Appendix provides the Accelerator Safety Envelope and Operations Envelope for the ATLAS facility.

The SAD, 2013 Revision 1, Intensity Upgrade, is based on material present in the previous version of the ATLAS Facility SAD, 2013 (approved January 26, 2013), information and analyses developed during the CARIBU Project and the ATLAS intensity upgrade, and hazard analyses performed for various ATLAS activities. The SAD has been reviewed by facility and Physics Division personnel having expertise in accelerator operations and safety. A committee of knowledgeable ANL and non-ANL members, having no relationship with the ATLAS facility, has also reviewed this SAD. The SAD has been approved and signed by the ATLAS Facility Manager and the Director, Physics Division. The Associate Laboratory Director for Physical Sciences and Engineering and the Deputy Laboratory Director for Operations provide concurrence by forwarding the SAD to the manager of the DOE Argonne Site Office.

1.4. Accelerator Safety Envelope

The Accelerator Safety Envelope (ASE) specified in this SAD is identical to the ASE in the previous two revisions of the SAD. In accordance with the requirements of LMS-PROC-188, the Accelerator Safety Review Committee (ASRC) reviewed the modified ASE and its supporting documentation (*i.e.*, the SAD). The Laboratory Director, based on the ASRC recommendation, approved that ASE, which remains unchanged in this revision.

The previous ASE and its supporting documentation were reviewed by DOE's Argonne Site Office in accordance with the requirements of DOE Order 420.2B, -"Safety of Accelerator Facilities." The Manager, Argonne Site Office, concurred in the approval of that ASE.

2. SUMMARY/CONCLUSIONS

2.1. Overview of Results and Conclusions

This Safety Assessment Document analyses the safety issues presented by the ATLAS accelerator facility. The conclusion reached as a result of this process is that there is no compromise to the safety of employees, the general public or the environment. All potential hazards have been either eliminated or mitigated through the use of engineered and/or administrative controls.

The postulated accidents which create the most significant hazards involve asphyxiation by helium, nitrogen, or sulfur hexafluoride and accidents involving high voltage electrical hazards. Both of those types of hazards are present in DOE accelerator facilities and are accepted risks, assuming that appropriate safeguards have been adopted to assure that the likelihood of occurrence is very low.

The maximum credible incident is a postulated gasoline fire resulting from a truck delivering liquid nitrogen (LN_2) sliding into the CARIBU addition to Building 203 and spilling its fuel. The radiological consequences of the incident are determined for an off-site individual at the nearest site boundary, assuming an unmitigated release of ^{252}Cf. The consequences are a small fraction of the evaluation guideline of 25 rem total effective dose equivalent.

2.2. Comprehensiveness of the Safety Analysis

Nineteen types of hazards present in the ATLAS facility were identified and examined. For the seven hazards having minor or major consequences, possible accidents were postulated, consequences considered, and appropriate safety systems identified. The hazard and safety analyses provided in this SAD provide a comprehensive review of the risks present in the ATLAS facility.

2.3. Appropriateness of Proposed ASE

The Accelerator Safety Envelope (ASE) is not proposed to change in the current version to the SAD. The ASE retains the feature of separate radiation limitations for the accelerator portions of the ATLAS facility and limits the potential hazards associated with the ^{252}Cf source used for radioactive beam ion production by limiting the size of the allowed ^{252}Cf source as well as identifying requirements for radiation monitoring of the areas near the source and exhaust effluents from the facility. The ASE provides an appropriate set of physical and administrative controls to assure the safety of the ATLAS facility.

2.4. Proposed Exemptions from the ASO

No exemptions from the Accelerator Safety Order (DOE Order 420.2C) are proposed for the ATLAS facility.

2.5 Exemption of Accelerator-produced Radioactivity from Inclusion in the RMS Database Calculations of HC3-SOF and Pu239-FGE

Radioactive items that result from accelerator operations covered by DOE Directive O 420.2C Safety of Accelerator Facilities and that are included in the hazard analysis contained in this Safety Assessment Document need not be included in the Calculations of HC3-SOF and Pu239-FGE in the Radioactive Materials System database detailed in LMS-PROC 45.

Discussion of the hazard analysis is found below in Section 4.1.2. Hazard Analysis Results.

3. SITE, FACILITY, AND OPERATIONS DESCRIPTION

3.1. Site Description

This site descriptive information is based on material contained in the previous ATLAS SAD (Reference 3-1) and material developed for other facilities at Argonne National Laboratory (Reference 3-2).

3.1.1. Geography

The ATLAS facility is located at the Argonne National Laboratory, a 1,500 acre site of gently rolling land in the Des Plaines River Valley of DuPage County, Illinois. Laboratory facilities occupy about 200 acres of the total site area. Surrounding the Argonne site is the 2,240 acre Waterfall Glen Forest Preserve, a greenbelt forest preserve of the DuPage County Forest Preserve District. The forest preserve areas to the south and east of the site are undeveloped. Areas to the north and west of the site have commercial and urban developments (Figure 3-1).

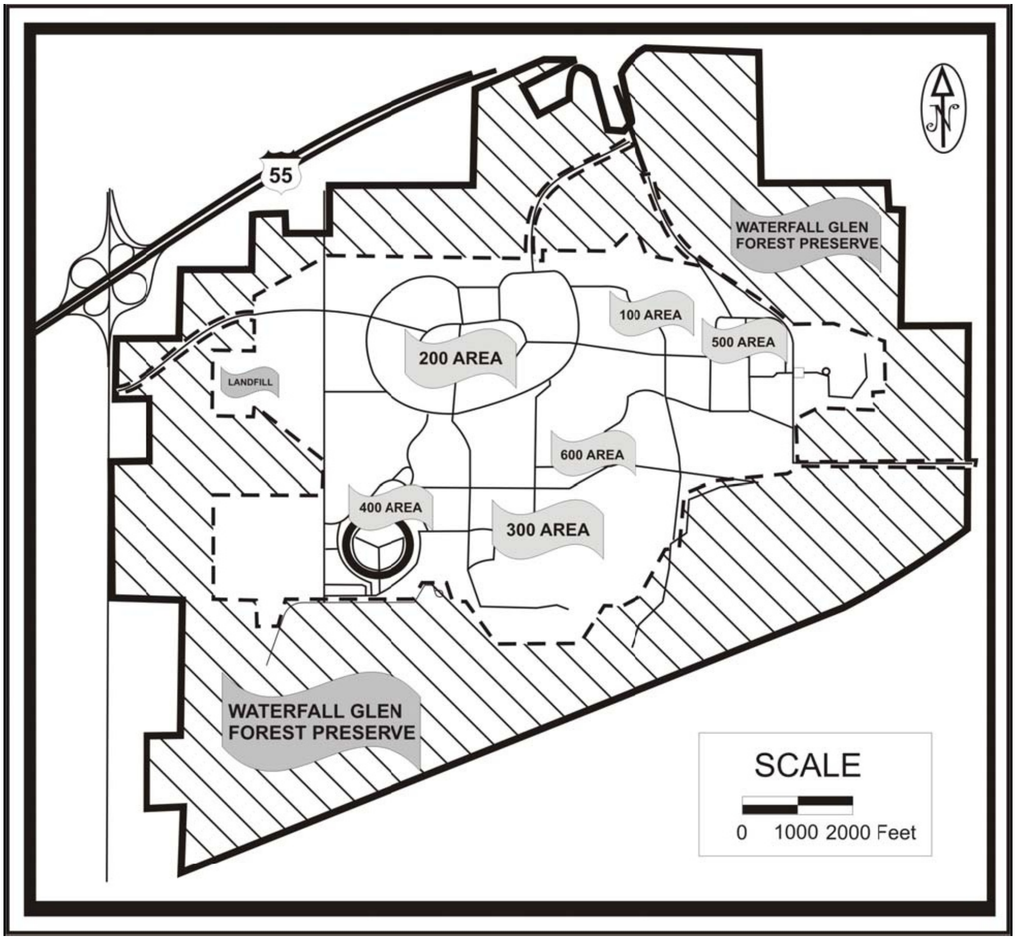

Figure 3-1. Argonne Site Map.

ANL is about 34 km (21 mi) southwest of downtown Chicago and 40 km (25 mi) west of Lake Michigan. Nearby highways are Interstate 55 about 520 m (1,700 ft) to the north, Interstate 355 to the west, and Illinois Highway 83 to the east. About 760 m (2,500 ft) south of Argonne are the Des Plaines River, the Chicago Sanitary and Ship Canal, and the Illinois Waterway (Illinois and Michigan Canal). The Santa Fe railroad line is located about 460 m (1,500 ft) southwest of the site. Several airports are located near to Argonne: O'Hare International Airport is located about 30 km (20 mi) northeast, Midway Airport about 21 km (13 mi) east, and the Brookeridge Airpark about 2.5 km (1.5 mi) north, northwest (Figure 3-2).

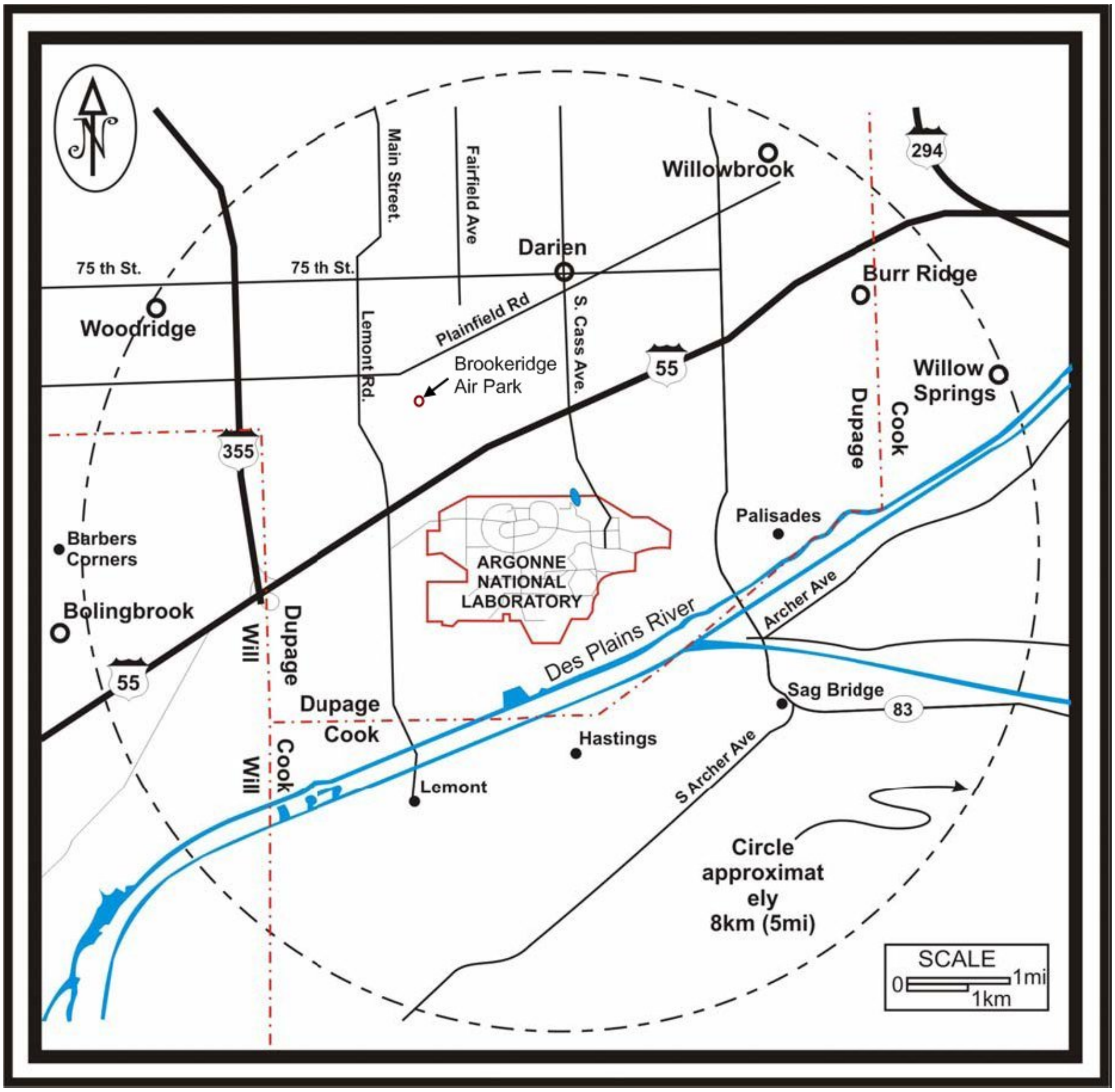

Figure 3-2. Argonne and Surroundings.

The ATLAS facility is located in Building 203 at the Laboratory. The distance to the nearest site boundary is 152 m (500 ft) and the distance to the nearest neighbor is 610 m (2,000 ft) (Figure 3-3).

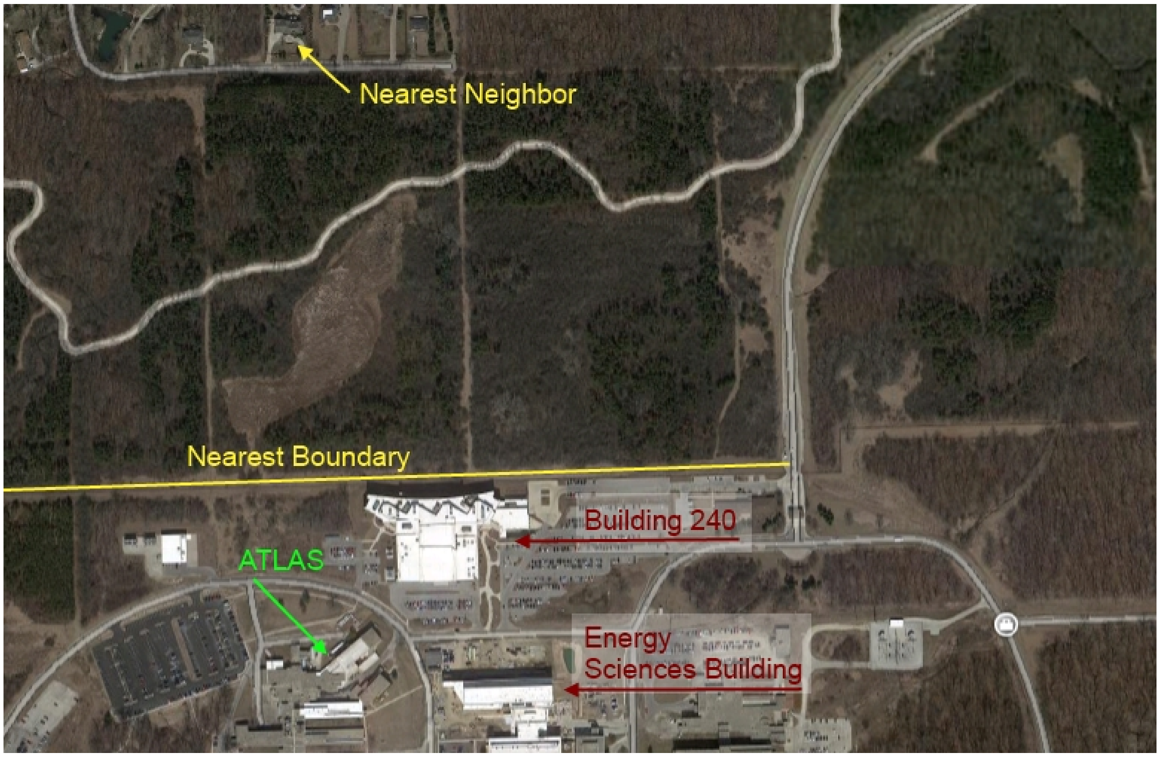

Figure 3-3. Location of ATLAS.

3.1.2. Meteorology

The regional climate is characterized as being continental, with relatively cold winters and hot summers, and is slightly modified by Lake Michigan.

The predominant wind direction is from the south, and wind from the southwest quadrant occurs almost 50% of the time. The average wind speed at ANL at a height of 5.8 m (19 ft) is 3.4 m/s (7.6 mph), with calm periods occurring 3.1 % of the time.

The meteorology conditions used for accident consequence analyses are based on analyzed site-specific data; they can be approximated by moderately stable wind conditions (Stability Class F) and a wind from the south blowing toward the nearest site boundary at a speed of 1.18 meters/second.

The average annual precipitation at ANL is 940 mm (37 in) and is primarily associated with thunderstorm activity in the spring and summer. The annual average accumulation of snow and sleet at ANL is 740 mm (29 in). Snowstorms resulting in accumulations greater than 150 mm (5.9 in) occur once or twice each year on the average, and severe ice storms occur once every 4 or 5 years.

The area experiences about 40 thunderstorms annually. Occasionally these storms are accompanied by hail, damaging winds, and/or tornadoes. Tornadoes frequently occur in Illinois, with more than 65% occurring during the spring months. The theoretical probability of a 67 m/s (150 mph) tornado strike at ANL is 3.0 x 10^{-5} each year, a recurrence interval of one tornado every 33,000 years. The ANL site has been struck by milder tornadoes, with minor damage to power lines, roofs, and trees.

3.1.3. Hydrology

Several drainages that may have intermittently flowing water are located on the ANL site. Freund Brook flows to the east-northeast and enters Sawmill Creek, which flows south to the Des Plaines River. Raw flow data from Freund Brook are not available. However, field observations of the stream size and channel configuration suggest that the discharge averages less than 0.08 m^3/s (3 ft^3/s) and peaks at 0.6 m^3/s (21 ft^3/s) during the maximum flood stage. The ANL site in general has a network of ditches and culverts that transport surface runoff, without treatment, toward the streams.

3.1.4. Geology and Seismology

Stratigraphy

The ANL site is underlain by 34-37 m (113-123 ft) of glacial till (Wisconsin stage of the Pleistocene series). It is clayey to silty-clayey till with few pebbles and cobbles and the base of this unit is locally rich in gravel. Gravel deposits are probably confined to the valleys carved in the bedrock surface that now lies buried beneath the Pleistocene sediments (alluvium and glacial till). The till is overlain by less than 0.3-0.6 m (1-2 ft) of loess and modern soil. Strata immediately underlying the till are identified as probably belonging to the Kankakee Formation of the Alexandrian Series lowermost Silurian System. The subcropping weathered zone is up to 10 m (33 ft) thick. This zone shows significant evidence of the solution weathering and fracturing, below which rock is generally unfractured and unaltered.

Silurian aquifers (including the Kankakee Formation) are separated from deeper Cambro-Ordovician aquifers by an aquitard, the Maquoketa Group (Ordovician). This group consists primarily of shale units. The top of the Maquoketa Group lies 75 m (246 ft) beneath the surface, and is about 45 m (148 ft) thick.

Soils

According to the USDA, the site consists mainly of upland soils belonging to the Morley Series. These soils formed in silty clay loam glacial till. Locally, a thin layer of overlying silty material is present.

Seismicity

No tectonic features within 100 km (62 mi) of ANL are known to be seismically active. The longest of these features is the Sandwich fault. Smaller local features are the Des Plaines disturbance, (An apparent meteor crater approximately 5 miles in diameter. It is centered in the city of Des Plaines, IL, 25 miles north of Argonne, is buried 75 to 200 feet beneath the town and is dated from the post-Pennsylvanian time.), and a few faults in the Chicago area. Although a few minor earthquakes have occurred in northern Illinois, none has been positively associated with a particular tectonic feature. Most of the recent local seismic activity is believed to be caused by isostatic adjustments of the earth's crust in response to glacial loading and unloading, rather than by motion along crustal plate boundaries.

There are several areas of considerable seismic activity at moderate distances (hundreds of kilometers) from ANL. These areas include the New Madrid Fault zone (southeastern Missouri), the St. Louis area, the Wabash Valley Fault zone along the southern Illinois-Indiana border, and the Anna region of western Ohio. Although high-intensity earthquakes have occurred along the New Madrid Fault zone, their relationship to plate motions remains speculative at this time.

Ground motions induced by near and distant seismic sources in northern Illinois are minimal. However, peak accelerations in the ANL area may exceed 10% of gravity (approximate threshold of major damage) once in about 600 years, with an error range of between -250 and +450 years.

3.1.5. Demography

The towns surrounding Argonne include Darien to the north, Burr Ridge and Willowbrook to the east, Lemont to the south, and Bolingbrook to the west (see Figure 3-2). Based on the 2000 census, there are almost nine million people who live within 80 km (50 mi) of Argonne.

There are approximately 2,900 people working on-site at Argonne.

3.1.6. Natural Phenomena Hazards

The general location of Argonne makes some natural phenomena hazards (*e.g.*, volcanism, avalanches, tsunamis, etc.) incredible. The characteristics of the site make some other hazards (*i.e.*, flooding) incredible. Some natural phenomena hazards like extreme meteorological conditions (temperature, snow, drought) and lightning are credible, but do not pose significant hazards. For the ATLAS Facility at Argonne, the most significant natural phenomena hazards are posed by earthquakes and wind/tornadoes. Postulated accidents involving an earthquake or a tornado at the ATLAS Facility are addressed in Section 4.2 of this SAD

3.1.7. External Man-Made Hazards

Neither facilities nor activities conducted on or near the Argonne site are likely to cause a direct threat to safety at the ATLAS Facility. Credible accidents scenarios include: building fires, releases of hazardous or radioactive materials from ANL facilities, fires within the forest preserve, and releases of hazardous materials from barge, rail or truck transportation activities near the ANL site. Such accidents could possibly initiate a building or site evacuation, but would not otherwise impact the ATLAS Facility.

A credible, although extremely unlikely, accident involves the crash of a liquid nitrogen delivery truck into the CARIBU addition to Building 203. Such a postulated accident is addressed in Section 4.2 of this SAD.

3.2. Facility Description

This description of the ATLAS facility addresses: (1) the building where ATLAS is located; (2) the major components of ATLAS including the ion sources, the linear accelerators, the target areas and experiments, and beam diagnostics and control (see Figure 3-4); and (3) the protection systems for ATLAS.

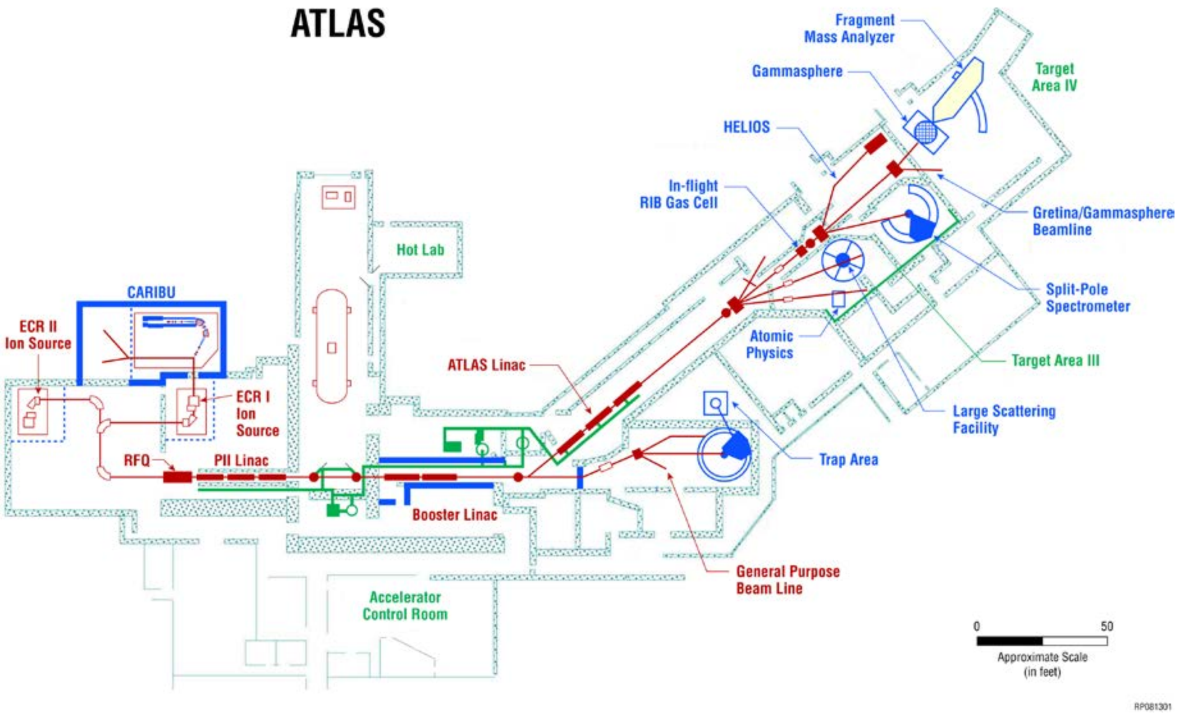

Figure 3-4. ATLAS Accelerator.

3.2.1. Building

The ATLAS facility is located in Building 203. The ATLAS portion of the building was formed by means of several independent construction projects beginning in 1961. The total area of the facility is about 48,000 square feet. The floor of the west end of the facility is at ground level and the east end is approximately 3 feet below ground level.

The construction of the building varies; some parts of the building have walls and roofs made of concrete several feet thick, other parts have thinner concrete walls and metal roofs. The main experimental halls have concrete walls at least 1.5 feet thick to a height of at least 11.5 feet. The lower portion of the outside walls of experimental areas III and IV are banked by earthen berms about 25 feet thick at the base. The upper portions of these walls are metal prefabrications with almost no shielding capability. All of the target rooms and the areas in which the main components of ATLAS are housed have overhead cranes with capacities in the range from 2 to 10 tons.

In addition to the portions of the facility shown in Figure 3-4, the ATLAS Accelerator Facility consist of the following areas that support accelerator operations:

- Rooms
    - G-042 (accelerator staff office)
    - G-049 Electronics Lab)
    - G-050 (accelerator staff office)
    - G-053 (Electronics Lab)
    - G-058 (accelerator staff office)
    - G-066 (detector storage)
    - G-090 (accelerator engineering drawing storage)
    - G-096 (accelerator spare parts)
    - G-097 (accelerator spare parts)
    - G-018 (Detector Lab)
    - G-118 (Gammasphere Lab)
    - H-166
    - H-174
    - R-154 (Target Fabrication Lab)
- Storage areas (“cages”)
    - For Accelerator Operations: Cages G1, G5, E1, E2, H2 and H8
    - For Accelerator Research: Cages E3, E4, F3, F5, F7, F7B, H5, H6 and H7

In 2007, a building addition was attached to the ATLAS area of Building 203 to contain the main components of the CARIBU Project (see Figure 3-5). The building addition is about 60 feet long, 30 feet wide and 20 feet high. The structure consists of a concrete slab on grade with a steel structure and metal panel siding. The building support systems include: electrical; smoke detection and alarm; fire suppression (sprinkler); heating, ventilating, and air conditioning (HVAC); lighting; plumbing; and an overhead crane.

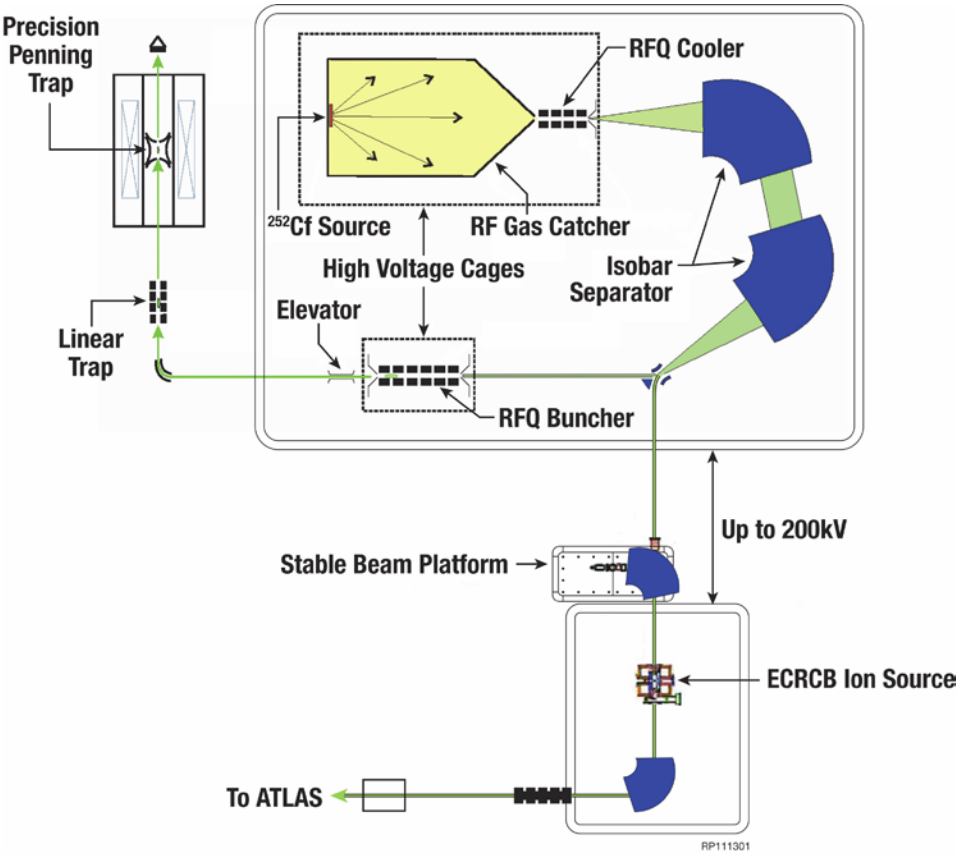

Figure 3.5. CARIBU Components.

Radiation shielding and confinement in the CARIBU addition for the radiological hazard presented by the ^{252}Cf source and its fission products are provided by the shield cask and the gas catcher. Analyses of postulated accidents showed that the consequences of such accidents are sufficiently low that the building addition does not need to be classified higher than Performance Category-1.

Because of the potential radiological hazards to facility personnel, the building addition includes the following safety features: area neutron and gamma ray detectors monitor radiation levels; the HVAC system achieves a slight negative pressure with respect to Building 203; the exhaust is monitored for radiation, HEPA filtered, and released through the thirty foot tall stack; and a local exhaust system collects volatile radionuclides released from the gas catcher and provides HEPA and charcoal filtration and a time delay before release to the stack (see Figure 3-6).

The area radiation monitors and the systems for controlling and monitoring potential airborne radioactivity in the CARIBU building are integrated into the New CARIBU Radiation Interlock System (NARIS) (see Figures 3-7 and 3-8) and are serviced by an emergency electrical power system. Requirements for the calibration and testing of those systems are specified in the ATLAS Operating Procedures.

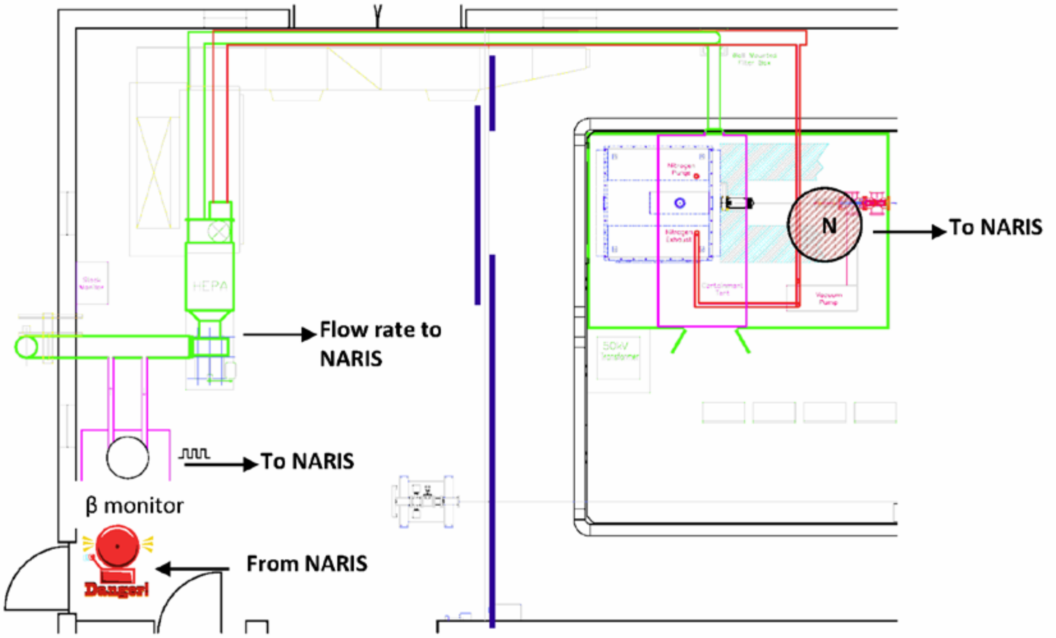

Figure 3-6. CARIBU Exhaust Stack Monitoring.

3.2.2. Major ATLAS Components

The layout of ATLAS and its major components are shown in Figure 3-4. These components are addressed in the following sections.

In the Positive Ion Injector (PII), positively charged ions are produced by either the ECR I Ion Source or the ECR II Ion Source. ECR I has been modified to function as a charge breeder accepting ions from the ^{252}Cf source positioned inside the Gas Catcher/RFQ Cooler. The positively charged ions produced by either ECRI or ECR II are accelerated in the PII Linac before they are introduced into the Booster Linac. In addition, radioactive ion beams are produced for experiments using the in-flight technique (Reference 3-3). Reactions with a heavy projectile incident on a light target are used for the efficient in-flight production of secondary radioactive beams. Depending on the radionuclide to be produced, the target can be a solid or a gas.

After acceleration through one of the injector systems, the charged ions are accelerated in the Booster Linac and then delivered to the ATLAS Linac for further acceleration (if necessary). After acceleration, a beam transport system delivers the ions to the designated experimental station. Beams delivered to Target Area II can only be provided from the Booster Linac and therefore cannot be provided at the maximum ATLAS energy.

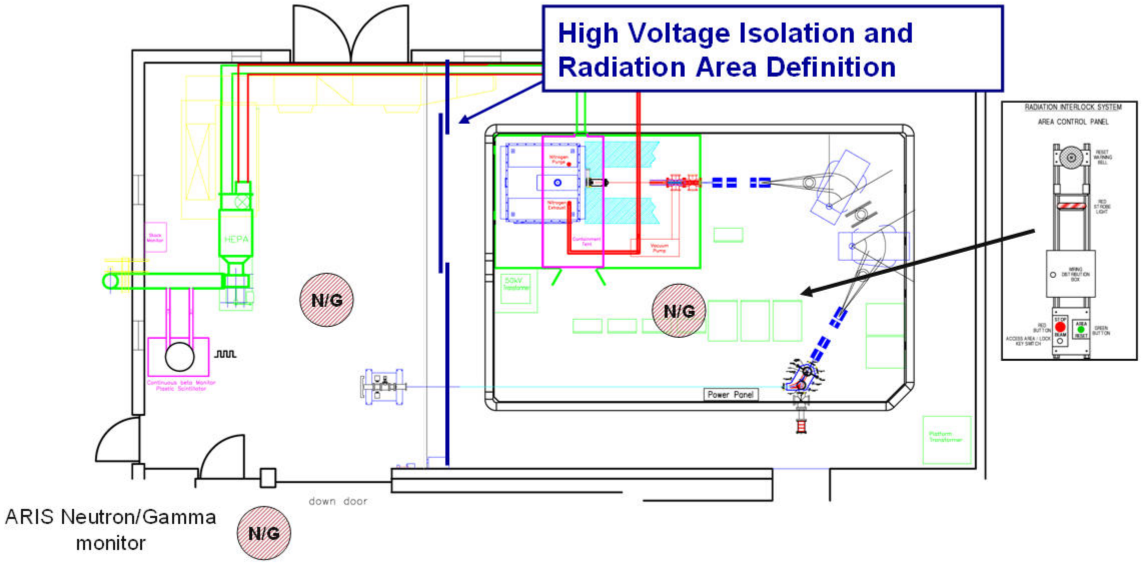

Figure 3-7. CARIBU Room Configuration for Radiation Monitoring.

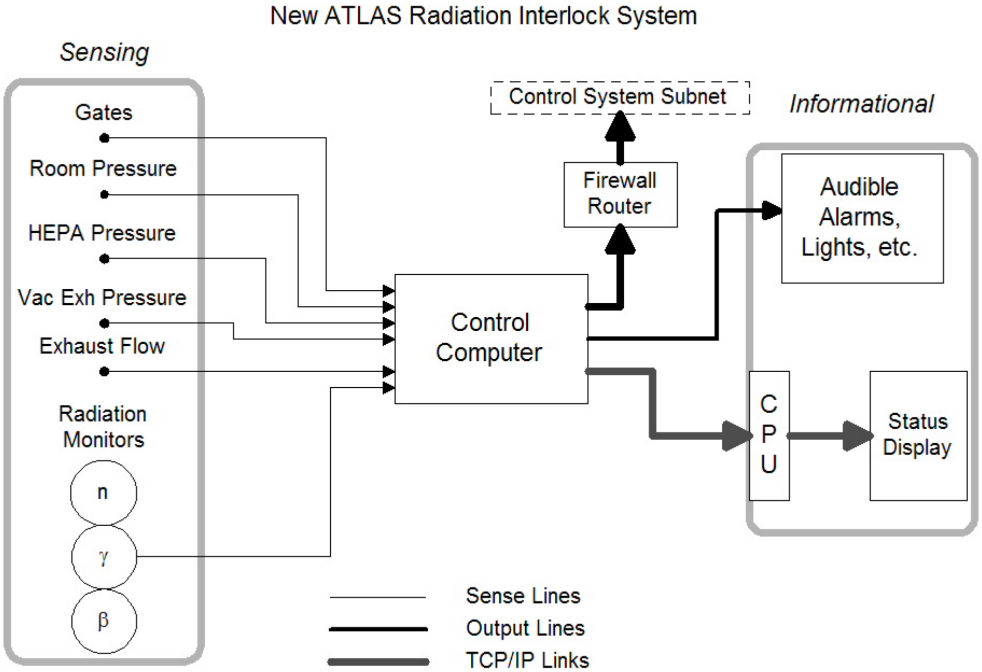

Figure 3-8. New ATLAS Radiation Interlock System: NARIS.

3.2.2.1. Cf Source

The radioactive source used in the CARIBU Facility is initially approximately 1.0 Curie of ^{252}Cf. ^{252}Cf has a half-life of 2.64 years, decaying dominantly by alpha particle emission to ^{248}Cm. ^{252} Cf also undergoes spontaneous fission with a branching ratio of about 3%. An unshielded ^{252}Cf source is an emitter of alpha particles, beta particles, gamma rays and x-rays, fission products, and neutrons. When the source is shielded, the radiations of concern are neutrons, x-rays, and gamma rays, including those resulting from the capture of the neutrons in the shielding material.

The radioactive source for CARIBU is typically referred to as nominally 1 Curie of ^{252}Cf. The actual isotopic composition of the source depends upon the material provided by ORNL and is expected to be 65% to 85% ^{252}Cf. The material currently available from ORNL consists of 68% ^{252}Cf, 17% ^{250}Cf, 8.3% ^{249} Cf, 6.4% ^{248}Cf, and 0.3% non-Cf isotopes. Only the ^{250}Cf isotope would contribute to the total radioactivity of the source. Assuming that the procured source will contain 1 Curie of ^{252}Cf, the total Californium mass and the total radioactivity of the source will depend upon the purity of the source. If the source material is 100% ^{252}Cf, then the Californium mass would be 1.85 mg and the radioactivity would be 1.00 Ci. If the source material is 85% ^{252}Cf, then the Californium mass would be 2.18 mg and the radioactivity would be 1.02 Ci. If the source material is

65% ^{252}Cf, then the Californium mass would be 2.85 mg and the radioactivity would be 1.06 Ci.

The source consists of nominally 1 Curie of ^{252}Cf electrodeposited on a 0.1 inch thick, approximately 12 cm^2 ellipse on a stainless steel or platinum plate. The deposition density is approximately ~83 mCi/cm^2. The source is covered by a thin metal foil (2 mg/cm^2) positioned about one millimeter above the source; a small hole in the foil allows the pressure of the gas trapped beneath the foil to equilibrate with the pressure in the gas catcher. An additional degrader foil supported above the metal foil tailors the energy loss of the emitted fission products. The source is mounted on a source holder that fits into the back of the gas catcher and is installed in the shielding cask for the on-site transport and mating with the gas catcher (see Figure 3-9).

The same specification of the source will be used whether the Californium is obtained from ORNL or a provider in Russia. The isotopic composition of the source material is expected to range from 65% to 85% ^{252}Cf; the actual isotopic composition of the source material depends on the material's age since removal from the reactor and will be determined when it is provided.

For the commissioning of the various CARIBU systems, other smaller Californium sources were used. These sources included a 2.2 mCi and a 72 mCi source.

> *Note: The Maximum Creditable Incident is based on the use of a 2 Ci Cf source to insure the system's safety should the actual source used be slightly more than 1 Ci. Although plans at the time of the writing of this document are to use a 1 Ci source, the use of a source up to 2 Ci has been evaluated and found to be acceptable, should this become desirable. The ^{252}Cf threshold for becoming a Hazard Category 3 nuclear facility is 3.2 Ci (Reference 3.4). Based on more recent analyses, a threshold of 6.4 Ci might be permissible (Reference 3.5).*

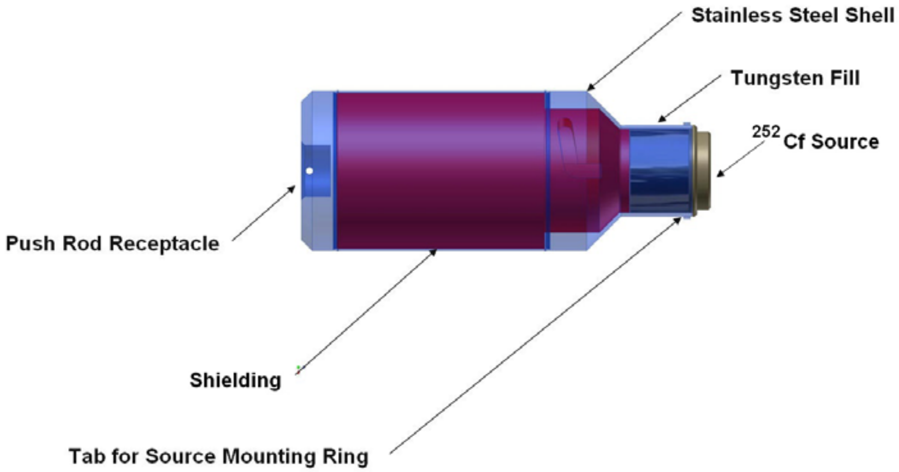

Figure 3-9. Source Holder.

3.2.2.2. Shielding Cask

The shielding cask provides the means for the on-site transport of the ^{252}Cf source, serves as part of the radiation shielding for the gas catcher, and is a secure storage location for the source when not in use or during maintenance of the Gas Catcher/RFQ Cooler and associated beamline to the isobar separator (see Figures 3-10 and 3-11). The shielding cask uses about 70 centimeters of borated polyethylene for neutron shielding with an additional 5 centimeters of tungsten for gamma/x-ray shielding, and is enclosed in a 3/8-inch stainless steel shell. The stainless steel shell is designed to have a low in-leakage rate so as to protect the polyethylene from the effects of a fire and to retain any polyethylene which may become melted during a fire. The shielding cask is designed to have a radiation intensity of less than 2 mrem/hour at 30 centimeters from its surface and weigh less than 10,000 pounds. The shielding cask provides for cask opening/closing and source movement during the installation of the source holder into the gas catcher.

The radiation shielding calculations for the shielding cask are based on 2.0 Ci of ^{252}Cf. The effectiveness of the radiation shielding will be determined by radiation surveys when the actual CARIBU source is obtained (Reference 3.6). Access to areas of the shielding cask and allowable stay times will be determined based on the radiation surveys.

3.2.2.3. Gas Catcher/RFQ Cooler

The gas catcher thermalizes the fission products emitted by the ^{252}Cf source in high purity helium gas as singly or doubly charged ions and then extracts them in less than 20 milliseconds as a cold beam into the RFQ Cooler. The gas catcher is a stainless steel cylinder having an inside diameter of about 50 cm, a length of about 50 cm, a gas pressure of about 3 psi, and a helium flow rate of about 1 liter per second.

The gas catcher is enclosed in a radiation shield designed to have a radiation intensity of less than 2 mrem/hour at 30 centimeters and mate with the shield cask which provides part of the gas catcher shielding (Reference 3.6). The radiation shielding calculations for the gas catcher are based on 2.0 Ci of ^{252}Cf. The effectiveness of the radiation shielding will be determined by radiation surveys when the actual CARIBU source is obtained. Access to areas of the gas catcher and allowable stay times will be determined based on the radiation surveys.

As shown in Figure 3-10 and 3-11, the shielding cask and the gas catcher are mounted on a high voltage platform at a height of about 26 inches above the floor.

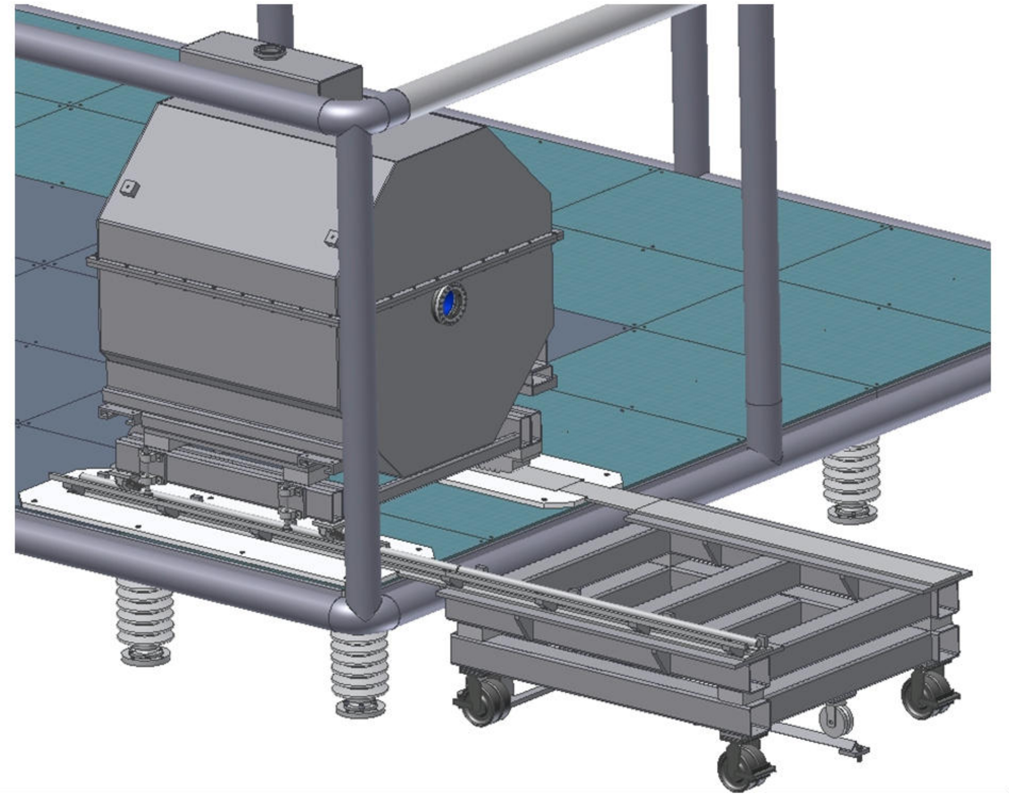

Figure 3-10. CARIBU Cask on HV Platform.

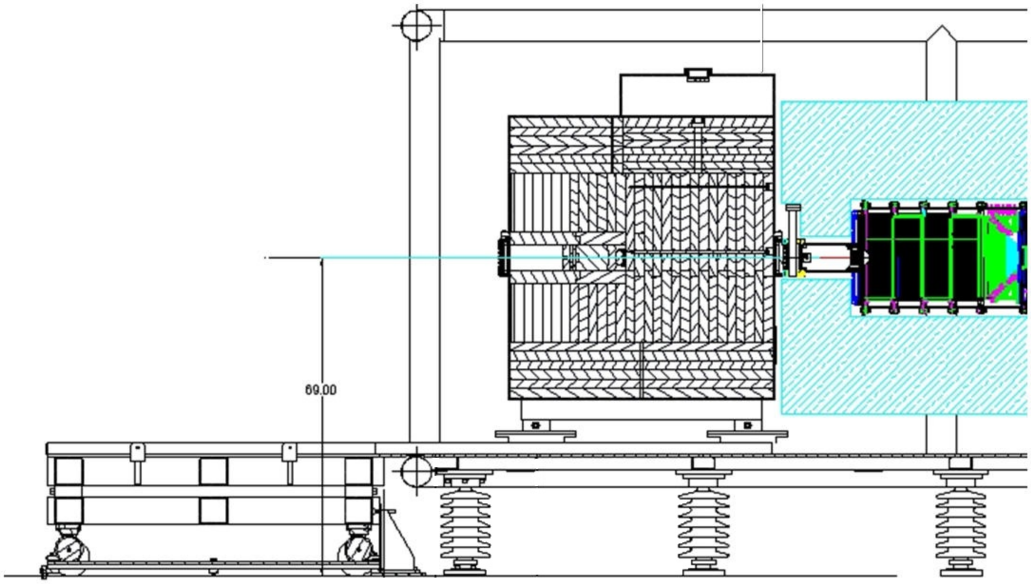

Figure 3-11. Elevation View of Shielding Cask and Gas Catcher.

3.2.2.4. Positive Ion Injectors

Positively charged ions are produced by either the ECR I or the ECR II ion source. Both electron cyclotron resonance (ECR) ion sources consist of a vacuum chamber (referred to as the plasma chamber) which is surrounded by rare earth magnets providing radial magnetic confinement. Axial magnetic confinement is provided by a set of room temperature solenoid coils which surround the plasma chamber. Radiofrequency (RF) energy is launched into the plasma chamber through multiple RF waveguides exciting a plasma within the chamber and producing energetic electrons. The electrons ionize neutral atoms within the plasma chamber thus producing highly charged ions. The ions are extracted from the source via a high voltage potential – typically 36 kV for ECR I and 14 kV for ECR II.

The ECR I ion source has been modified from a standard ECR source geometry in order to function as a charge breeder. The ion source accepts low charge state ions from the ^{252}Cf source positioned inside the Gas Catcher/RFQ Cooler and raises their charge state for efficient acceleration in the ATLAS linac. The ion source is open on the upstream side of the device allowing the low charge state ions to enter the plasma region. The peak magnetic field produced by the permanent magnet hexapole is 0.84 T on the plasma chamber wall. The solenoid coils produce axial fields of 1.4 T on the injection side and 0.8 T on the extraction side of the source. A heavy iron yoke confines the magnetic field resulting in low stray fields around the source. The ECR I plasma can be excited with multiple frequencies between 10 and 14 GHz.

ECR II has a typical ECR source geometry where an iron plug serves to enhance the magnetic field on the upstream side of the source resulting in a peak axial fields of 2.0 T and 0.94 T during normal operation. A heavy iron yoke confines the magnetic field resulting in low stray fields around the source. The ECR II plasma can be excited with multiple frequencies between 10 and 18 GHz.

Both ECR sources produce ionizing radiation and utilize high voltage electricity (a maximum of 200 kV for the ECR I high voltage platform and 300 kV for the ECR II high voltage platform) in their operation. Each ion source and its associated high voltage platform are contained within an interlocked enclosure (see Figures 3-4 and 3-12). The enclosures serve to limit access to the sources when radiation and/or hazardous electrical voltages are present. In addition to the ECR high voltage platforms, the CARIBU cask and gas catcher are installed on a separate high voltage platform capable of 200 kV operation.

Access to each of the high voltage enclosures is controlled through high-voltage interlock systems and by the ATLAS Radiation Interlock System (ARIS) (see Figure 3-12 and Reference). The high voltage interlock systems monitor the status of the enclosure access gates, overhead crane positions, magnetic door locks, and grounding arms via redundant position switches. During radioactive beam experiments, the CARIBU and ECR I ion source platforms are physically and electrically joined via the beamline vacuum pipe and biased to a common potential provided by a single high voltage power supply – referred to as ‘joint mode operation’. The high voltage interlock system monitors the switch status of the two enclosures and inhibits the high voltage power supply should an unsafe condition arise for either high voltage enclosure. During ‘stand alone’ operation, the beamline pipe is removed and a set of KIRK key interlocked doors between the two high voltage enclosures are closed thus severing all physical and electrical connections between the two high voltage platforms. With the doors closed, the KIRK key becomes part of the interlock chain and allows the ECR I high voltage platform to be biased regardless of the status of the CARIBU high voltage enclosure gate or crane switches. The CARIBU platform does not have a separate power supply and thus cannot be biased in this case.

The ARIS system utilizes the enclosure gate position switches to determine if the areas are occupied or not occupied for the purpose of dose accumulation. For dose accumulation purposes, the ECR I and ECR II areas are considered a common area and the accumulated dose of each area is summed. The CARIBU area is not part of this summed dose. Should the accumulated dose reach 10 mrem or the instantaneous dose exceed a prescribed ARIS limit, the operation of the RF transmitters is inhibited immediately eliminating the source of the ionizing radiation.

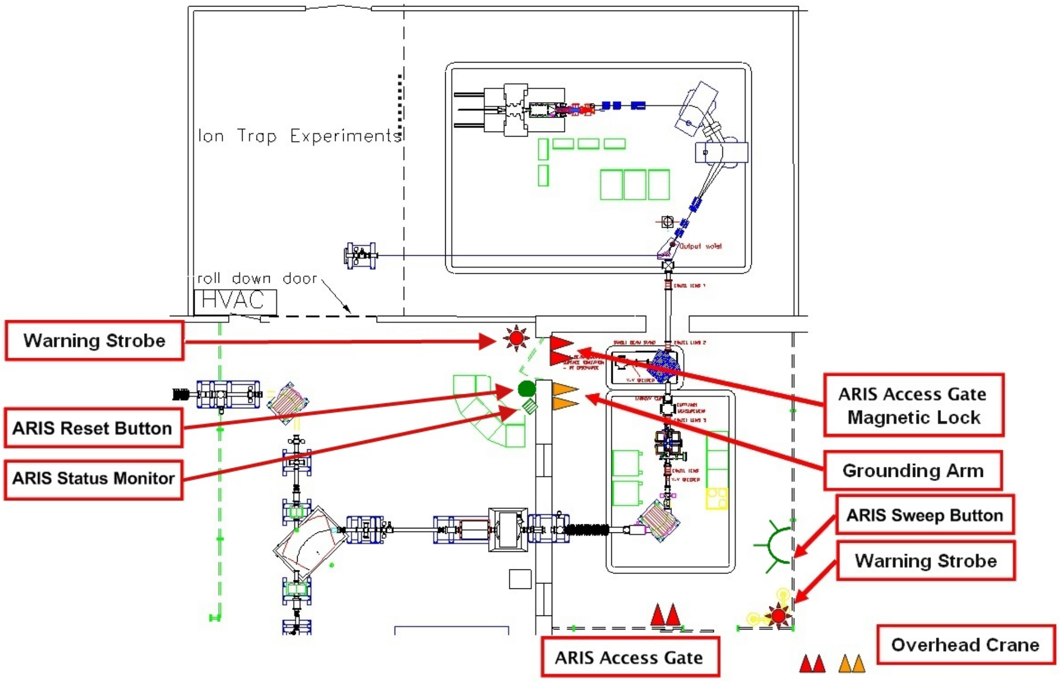

Figure 3-12. HV Platform Electrical Interlock and ARIS components. The yellow and red triangles indicate interlock switch locations with redundant interlocks at each position.

3.2.2.5. FN-Tandem Accelerator Retired

The ATLAS Booster linac upgrade includes the retirement of the tandem injector as a component of the ATLAS accelerator facility. At the present time, the tandem injection beamline and high energy beamline has been dismantled, but the tank containing the accelerator system continues to exist and includes the insulating gas for the tandem, sulfur hexafluoride (SF_6) at a pressure less than 80 psig. This gas can also be stored in liquid form at a pressure of 500 psig in a 317 ft^3 tank located in a service area above the tandem vault. The piping system used to transport the SF_6 between the tandem tank and the storage tank, as well as the tandem tank and the storage tanks themselves, all contain over-pressure devices to ensure that no explosive pressures develop within the system.
This disposition of this system will begin in 2014, but the exact time line for the removal of the tandem is not yet defined. For the present all aspects of monitoring and controlling the SF_6 insulating gas will be retained and the description of that system and the hazard mitigation described in this SAD remains current.

3.2.2.6. PII Injector RFQ and Linac

The positively charged ions produced by one of the ECR ion sources are accelerated by a Radio Frequency Quadrupole (RFQ) accelerator and a 11-MV superconducting injector linac. The RFQ is a normal conducting structure to accelerate ions from 30 keV/u to 296 keV/u. The maximum installed RF power for the RFQ is 120 kW. However, the RFQ requires only 60 kW for operation at design parameters. All this power is dissipated as heat in the cavity walls which is removed by water cooling. The maximum beam power generated by the RFQ cannot exceed 200 W. Due to the low energy of the ion beams accelerated in the RFQ, there is no beam-induced radiation due to the RFQ. Some X-rays can be produced inside the RFQ resonator due to 70-kV intervane voltage. X-ray radiation is well shielded by the thick resonator walls and additional local shielding.
The PII SC-linac is the same in general concept as the main ATLAS linac, but its components are different in design because of the low velocity of the ions involved. The installed RF power for the injector linac is ~4 kW. The maximum beam power that can be generated by the PII is, in principle, ~ 625 watts. The PII linac is cooled by the same cryogenic system as is used to cool the main ATLAS linac. The beam-induced radiation generated by PII is a minor hazard because the maximum beam energy that can be achieved is small (under 2.5 MeV/u).

3.2.2.7. Booster and ATLAS Linac

The main superconducting linac of ATLAS consists of 35 independently-phased accelerating structures (resonators). These are grouped into two main sections, the

Booster linac and the ATLAS linac and three single cavity cryostats used as bunchers. In addition, there are two individual resonators after the linac used as rebunchers to provide a time focus or minimum energy width on target. The first cryomodule in the Booster linac consists of seven resonators. These resonators are of a new design which is capable of accelerating higher beam currents. Each of the seven resonators in the new cryomodule is excited by a 4 kW RF amplifier at a frequency of 72.75 MHz. Each resonator operating at frequencies of 97 or 109 MHz is excited by a 250 watt RF amplifier. The resonators are cooled by flowing liquid helium at a pressure in the range 3-15 psig and a temperature of ~ 4.6 K. The nominal accelerating voltage provided by this linac is ~53 MV and the installed RF power is ~ 38 kW. However, other technical factors limit the steady-state beam power to ~~2.7 kW and, because of the nature of the research program, the beam power is usually less than 300 W.

The liquid helium used for cooling is generated by three commercial refrigerators, with a total cooling capacity of ~ 1000 W located in the accelerator area. In closed-cycle operation, flowing liquid helium from these refrigerators cools the superconducting linac and then returns to the refrigerators in the form of cold gas. Almost no helium is lost in normal operation. Excess warm gas is stored at a pressure less than 250 psig in a 12,000 gallon storage tank outside the facility. The helium-gas compressors for the refrigerator are located in the service area above the tandem vault.

Shielding for the Booster linac has been increased to maintain personnel safety from higher levels of radiation resulting from the upgrade (Reference 3-9). The additional number of particles accelerated by the Booster linac increases the radiation levels when beam losses occur. A new labyrinth has been added which permits beam-off personnel access while providing increased radiation protection when the beam is on (Figure 3-13). Further discussion of the shielding is found in Section 3.2.1 below.

3.2.2.8. Beam Lines and Target Areas

The beam lines in the experimental areas form "trees" that branch at switch magnets. At the end of each line is an experimental station. Each experimental area is posted as either a Radiation or a High Radiation area when the beam is present because of the possibility of radiation fields within the area at that time. Access to these areas is controlled by the ATLAS Radiation Interlock System (ARIS), an engineered safety system which is designed to allow access to areas in a way which minimizes the possibility of personal harm due to radiation (see Figure 3-14).

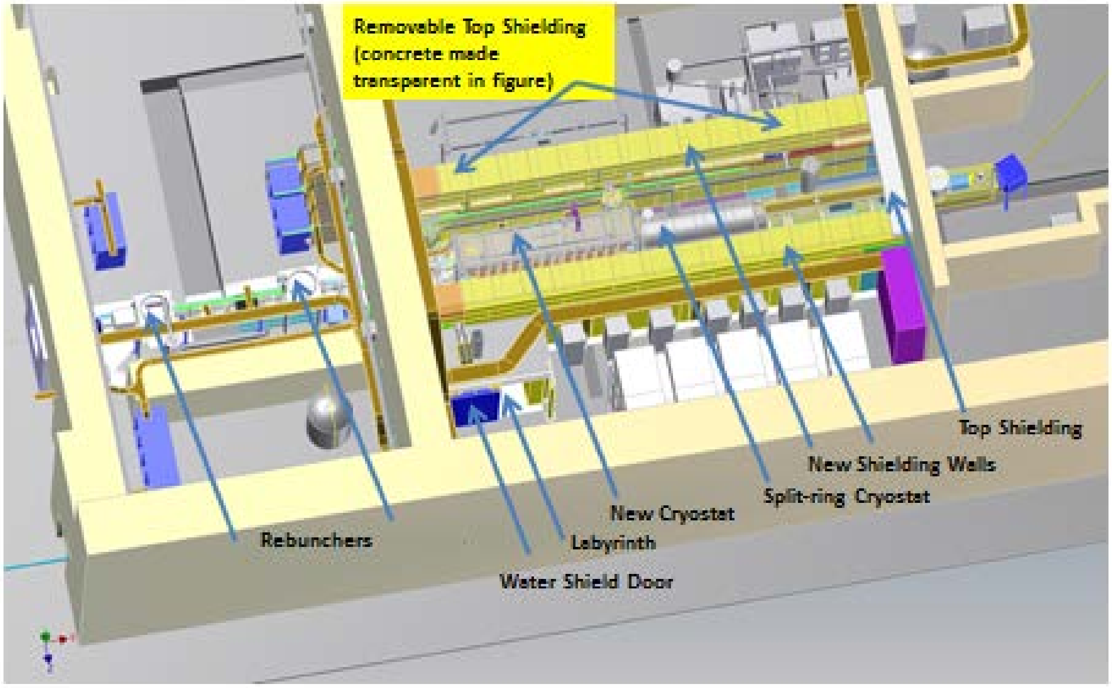

Figure 3-13. Upgraded Booster linac.

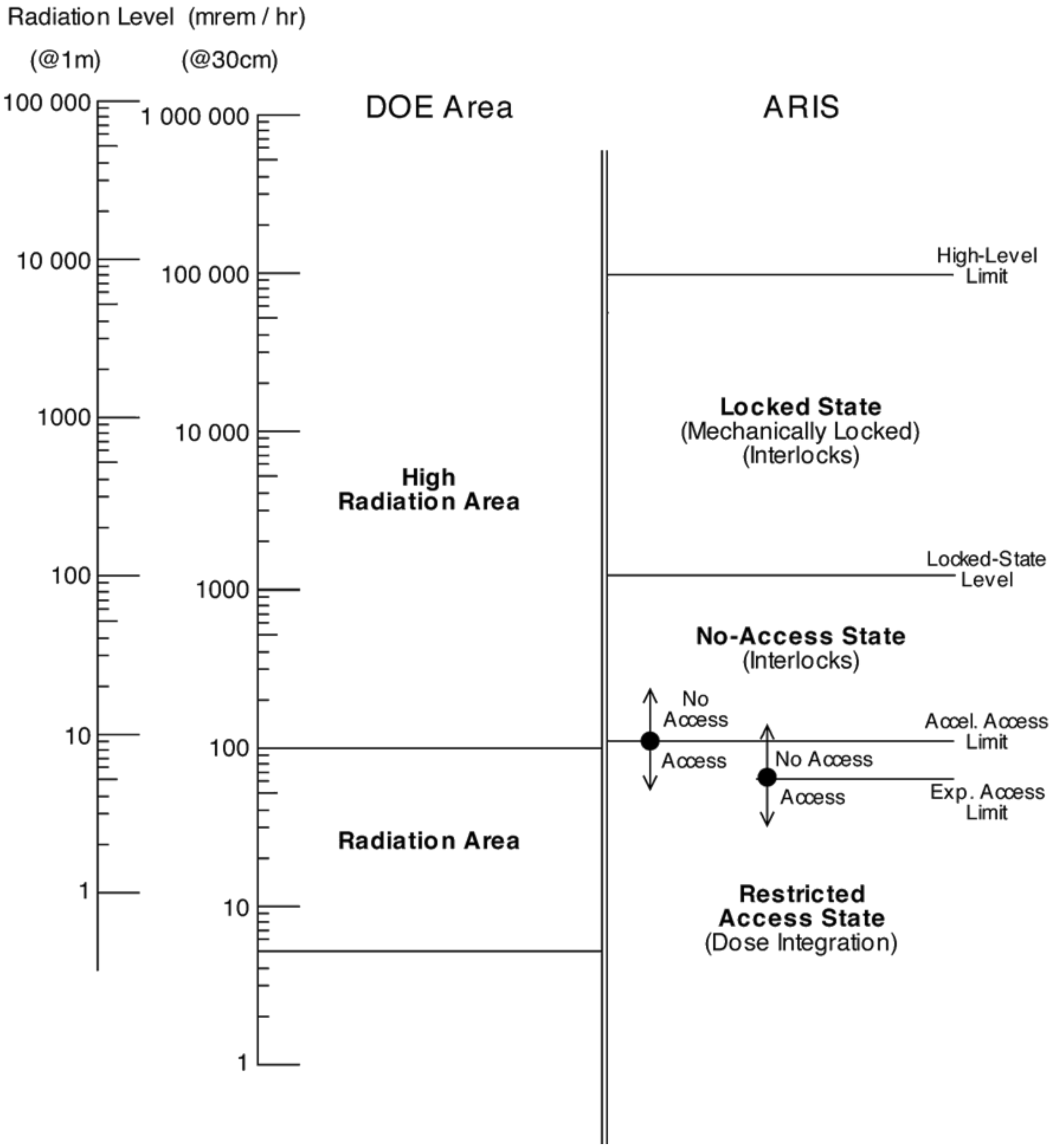

Figure 3-14. Chart Comparing DOE Radiation Area Definitions to Area Status Definitions Used in the ATLAS Radiation Interlock System.

3.2.2.9. Experimental Equipment

The equipment located at the experimental stations is described in the document entitled “Experimental Equipment at ATLAS” (Reference 3-7). This document includes a description of each piece of permanently installed experimental equipment. Every piece of experimental equipment installed in the ATLAS facility receives a thorough initial safety review as well as yearly reviews of any major changes.

3.2.2.10. ATLAS Control

Focusing, steering and bending magnets are used throughout the accelerator area to control the beam. Magnetic fields as high as 10 gauss at 2 feet from their outer surface can be produced by these magnets. The magnets operate at various voltages, up to a maximum of 500 volts.

3.2.2.11. ATLAS Performance

Figure 3-15 summarizes the maximum beam energies available from ATLAS for various ion species. Beam energy depends on many assumptions. Figure 3-15 shows two major operating modes for the facility. The first mode, identified as ‘Unstripped’, uses the charge states provided by the ion source for acceleration in the remainder of the linac. This mode provides the highest beam currents possible, but slightly lower maximum energy than possible by stripping the ions an additional time. The curve labeled ‘Stripped’ assumed that a carbon foil is used to remove additional electrons from the beam at the exit of the ‘booster’ linac section and then further accelerated in the last section (‘ATLAS’) of the linac. This provides the highest possible energy but with a reduction in beam current of a factor of 5 to 6.

Beam current that can be provided by ATLAS varies significantly by beam species. For species with $A<30$ and for most gases (Ar, Kr, Xe) beam currents as high as 10 pμA are physically possible. Both transmission losses in some portions of the accelerator and the Beam Current Monitor now limit this value somewhat. For most other beams the maximum current is around 1.0 pμA for $40<A<130$ and around 0.25 pμA for $A>130$. Other beam current limitations are discussed in subsequent paragraphs below.

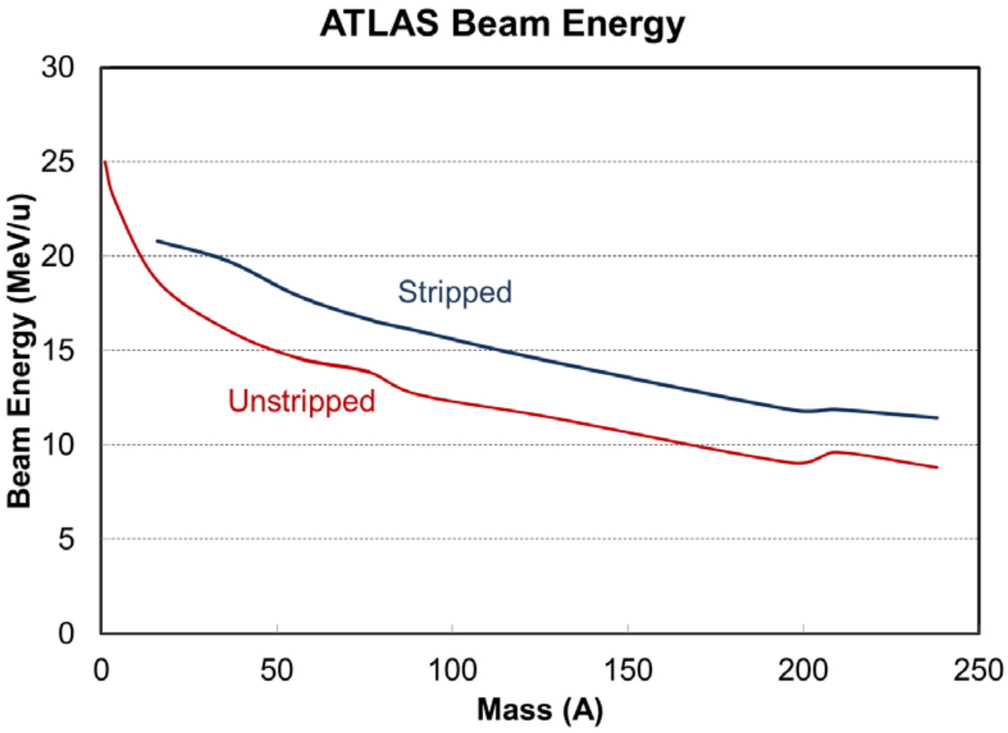

Figure 3-15. Maximum Beam Energies Feasible at ATLAS.

The highest level of radiation that can be produced at ATLAS is limited somewhat by the maximum beam power capability of the PII accelerator system. Two kinds of limits apply. For very short times (a few seconds), the upper limit is set by the RF power available to each accelerating structure. If the beam loading in any resonator exceeds the available RF power, that resonator goes out of lock; acceleration by the remainder of the linac stops, and the beam is lost. It is estimated that this kind of limit on beam power is 2.7 kW, much less than the total installed RF power because most of the power is required to maintain phase control. The short-term RF power limit implies that the maximum beam current that the main linac can accelerate is approximately 75/Q particle microamperes, where Q is the ion charge state. This limit is smaller than the currents that the ECR ion sources of PII can provide for ions with $A \leq 40$ and about the same as the source limit for some species with $40 < A < 136$. Specific cases can vary somewhat from these rules of thumb.

The second kind of beam power limit is set by the components in the beamlines (not one of which is actively cooled). During tuning the beam always strikes beamline components. During most steady state operation a large part (more than 50%) of the beam is stopped by beamline components such as slits and diaphragms used to tailor the beam to user requirements, and for most experiments the beam is stopped by a Faraday cup mounted behind the target used in the experiment. Consequently, the lack of cooling of low mass beam-line components limits steady-state operation to beam power less than

~ 300 W, which implies a maximum beam current of 50/A particle microamperes for the typical ATLAS experiment. This limit on beam current is smaller than the capability of the ECR ion sources for a large variety of ions.

Overall, the limits on beam power are not expected to mitigate radiation incidents that occur on very short time scales, but would limit the maximum radiation flux that could be induced.

3.2.3. Protection Systems

3.2.3.1. Radiation Shielding

The shielding at ATLAS has been designed, in combination with other systems, to limit the dose rate to acceptable levels at accessible locations from all radiation sources associated with normal operation of the facilities.

For the accelerator portion of ATLAS, the primary radiation concern is neutrons generated by beam interaction with targets. A secondary concern is with x-rays generated in the ECR ion sources and the ATLAS resonators. Details of the calculations and considerations involved in the shielding of the various areas within the ATLAS facility are given in Reference 3-8.

For the CARIBU portion of ATLAS, the primary radiation concerns are neutrons emitted by the ^{252}Cf source, gamma radiation from the spontaneous fission products, and gamma radiation produced by neutron interaction with shielding materials. The shielding calculations for the CARIBU project are provided in Reference 3-6.

For the Booster linac portion of ATLAS, the primary concern is the production of secondary particles from interactions of the accelerated beam with accelerator components. The shielding design considers both the radiation from these beam losses and the bremsstrahlung radiation from the resonators. Details of the calculations and considerations involved in the shielding of the Booster linac and surrounding areas within the ATLAS facility are given in Reference 3-9. Two scenarios were considered: A point loss of 1% of the beam and and a loss depositing one watt per meter over any section of the beam line downstream from the first Booster linac cryomodule. The 1% beam loss resulted in higher radiation levels outside of the shielding. Based on the calculations, the increase of beam in the Booster linac has necessitated additional concrete shielding surrounding the Booster linac.

- The design objective for controlling personnel exposure from external sources of radiation in areas of continuous occupational occupancy (2000 hours per year) was to maintain exposure levels below an average of 0.5 millirem (mrem) per hour and as far below this average as is reasonably achievable. The design objectives for exposure rates for potential exposure to a radiological worker where occupancy differs from the above was ALARA and could not exceed 20 percent of the applicable standards (Section 1002 of Reference 1-2). Exposure rates just outside of the Booster linac in an area where occupancy is limited was calculated to be <1 mrem/hour, based on a 1% beam loss at the end of the first cryomodule for a ^{16}O beam incident on a ^{56}Fe target (Reference 3.6). Shielding has been added to achieve this radiation level. Ordinary concrete shielding 3' thick on the sides of the Booster linac and 2' thick on top now enclose the Booster linac (see Figure 3-15). The ATLAS Control Room is the nearest continuously occupied area (see Figure 3-4). The exposure level in the Control Room is calculated to be <0.5 mrem/hour based on the additional shielding and the following beam parameters: (Design source term is for a continuous point loss that goes uncorrected)

- 10 pμA $^{16}O^{6+}$ (135 MeV) accelerated through cryostat A
- 1% of beam (100 pnA) is lost at high-energy end of cryostat
- beam is incident on ^{56}Fe

The shielding was designed conservatively (without averaging) to facilitate future increases in the ASE. During startup following the Booster linac upgrade, beam tests will be conducted before installation of the upper portion of the shielding, including roof shielding blocks. At least ten vertical feet of shielding (vertical block plus first horizontal block on top of it) will be in place before the tests begin. To ensure that doses are kept ALARA, the ARIS interlock system for that area will be operational and the beam current monitor will be set to limit beam current. Interlocked detectors are mounted on the walls outside the Booster linac at heights greater than that of the roof shielding blocks. Alarm levels will be set to keep doses ALARA and additional administrative controls will be introduced and approved by the Physics Division Radiation Safety Committee, as necessary.

The Physics Division Shielding Control Policy is provided in Reference 3-10.

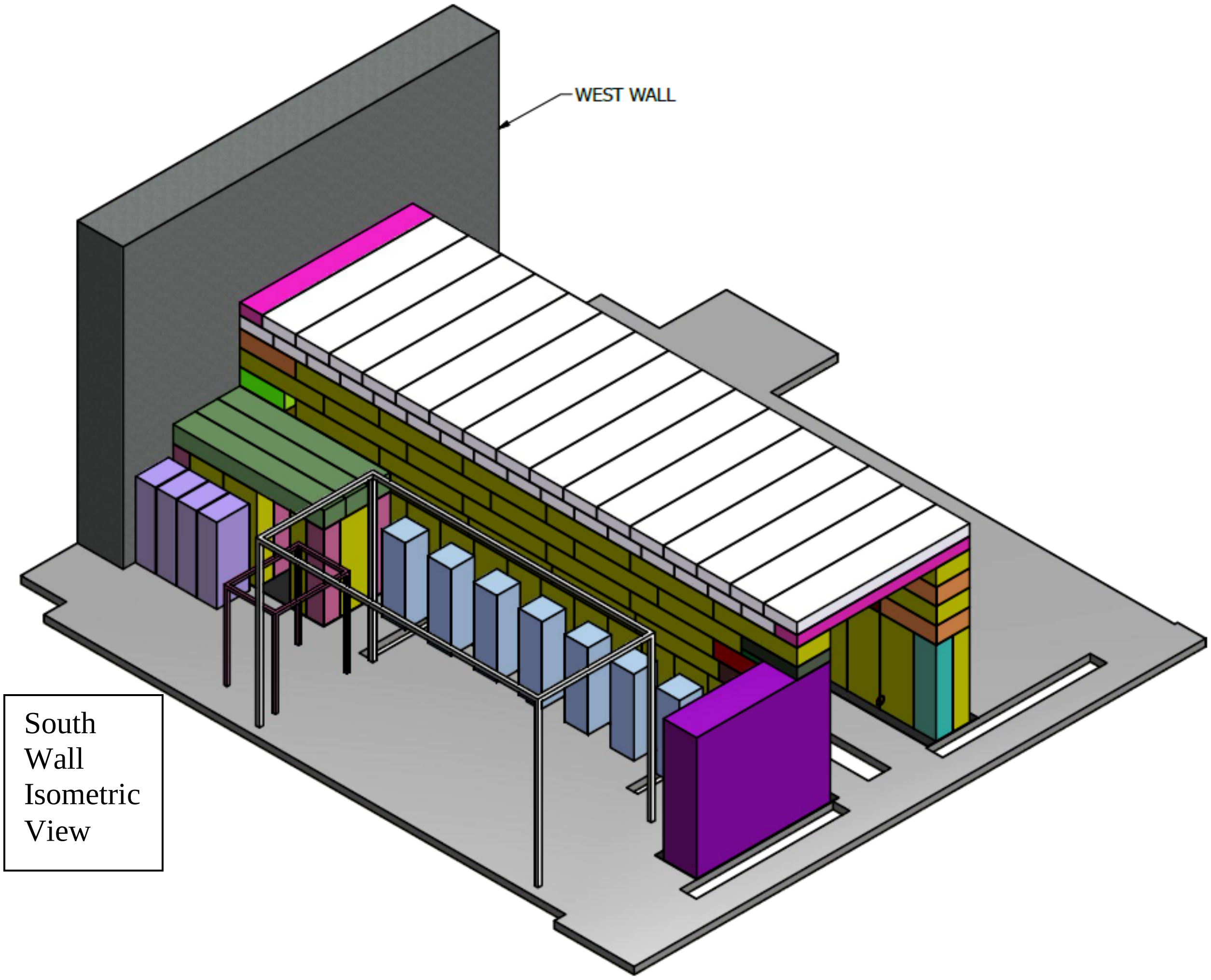

Figure 3-16. Booster linac shielding modification. See also Figure 3-13 for a different perspective.

3.2.3.2. ATLAS Radiation Interlock System

The ATLAS Radiation Interlock System (ARIS) is designed to: limit exposure to radiation, prevent access to locked areas, shut down the accelerator in the event of security breaks to locked accelerator beam-line areas, and stop the beam in the event of radiation levels above acceptable levels (see Figure 3-17). A description of ARIS is given in References 3-11 and 3-12.

Because of the usually low radiation levels and the nature of the experimental equipment at ATLAS, it is highly desirable to permit users to enter areas where an ion beam is present under controlled conditions. ARIS permits such access when the radiation levels are sufficiently low and other conditions are satisfied.

ARIS is controlled by a pair of programmed computers, one of which is specifically designed for the control of complex industrial processes. Because the integrity of ARIS depends on the programming of the computer control system and the proper functioning of the associated hardware, tests are performed at least annually to confirm that ARIS is functioning correctly. These tests simulate every potential fault that the program monitors to ensure that ARIS responds with the appropriate actions. From time to time, the computer code is modified. A complete test of the entire system is conducted before ATLAS is allowed to run with the new ARIS code. The computers containing the ARIS control system are physically separated from any network. Thus it is impossible to access the ARIS code from any location other than those computers.

ARIS includes a radiation monitoring system and an access and beam control system which communicates with the radiation monitoring system to determine access and permission status.

3.2.3.2.1. Radiation Monitoring

The radiation produced by ATLAS can be from X-rays generated in the ECR source or in superconducting resonators, and from the accelerated beams hitting components along the beam path (Reference 3-13).

ARIS includes low-level radiation monitors near work areas and high-level radiation monitors along the entire beam path. Both photon and neutron radiation detectors are used and the locations of these detectors have been selected to provide reliable measurements of both the low radiation levels encountered in normal operation of the facility and the high levels that could be generated accidentally by the accelerator. The raw data from all detectors are in the form of individual counts. Calibration data for each detector allows the count rate to be translated into radiation levels at the detector. These levels are scaled by an individual r^2 factor in order to estimate the highest possible radiation level in the monitored area. This instantaneous radiation level is displayed on monitors and is used to calculate the integral of the dose rate during the preceding 8-hour period.

3.2.3.2.2. Access Control

The areas where beam-induced radiation needs to be controlled at ATLAS are divided into a number of interlocked and monitored areas, as shown in Figure 3-16. These areas are separately shielded, and each area in which beam is present must be monitored by ARIS and satisfy other requirements. Access to all beam areas is controlled by the radiation interlock system which not only measures and assesses radiation levels, but also serves to define the areas that the beam can enter and monitor and limit the physical access of personnel into these beam areas.

Access gates and doors which limit personnel access to beam areas are part of the interlock system. Only one gate for an active beam area is defined as the "Access Gate"; all other gates for that area are locked and interlocked.

The access gate of every ARIS interlockable area (whether an active beam area or not) has a display mounted near the gate showing the current status of that area, radiation levels, and integrated dose, as determined by ARIS.

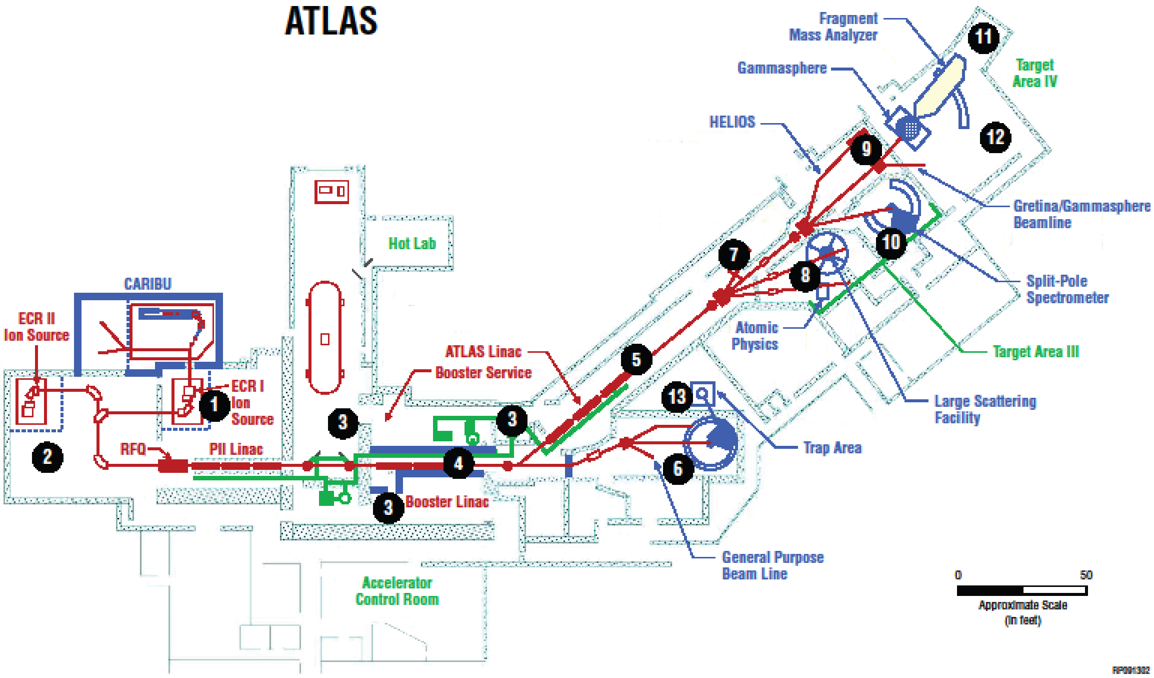

Figure 3-17. Radiation Interlocks for areas defined by the ARIS System. The CARIBU area is monitored separately by the NARIS system, discussed previously and in Section 3.2.3.3 below.

When access has been granted to an ARIS interlockable area in which a beam may be present, it is in either a Restricted Access - Occupied or Restricted Access – Not Occupied state. To change from an OCCUPIED to a NOT OCCUPIED state requires that a sweep of the area be performed to insure no personnel remain in it. The route of the sweeps in the various areas are determined by the location of one or more buttons that must be pushed before ARIS will allow the area's status to be changed and are described by an ATLAS Operating Procedure. The final button in all areas is on the "outside" of the Access Gate. The gate must be closed before this button is pushed for ARIS to change the area's status from OCCUPIED to NOT OCCUPIED.

3.2.3.2.3. Beam Control

Beam valves, just downstream of each switching magnet, which determine the beam path are part of the interlock system. The interlock system requires that the beam valves be open along only one beam path. When the beam valve to an area is opened, this area is treated as an active beam area, with respect to radiation safety, whether or not a beam is actually present.

The interlock system will inhibit the beam by inserting a Faraday cup into the beam line upstream of the accessed area if any gate other than the ‘Access Gate’ to an active beam area is opened.

3.2.3.2.4. ARIS Control System

ARIS is a computer-based interlock control system that processes all information from beam valves, access gates, and radiation detectors and, from these data, determines whether or not to grant passage of the beam into any potential beam area.

By processing individual counts from the detectors, the ARIS control computer checks continuously that each detector is working, measures radiation levels over the full range involved at ATLAS and, for each beam area, determines the radiation dose that has been accumulated by a pair of gamma ray and neutron detectors while a monitored beam area is occupied during a running 8-hour interval.

ARIS recognizes four action levels and inhibits the beam if any of these radiation levels are exceeded under specified conditions:

- "high level limit", above which the beam is always inhibited,
- "locked state level", above which access is not allowed, and the gates to the monitored area must be mechanically locked and interlocked,
- "access level limit", above which the beam is inhibited if an interlocked access gate is opened,
- "integrated dose limit", the maximum integrated dose permitted during any 8 hour period while the interlocked access gate has been opened and not reset.

The relationships of the above action levels to the radiation level categories defined by the DOE are shown schematically in Figure 3-14.

When the measured radiation in a monitored beam area is in the range between the "access level" and the "locked state level", the area is defined as being in the "no access" state. In this state, if an interlocked access gate is opened without the beam being stopped manually, the beam will immediately be inhibited by the interlock control system. An inhibit action of this kind inserts a beam stop that can be reset only with the accelerator operator's involvement.

The numerical values for the trip levels defined above are given in an ATLAS Operating Procedure. These values may be modified after an appropriate safety review, if operating experience shows that the present choice of values becomes no longer appropriate.

3.2.3.2.5. ARIS Operation

The following paragraphs summarize the main features of ARIS operation.

The set of interlocked beam valves defines a single beam path based on the information given in the "Authorization to Operate" document. When the interlocked beam valve for any beam area is opened, ARIS inserts a low energy beam stop and prevents it from being removed until the accelerator operator inspects the area to determine that no one is present, sets its access gate interlock to a “Locked” state, and mechanically locks the gate with a controlled key. The interlock control prevents the beam stop from being removed until the key has been returned by the operator to its normal captured location in the control room. The ARIS Operating Procedure specifies that the operator may unlock the gate only after it has been determined that:

- the required radiation monitors are connected and functioning (as indicated by ARIS),
- the Estimated Radiation Level for that measurement is lower than the "locked state level", and
- the beam has been initially tuned into the area.

If ARIS does not sense that the requirements of a unique beam path and functioning radiation monitors are satisfied, or if any measured radiation level exceeds its prescribed trip level, then ARIS will inhibit the beam by inserting a low energy beam stop. A beam area becomes a "monitored access area" when its ARIS-monitored beam valve is open and the associated radiation monitors are functioning.

During Standard Operations, the accelerator operator is required to mechanically lock and interlock all active beam areas beyond the booster linac if the Estimated Radiation Level value for the beam is above the "locked state level" of 100 mrem/h at one meter. Under this locked state, ARIS will cause a "trip" condition and inhibit the beam if:

- any beam valve that is inconsistent with the approved beam path is opened,
- any required radiation monitor fails to function,

- the radiation level read by any monitor exceeds the high level limits of 5 rem/h for the Tandem, 40^0 Bend, and Booster; 10 rem/h for the ATLAS Linac Tunnel; or 5 rem/h for Experimental Areas,
- the interlock control system fails,
- any interlocked gate to an active beam area is opened, or
- the “Emergency Stop” button in any beam area is pushed.

During Standard Operations, when the Estimated Radiation Level is less than the "locked state level", the access gate leading into a monitored beam area is monitored by ARIS, but does not need to be mechanically locked, except for the experimental area which must be placed in a “Locked” state until the initial beam tune to target is complete. Thus, a monitored beam area may be occupied under specified conditions. During such low radiation operation, ARIS will inhibit the beam if any of the incidents listed above occur or if:

- any access gate is opened when the measured radiation level is greater than the specified "access limit" dose rate at one meter of 9 mrem/h for the ECR Deck, Tandem, 40° Bend, Booster and ATLAS Linac Tunnel; or 5 mrem/h for Experimental Areas, or
- the integral of the dose rate measured in any occupied area exceeds the "integrated dose limit" of 10 mrem at one meter during the preceding 8-hour period.

The operator must reset the interlock, and the administrative and software procedures require that the operator lock the access gate before the beam can be re-injected into that area. Depending on the cause of the “Trip”, approval to restart may be administratively required; these conditions are specified in the ATLAS Operating Procedures.

During operations involving a beam of mass less than 12 or one with otherwise high Estimated Radiation Level, all beam areas are locked and the conditions specified above are applicable except for the limit imposed on a high-level trip. The "high-level trip" may be changed from the present value only after a special ad hoc committee review and with the approval of the Division Director.

3.2.3.3. New ATLAS Radiation Interlock System

The New CARIBU Radiation Interlock System (NARIS) is implemented to provide protective services to the CARIBU area of ATLAS (see Figures 3-7 and 3-8).

NARIS uses the Vsystem software environment which provides a stable software environment; standard hardware, scalable for later growth; and creates a shared environment with Vsystem-based ATLAS control system.

NARIS has neutron and gamma detectors for area monitoring and a beta particle exhaust stack monitor. In addition, the exhaust flow and room pressure differential are monitored. NARIS will alarm locally and in the ATLAS control room when radiation levels exceed 2 mrem/h on the floor or 9 mrem/h on the high-voltage platform, or when an 8-hour integrated dose reaches 10 mrem. These alarm values may be revised in the future by a process identical to that used to determine all other ARIS access and operating limits.

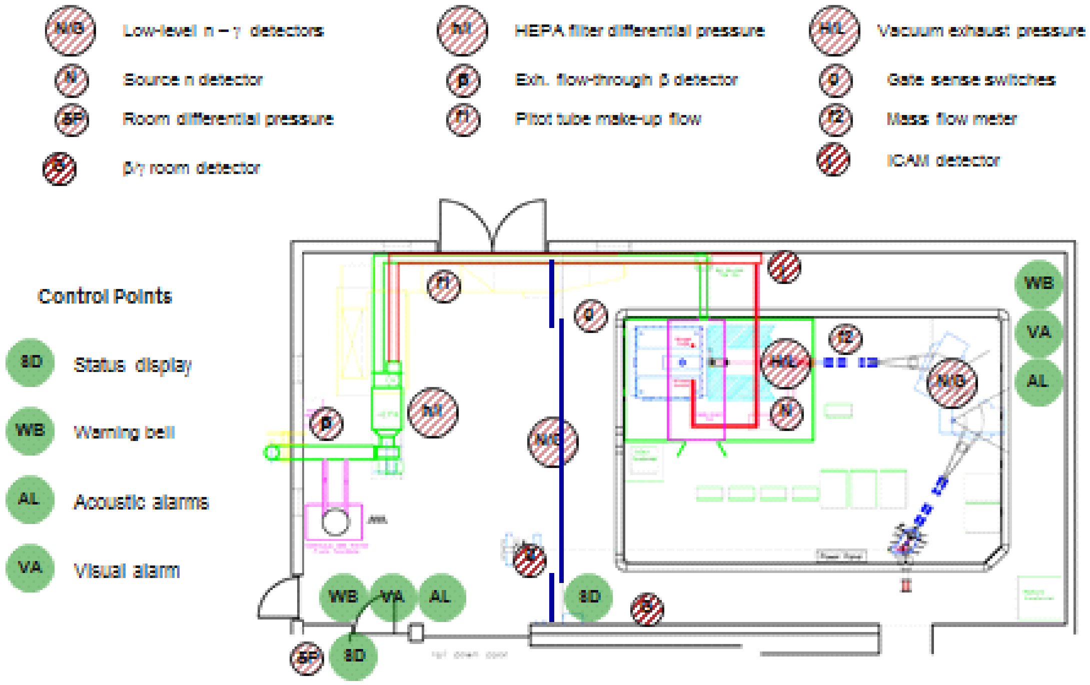

Figure 3-18. NARIS Monitoring / Control Points.

3.2.3.4. Beam Current Interlock System

The function of the beam current interlock system is to provide protection against hazards that can be generated by intense high energy beams of light ions (particularly beams with atomic number A <23) from an ECR source. This system is based on a self checking (fail-safe), redundant pair of RF pickup probes mounted on the beamline entering the booster linac. At this location, the beam current injected into the booster is sensed independently of whether PII or the tandem is the source of ions. The hard-wired interlock system associated with the beam current detectors independently controls the state of three different beam-stopping devices:

- the platform high-voltage power supply of the ion source in use (the power supply is deenergized when a fault is sensed),
- magnetic beam deflectors located just downstream of the sources, and

- one of two Faraday cups, located either at the entrance to PII or the entrance to the Tandem accelerator is inserted in the beam path.

If either beam current monitor detects a current in excess of its trip point the beam is shut off in less than 20 ms and an alarm is sounded. The beam current monitors are always set at a level to ensure that the radiation limits specified in the Accelerator Safety Envelope and the Operations Envelopes (see Section 5) are satisfied and the approved maximum beam current will not be exceeded.

3.2.3.5. Fire Detection and Fire Suppression Systems

Fire detection and fire suppression systems are installed throughout the ATLAS facility, including the CARIBU addition. The fire detection system alarms both locally and at the Argonne Fire Department.

Automatic wet-pipe fire sprinklers are installed throughout the facility. Portable fire extinguishers are placed at key locations throughout the facility.

Fire alarm bells with strobe lights are installed throughout the facility and manual pull stations are located at all the exits.

A gaseous fire suppression system is located in a modular electronics room in one experimental area. The system is used to protect data gathering electronic equipment associated with Gammasphere. Its design is such that its operation would not cause an oxygen deficiency condition to exist in the room.

The system controls are tested annually by an outside inspection contractor; the contractor also performs a visual inspection of all controlled devices in this system twice a year. Twice a year, a separate contractor performs a visual inspection of the container holding the extinguishing agent, associated manifolds and piping and verifies that the proper amount of extinguishing agent is in the container.

3.2.3.6. Oxygen Deficiency Hazard Alarm System

An oxygen deficiency hazard (ODH) alarm system provides coverage of the Tandem vault area and the rooms above the Tandem Vault, the Booster-linac room, and the experimental areas. The system provides protection against the asphyxiation hazards presented by SF_{6}, liquid nitrogen and helium. Oxygen deficiency sensing heads are positioned immediately above the K Dewar, in a trench beneath the Tandem Tank, in Room L001 near the floor , under the SF storage tank in the Mezzanine, in room L123A near the floor, near the ceiling in the PII area and above the helium compressors in Room L123A and inside the Booster tunnel. These sensing heads were positioned to provide protection against the asphyxiation hazards presented by SF_6 and/or liquid nitrogen and helium.

If the system were to detect a low oxygen level:

- alarms would sound and warning lights would flash throughout the ATLAS facility, including the control room, alerting personnel to leave the ATLAS facility immediately;
- the Argonne Fire Department would automatically be notified; and
- a normally closed valve on the liquid nitrogen storage tank would automatically close

Once the SF_6 gas has been removed from the tandem tank, the ODH sensors in the tandem trench will be disabled or removed.

3.3. Operations Description

3.3.1. Organization

The line management structure, extending from the Laboratory Director down through the ATLAS facility organization, is shown in Figure 3-19.

The responsibilities of line management positions for health, safety, and environmental protection are specified in LMS-PROC-80, Roles, Responsibilities, Accountabilities, and Authorities (R2A2s)" and in LMS-PROC188, Accelerator Safety. For the purposes of this SAD, attention will be given to the specific responsibilities those line management positions have with respect to the ATLAS facility.

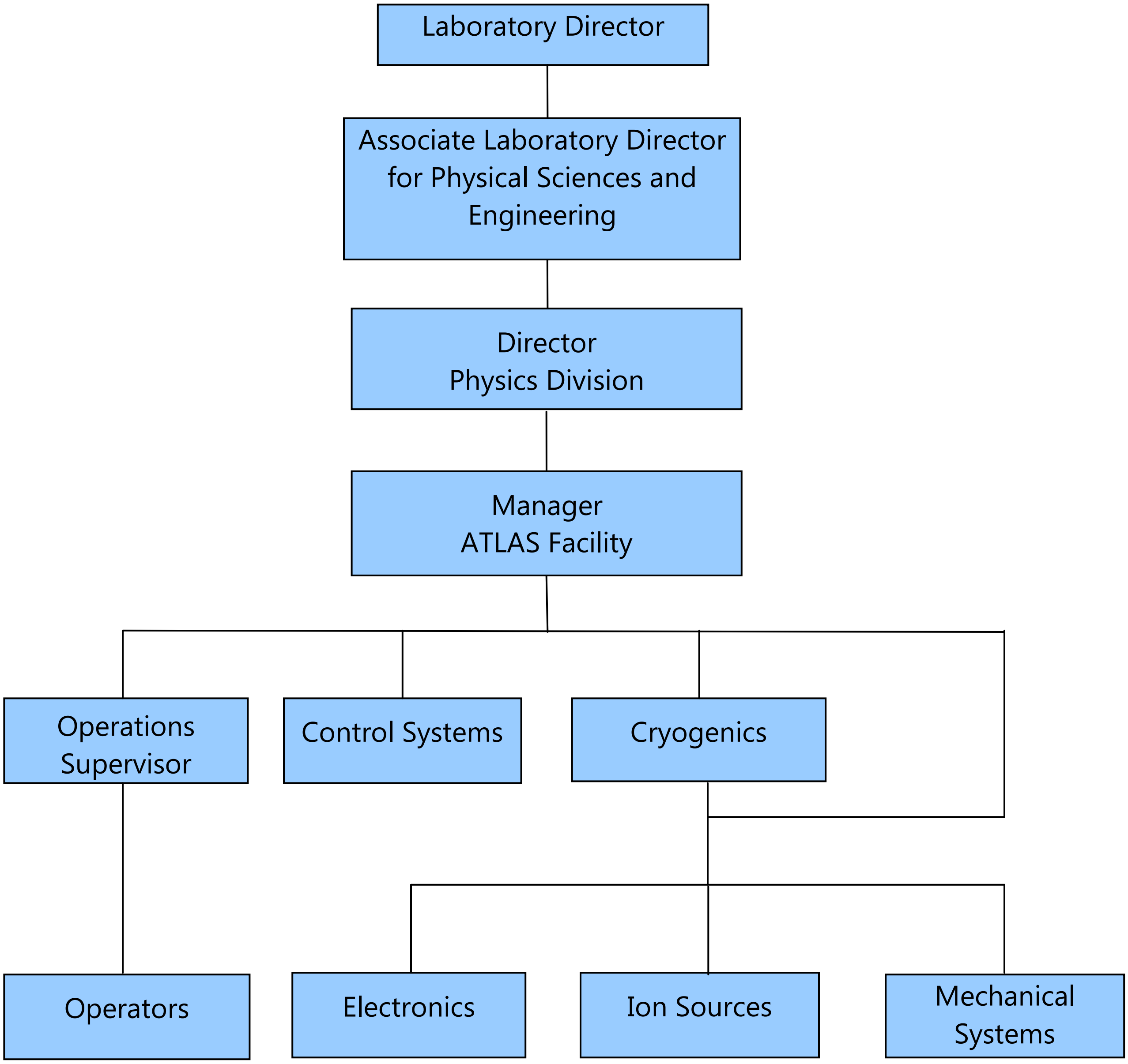

Figure 3-19. Line Management Structure for the ATLAS Facility.

The Laboratory Director is responsible for establishing the overall policy for health, safety, and environmental protection at the Laboratory and for assuring that the mechanisms are in place to implement that policy. With respect to the ATLAS facility, the Laboratory Director is responsible for reviewing and approving ATLAS documents which required DOE review and approval, such as the Accelerator Safety Envelope.

The Associate Laboratory Director for Physical Sciences and Engineering is responsible for the implementation of the Laboratory's health, safety, and environmental protection program in the organizations in the Physical Science directorate, including the Physics Division. With respect to the ATLAS facility, the Associate Laboratory Director is responsible for assuring that ATLAS facility operations meet the requirements of the Accelerator Safety Procedures Manual.

The Director of the Physics Division has line management responsibility for the oversight of all programs and facilities within the Physics Division, including the ATLAS facility. The Physics Division Director is responsible for appointing the Director and the Operations Manager for the ATLAS facility, and for appointing members to the various standing and ad-hoc ATLAS safety committees. The Division Director is responsible for approving changes to the ATLAS facility which involve substantial changes to the facility or major new equipment for the facility. The Division Director is also responsible for approving the performance of proposed experiments that fall outside the standard operations of ATLAS, including experiments involving low mass beams, high estimated radiation levels, and new hazards. The Division Director is responsible for approving key ATLAS documents such as Operational Readiness Review documents and revisions to the Safety Assessment Document and the Accelerator Safety Envelope.

The Director of the ATLAS Facility has primary responsibility for all aspects of the ATLAS facility including technical, administrative, and budgetary. He is responsible for assuring that the ATLAS facility is in compliance with the applicable DOE and Laboratory policies and procedures.

The ATLAS Operations Manager is responsible for planning, organizing, and supervising the technical and administrative staff and the activities involved in the operation of ATLAS. The Operations Manager is responsible for implementing applicable DOE and ANL policies and procedures to assure the health and safety of the facility workers and the public, and to protect the environment. These responsibilities include the review and approval of changes and modifications to the ATLAS facility, and proposed experiments.

The ATLAS Operations Supervisor is responsible for the selection, training, and supervision the ATLAS facility operators. The Operations Supervisor is responsible for the configuration of the accelerator and delivery of beams to the scheduled experiments within the rules of operation described in the ATLAS Operations Procedures, the current ATLAS SAD, and other facility requirements. This includes proper configuration of the facility, ascertaining that all required safety systems are in place and functioning and all necessary reviews have been completed prior to delivery of beam to the scheduled experiment. This is usually accomplished by ascertaining that the "Authorization to Operate' form is completed, reviewed and approved by the experiment spokesperson, Division ESH/QA engineer, and the Operations Supervisor.

The Group Leader of a systems group (Control Systems, Cryogenics, Ion Sources, Mechanical Systems, and Electronics) is responsible for the development, operation, and maintenance of the system.

3.3.1.1. Divisional Safety Support

3.3.1.1.1. ESH/QA Engineer

The Physics Division ESH/QA Engineer is responsible for advising management and staff concerning health, safety, and environmental protection and quality assurance aspects of their activities, for coordinating these activities within the Division, and for monitoring compliance with DOE and ANL requirements. The ESH/QA Engineer reports directly to the Physics Division Director.

Within the Physics Division, the ESH/QA Engineer is assigned the following roles and responsibilities: Environment, Safety, and Health Coordinator, Quality Assurance Representative, Environmental Compliance Representative, Chemical Hygiene Officer, ALARA Coordinator, and Building 203 Area Emergency Supervisor. The duties and responsibilities of those positions are specified in LMS-PROC-80, Roles, Responsibilities, Accountabilities, and Authorities (R2A2s)

With respect to the ATLAS facility, the ESH/QA Engineer is responsible for providing safety support to facility activities and operations, including the review and approval of changes and modifications to the ATLAS facility, and proposed experiments.

3.3.1.1.2. Safety Committees

The Physics Division maintains five standing committees: the Safety Coordinating Committee, the General Safety Committee, the Electrical Safety Committee, the Cryogenic Safety Committee, and the Radiation Safety Committee.

The Safety Coordinating Committee is composed of the chairs of the other four committees along with the Division’s ESH/QA Engineer, the Building 203 Building Manager, and the ESH/QA Coordinator for the Physical Sciences and Engineering Directorate. The Committee serves as a coordinating and communication mechanism for the activities of the other four committees. The Safety Coordinating Committee meets as needed, typically yearly.

The General Safety Committee performs safety reviews of Division activities and conducts walk-through inspections of the Division’s areas. The Committee meets to conduct safety reviews on an as-needed basis, typically bimonthly. The Committee conducts a walk-through inspection of about one-sixth of the Division’s areas on a bimonthly basis, assuring the all of the Division’s areas are inspected annually.

The Electrical Safety Committee, the Cryogenic Safety Committee, and the Radiation Safety Committee perform safety reviews, within their areas of expertise, of all major pieces of equipment before they are first used. The Committees may also review proposed experiments at the ATLAS facility. The Committees also provide a mechanism for addressing changes and improvements which are needed in the Division's activities, equipment, and procedures to provide compliance with safety directives issued by DOE, the Laboratory, or industrial codes and standards organizations. These Committees meet on an as-needed basis, typically at least semi-annually.

Each of the committees includes about six to eight individuals and has a broad representation of Physics Division membership, from Group leader to technician. In addition, each committee includes in its membership independent subject matter experts from other Laboratory organizations and the ESH/QA Coordinator for the Physical Sciences and Engineering Directorate. Committee members are appointed by the Physics Division Director and are rotated on a regular basis, typically three years.

In addition to the above standing committees, ad-hoc committees are appointed to review particular apparatus or safety issues that fall outside the technical competence of the standing committees or to review major documents where reviewers independent of ATLAS are considered to be needed to assure the credibility of the review. These ad-hoc committees usually include people with appropriate expertise for the committee's responsibilities from outside the Physics Division. An ad-hoc committee is typically appointed by, and reports, to the Physics Division Director. Design reviews recently conducted by ad-hoc committees include: a Preliminary Safety Review of the CARIBU Project; the CARIBU Shield Cask, Source, and Gas Catcher/RFQ Design and Safety Review; and a review of the design of the New CARIBU Radiation Interlock System (NARIS). Documents reviewed by an ad-hoc committee include Operational Readiness Review documents, and revisions to the Safety Assessment Document and the Accelerator Safety Envelope.

3.3.1.1.3. Facility Inspections

Facility inspections of the Division's areas are conducted by the General Safety Committee and by the Division's ESH/QA Engineer. The Committee conducts its inspections on a bimonthly basis; on the months when an inspection is not being conducted by the Committee, the ESH/QA Engineer, accompanied by a representative from ESQ, inspects Division areas which have not been recently inspected by the Committee. The purpose of these inspections is to ascertain the conditions within these areas and verify that previously identified problems have been satisfactorily corrected.

3.3.1.2. Laboratory Safety Support

The ATLAS facility obtains operational health physics services from the Radiological Safety Group in the ESQ Division. This support includes a health physicist and health physics technicians. The services provided include area radiation monitoring and posting, personnel dosimetry, operational radiation surveys, and radiological work permit preparation, review, and approval.

The ATLAS facility also regularly utilizes safety support from the Industrial Hygiene Group and the Safety Group of the ESQ Division. This support includes participation in facility inspections, safety reviews, and hazard assessments.

3.3.1.3. Laboratory Safety Oversight

3.3.1.3.1. COA Independent Assessments

Compliance, Oversight and Assessments conducts Laboratory-wide, independent assessments of various safety programs. Recent assessments conducted at the Physics Division have addressed the following areas: hoisting and rigging; lockout/tagout, pressure vessels, work planning and control, confined space entry, and radiation protection.

3.3.1.3.2. Accelerator Safety Review Committee

The Accelerator Safety Review Committee (ASRC) assists the Laboratory Director in assuring that accelerator facilities at ANL are designed, constructed, operated, and maintained in accordance with DOE and ANL health, safety, and environmental protection requirements. Members of the Committee are appointed by the Laboratory Director; the Committee reports directly to the Laboratory Director.

The ASRC conducts a triennial safety review of each operating accelerator facility at ANL. The most recent ASRC safety review of the ATLAS facility occurred in April, 2011.

3.3.2. Work Controls

Administrative work controls, including manuals and procedures, permits, and safety reviews, are used to assure that ATLAS activities are performed in accordance with specified DOE and ANL requirements for the protection of the workers, public, and the environment.

3.3.2.1. Manuals and Procedures

The Physics Division and the ATLAS facility have developed manuals and procedures to provide specific guidance and controls for activities that affect safety.

3.3.2.1.1. Physics Division Electrical Safety Policy and Manual

The Physics Division Electrical Safety Policy and Manual (Reference 3-14) contains the Division's policy on electrical safety and specifies requirements for electrical safety as they apply to operations and activities within the Division, including the ATLAS facility. The manual addresses various electrical safety concerns including requirements for high-voltage electrical equipment, high-voltage platforms, capacitors, magnets and inductors, and electromagnetic radiation.

3.3.2.1.2. Physics Division Cryogenic Safety Manual – Technical Section

The Division maintains a portion of the now obsolete Physics Division Cryogenic Safety Manual (Reference 3-15). The Technical Section of that document remains as a useful source of technical information useful in the design of cryogenic systems, and thus remains a part of the Division's documentation.

3.3.2.1.3. Physics Division Radiation Safety Manual

The Physics Division Radiation Safety Manual (Reference 3-16) is primarily a manual for radiation safety at the ATLAS facility. The manual contains a summary of policies and practices for radiation safety as they apply to operations and experiments at the ATLAS facility. The manual addresses personnel responsibilities, radiation protection standards, work practices, training requirements, and requirements for the storage, labeling and handling of radioactive materials.

3.3.2.1.4. ATLAS Operating Procedures

The ATLAS Operating Procedures Manual (Reference 3-17) provides detailed procedures for the operation of the accelerator and associated equipment. These procedures address normal operating conditions, non-standard operating conditions, and emergency conditions. The manual provides detailed documentation for accelerator trainees and is available for reference to operators.

3.3.2.1.5. ATLAS User Manual

The ATLAS User Manual (Reference 3-18) is a technical document which provides information on the accelerator facilities and experimental facilities available to an ATLAS user. The manual also provides the user with information about user safety and the safety aspects of experiments at ATLAS.

3.3.2.2. Permits

Radiological Work Permits (RWPs) are utilized at ATLAS as required by LMS-PROC-140 Radiological Work Permits. Operations involving the 1 Curie Cf source or access to components which could possibly become contaminated due to the source will require RWPs. RWPs will also be required for operations which involve access to equipment that is inside the beam line (*e.g.*, beam stops, targets, etc.) and could possibly become contaminated due to activation or radionuclide deposition.

Permits are required for other potentially hazardous activities such as confined space entry, work on energized electrical circuits, and open flame torch brazing, cutting, and welding.

3.3.2.3. Safety Review and Special Approval

All aspects of the operation, maintenance, modification and use of the ATLAS facility are examined in documented reviews if a significant safety issue may be involved. The scope of the review and the persons responsible depend on the nature of the subject to be reviewed. One or more of the standing safety committees of the Physics Division or an ad-hoc committee reporting to an appropriate level of management usually conduct such reviews. The person responsible for approving the recommendations of the review committee will inform the next higher level of management (up to and including the Division Director) concerning the nature of the review and its conclusions.

The ATLAS Operations Manager, with assistance from the ESH/QA Engineer, determines the safety significance of the proposed activity. The review process for various categories of equipment, procedures, and documents is summarized below:

- Technical details of new or modified accelerator equipment are reviewed by individual technical experts or small groups of experts.

- Minor changes in safety procedures are reviewed by one or more of the standing safety committees, as necessary.

- More substantial changes and major new equipment require a review of the entire sub-system involved. Such reviews are carried out by a technically competent ad-hoc committee reporting to the Division Director.

- Any changes in the equipment or procedures which introduce new hazards to the ATLAS facility are reviewed by the standing safety committees or an ad-hoc committee reporting to the Division Director.

- Revisions to Operational Readiness Review documents are reviewed by an ad-hoc committee reporting to the Division Director.

- Any changes which require revisions to the SAD and/or the ASE are reviewed by an ad-hoc committee reporting to the Physics Division Director.

The Division Director's approval is required for the following documents:

- Operational Readiness Review documents
- Revisions to the ATLAS SAD
- Revisions to the ATLAS ASE.

Any changes which require revisions to the ATLAS SAD and/or the ATLAS ASE cannot be made until the SAD and/or ASE have been revised, reviewed, and approved by the appropriate authorities.

The review and approval process described above is intended to assure that no proposed change, test, or modification to ATLAS equipment is implemented which could result in a situation for which a safety analysis has not been performed and documented in the current Safety Assessment Document and the Accelerator Safety Envelope. If it is determined that the proposed change, test, or modification is needed, the activity constitutes an Unreviewed Safety Issue (USI) and cannot be performed until an analysis of the hazards has been conducted and proper controls implemented in accordance with the requirements of the ANL Accelerator Safety Procedures Manual.

3.3.3. Staff Training and Qualification

3.3.3.1. ANL Training

At ANL, employee training in the areas of worker health and safety, environmental protection, and quality assurance is provided through the ANL Training Management System (TMS). The TMS includes a comprehensive method for determining the training needed to prepare employees for the hazards to which they may be exposed in the course of their duties, as well as an organized system for delivering and documenting that training.

For an ANL employee, the content of an individual's training program depends on the nature of the individual's work as determined by the ANL Job Hazard Questionnaire (JHQ). The JHQ is prepared by the employee, reviewed by the employee's immediate supervisor and the Training Coordinator, and submitted to the TMS. A training profile, developed by TMS, indicates the courses the employee is required or recommended to attend for specific job requirements. The courses are given by subject matter experts who are qualified as instructors. Attendance at training classes is documented. The TMS sends the employee and the employee's supervisor, notifications of initial training required and required refresher training.

Although the specific safety training required for an ANL employee is dictated by the employee's completed JHQ, the following is a list of courses that are likely to be required:

ESH100	ES&H Orientation
ESH107	Fire Extinguisher Training - Orientation
ESH108203	Building Safety Orientation (Building 203)
ESH112	Pollution Prevention
ESH113	Confined Space Training
ESH114	Lockout/Tagout Training
ESH119	Pressure Safety Orientation
ESH140	Emergency Services Orientation
ESH145	Cryogenic Safety
ESH146	NEPA Training

ESH171	Lead: Hazards and Controls Training
ESH174	Noise and Hearing Conservation Training
ESH175	Physical Agents Training
ESH195	Personal Protective Equipment
ESH196	Hazard Communication
ESH371	Electrical Safety Training - General
ESH377	Electrical Safety Awareness
ESH700/702	Radiation Worker Training Level I or Level II
ESH703	ALARA Review Process
ESH707	Accelerator Worker Training
ESH714	Radiological Work Planning for Supervisors

Information on the content of these courses is available in the TMS course catalog. Some of the courses require retraining on an annual or biannual basis.

3.3.3.2. ATLAS Specific Training

The ATLAS facility imposes additional training requirements beyond those generated by ANL's TMS to assure the safety of personnel working in the ATLAS facility.

An individual needing unescorted access to the ATLAS facility is required to take PHY101 ATLAS Site Specific Training. This course addresses radiological hazards, ALARA, the ATLAS Radiation Interlock System (ARIS), and the search and secure process for interlocked areas.

An individual whose work will involve open radioactive sources is required to take PHY102 Open Source Training. If the individual's work involves sealed radioactive source, the individual will take the Laboratory's Radiation Worker Level I course.

An individual needing unescorted access to the ATLAS facility is required to take ESH700/702 Radiation Worker Training Level I or Level II.

The courses identified above all require retraining every two years.

This ATLAS-specific training is required for all employees whose JHQ states that they will be working at the ATLAS facility. The completion of the courses and the requirement for retraining are shown on the individual's Training Profile.

3.3.3.3. ATLAS Operator Training

The ATLAS facility has a formalized program for operator training. The program is documented in ATLAS Report Series documents TR-1 "ATLAS Operator Training Program" and TR-2 "Training Program for Radiation Safety at ATLAS" (References 3-19 and 3-20). This training addresses the ATLAS accelerator and associated systems, including safety systems (e.g., the ATLAS Radiation Interlock System (ARIS), the ATLAS Oxygen Deficiency Monitoring System, etc.). The training includes procedures for normal operation, maintenance, and emergencies. ATLAS safety matters including chemical, cryogenic, electrical, fire, and radiation safety are also addressed. The training is documented in the TMS through completion of the Course Number PHY109, ATLAS Operator Training. The requirement for this training is entered into the TMS as a Division Requirement.

Trainees are required to pass a written examination as well as a practical examination. The practical examination is carried out over a period of time by the ATLAS Operations Supervisor. Records of the operator training are kept by the ATLAS Operations Manager.

The operator training program is not limited to studying documents and passing examinations, but also includes a period of apprenticeship along side an experienced operator. The training time ranges from six months to a year, depending upon the learning skills of the trainee.

In addition to the training required to become qualified as an operator, the trainee is required to take the ATLAS-specific training required for ANL ATLAS personnel and the safety training which is dictated by the trainee's JHQ.

3.3.4. ATLAS Experiments

Experiments are run at ATLAS to perform basic research in the fields of atomic physics, nuclear physics, and other scientific disciplines. During Fiscal Year 2011, the ATLAS facility provided more than 5300 hours of beams for the research programs involving 411 scientists and 46 experiments. During Fiscal Year 2012, the number of beam hours was reduced to about 3400 due to the effects of budgetary constraints.

A formal written User Agreement between the experimenter's organization and the Laboratory permits the user access to and use of the ATLAS facility, subject to approval of the proposed experiment by the ATLAS Scientific Director (based on the advice of the Program Advisory Committee) and the availability of the facility. The Safety and Health clause in the User Agreement requires the experimenter to take all reasonable precautions in the installation of equipment and performance of experiments to protect the safety and health of others and to protect the environment. The clause also requires the experimenter to comply with all applicable safety and health regulations and requirements of ATLAS, Argonne, and the Department of Energy.

3.3.4.1. Selection

The ATLAS Scientific Director, with the assistance of a Program Advisory Committee, selects the experiments to be conducted at the ATLAS facility.

3.3.4.2. Safety Review and Approval

Each individual experiment to be performed at ATLAS undergoes an initial safety review by the Operations Manager, the Physics Division ESH/QA Engineer, and the chairperson of the Radiation Safety Committee. If necessary, the written description of the apparatus used, or the procedure, is submitted to the Safety Coordinating Committee to determine which of the other standing committees, or an ad-hoc committee, needs to review it. The responsible committees then review the experiment and report in writing the results of those reviews.

Based on those reviews, the needs of the experimenter and the capabilities of the accelerator, the beam energy and beam current approved for delivery to the experimental area during each running period are specified in an "Authorization to Operate" form. Approval signatures for this document include those of the Operations Supervisor, the Spokesperson for the experiment and the Physics Division ESH/QA Engineer, or their delegates.

Any proposed experiment that involves a beam of mass less than 12 or with a high estimated radiation level is reviewed by a committee reporting to the Physics Division Director, and must be approved by the Division Director. Records of these reviews are maintained by the Chair of the Physics Division Radiation Safety Committee.

Any proposed experiment that introduces new hazards to the ATLAS facility is reviewed by a committee reporting to the Physics Division Director, and must be approved by the Division Director. The records of these reviews are maintained in the office of the Physics Division ESH Engineer.

The approvals of each experiment performed at ATLAS are documented on the experiments' individual Proposal Fact Sheet cover pages and Run Sheets. These are maintained in the ATLAS Control Room.

The review and approval process described above is intended to assure that no proposed experiment is performed which could result in a situation for which a safety analysis has not been performed and documented in the current Safety Assessment Document and the Accelerator Safety Envelope. If it is determined that the proposed experiment must be performed, the activity constitutes an Unreviewed Safety Issue (USI) and cannot be performed until an analysis of the hazards has been conducted and proper controls implemented in accordance with the requirements of the ANL Accelerator Safety Procedures Manual.

3.3.4.3. Experimenters' Training

ATLAS facility experimenters are required to take PHY101 ATLAS Site Specific Training and PHY103 Radiation Worker Training for ATLAS Users.

PHY101 provides information about ANL and ATLAS safety requirements and procedures, and detailed information about the safety aspects of the experimental equipment and the radiation safety system at ATLAS.

PHY103 is an ATLAS-specific radiation safety course designed to meet the Laboratory's training requirements for working in a radiation area. PHY103 is not required if the experimenter has taken the Laboratory’s Radiation Worker Level I or Level II course.

Both PHY101 and PHY103 require retraining every two years.

3.3.4.4. Experimenter’s Safety

The ATLAS facility has established requirements to protect the health and safety of experimenters at the facility. The experimenters are made aware of these requirements by the required training (*i.e.*, PHY101 and PHY 103), by various documents provided to the experimenter (*e.g.*, ATLAS User Manual), and by orientation briefing provided by ATLAS and Physics Division personnel.

The health, safety, and environmental protection requirements applicable to experimenters at the ATLAS facility are the same as those applicable to activities at other Argonne facilities.

Requirements that are specific to the ATLAS facility include the following:

- An individual is not permitted unescorted access to the ATLAS facility until the individual has completed PHY101 ATLAS Site Specific Training and either Radiation Worker 1 (minimum) or equivalent training.

- A thermoluminescent (BGN) dosimeter (TLD) must be worn at all times when within the ATLAS facility.

- Equipment which may have been contaminated or activated can be removed from an experimental area only after it has been surveyed by Health Physics personnel.

- Any materials which were in a beam line must be surveyed by Health Physics personnel before they can be removed from an experimental area.

4. SAFETY ANALYSIS

4.1. Hazard Analysis for Normal Operations

4.1.1. Hazard Analysis Methodology

A screening for the potential hazards associated with the ATLAS facility was performed using a checklist based on Appendix A "Potential Hazards" of ANL ES&H Manual Section 21.2 "Experiment Safety Review". The results of the screening are given in Table 4-1 "Potential Hazards Checklist". An "X" in the "YES" column indicates that the potential hazard is present. The entry in the "REMARKS" column refers to the section in this document where more information on the hazard is provided.

This approach serves to identify some hazards that are not normally addressed in an accelerator facility SAD (*e.g.*, chemical hazards, combustion hazards, etc.). However, this approach is a worthwhile implementation of Integrated Safety Management (ISM) and permits this SAD to serve as a key document in the ATLAS facility portion of the Physics Division's ISM program.

The hazard analysis method included the identification of the potential hazards in all areas of the facility, including the existing portions of the facility and the CARIBU additions. The potential hazards included those identified in the prior ATLAS SAD, in various hazards assessment documents produced for facility modifications, and in documentation developed for the CARIBU project. This identification of potential hazards has been reviewed by ATLAS facility and Physics Division personnel having detailed knowledge of the ATLAS facility. A description of the mitigating measures for each hazard is described.

TABLE 4-1. Potential Hazards Checklist
(Form ANL-544)

POTENTIAL HAZARD	YES	NO	REMARKS
Radiation and Electromagnetic Fields			
Ionizing Radiation			
Alpha	X		See sections 4.1.2.1 and 4.1.2.3
Beta	X		See sections 4.1.2.1 and 4.1.2.3
Gamma and/or X-Ray	X		See sections 4.1.2.1 and 4.1.2.3
Neutron	X		See sections 4.1.2.2 and 4.1.2.3
Proton		X	
Subatomic		X	
Nonionizing Radiation			
Laser	X		See section 4.1.2.4
Visible Light		X	
Ultraviolet		X	
Microwave	X		See section 4.1.2.5
Radiofrequency	X		See section 4.1.2.5
Electric Fields	X		See section 4.1.2.6
Magnetic Fields	X		See section 4.1.2.7
Chemicals and/or Materials			
Health and Injury Hazards			
Carcinogens		X	
Mutagens		X	
Teratogens		X	
Toxins	X		See section 4.1.2.8
Corrosives	X		See section 4.1.2.8
Irritants, Allergens, and/or Sensitizers	X		See section 4.1.2.8
Volatile Solvents	X		See section 4.1.2.8
Combustion and Injury Hazards			
Flammable Liquids and/or Solvents	X		See section 4.1.2.9
Metallic Combustibles		X	
Flammable Gases	X		See section 4.1.2.9
Compressed Oxygen	X		See section 4.1.2.9
Open Flame or Sparks	X		See section 4.1.2.9
Combustible Materials	X		See section 4.1.2.9
Explosives		X	
Flammable Suspended Dust Particles		X	
Pyrophoric Chemicals		X	
Respiratory or Contact Injury Hazards			
Cryogenics	X		See section 4.1.2.10
Thermal (High or Low)	X		See section 4.1.2.10
Dust, Particulates, and Fibers		X	
Asbestos		X	
Explosives		X	
Reactive Chemicals		X	
Compressed Gases	X		See section 4.1.2.11
Pressure and/or Vacuum Systems	X		See section 4.1.2.12

POTENTIAL HAZARD	YES	NO	REMARKS
Steam		X	
Asphyxiation	X		See section 4.1.2.13
Stored Energy Not Elsewhere Addressed			
Hydraulic Energy		X	
Kinetic Energy		X	
Mechanical Energy		X	
Potential Energy		X	
Other		X	
Biohazards			
Virus		X	
Bacteria		X	
Human Tissues and/or Body Fluids		X	
Animals and Animal Tissue		X	
Electrical			
High Voltage Devices	X		See section 4.1.2.14
Storage Devices	X		See section 4.1.2.14
Static Charge		X	
Lightning Protection		X	
Grounding	X		See section 4.1.2.14
Exposed Conductors	X		See section 4.1.2.14
Mechanical			
Lifting Devices	X		See section 4.1.2.15
Low Friction Surfaces		X	
Load-Bearing Components	X		See section 4.1.2.16
Vibration		X	
Sharp Points or Edges	X		See section 4.1.2.17
Moving Parts	X		See section 4.1.2.17
Pinch Points	X		See section 4.1.2.17
Ladders, Scaffolds, and/or Platforms	X		See section 4.1.2.18
Work Environment			
Activities at Known or Suspected Hazardous Waste Sites		X	
Use of Self-Contained Breathing Apparatus		X	
Temperature or Other Climatic Extremes		X	
Severe Weather		X	
Noise		X	
Confined Spaces	X		See section 4.1.2.19
Others (Tripping Hazards)		X	

4.1.2. Hazard Analysis Results

In this section, each of the hazards identified in Table 4-1 “Potential Hazards Checklist” is described and the engineered and administrative hazard controls are described.

4.1.2.1. Radioactivity

The hazards of radioactivity are present in the ATLAS facility due to (1) radioactive material for the production of ions to be accelerated, (2) radioactive materials for use as irradiation targets, (3) radioactive material for radiation detector calibration, and (4) radioactive material deposited or induced by the beam. These hazards are addressed separately.

4.1.2.1.1. Radioactive Material for Ion Production

Hazard Description

Prior to the CARIBU project, the radioactive materials used for ion production were limited to small sources having an activity of less than 1 Curie with a relatively short half-life. Such sources presented minimum hazards.

With the implementation of the CARIBU project, the radioactive material used for ion production is a ^{252}Cf source having a nominal intensity of 2 Curies and a half-life of 2.6 years. ^{252}Cf decays by alpha particle emission (97%) and by spontaneous fission (3%) releasing fission products, neutrons, and gamma rays. The unshielded neutron dose rate from the source is 92.0 rem/hr at 30 cm; the unshielded photon dose rate is 5.6 rem/hr at 30 cm.

During normal activities, the fission products produced by the Cf source will cause radioactive contamination of the shielding cask, gas catcher, and some down-stream components of the beam line (*e.g.*, the ECR). In addition, gaseous fission products (*i.e.*, krypton and xenon) which enter the gas catcher will be released to the environment.

The radioactive contamination of the inner surfaces of the shielding cask and gas catcher has been estimated (Reference 4-1). One half of the fission products produced by the source go forward into the gas catcher; the gas catcher has a 50% efficiency for collecting fission products and sending them into the beam line. Thus, 25% of the fission products produced by the source will be deposited within the gas catcher. It is assumed that 25% of the fission products produced by the source over a three months period are deposited on a 1 m^2 surface. The beta skin dose rate calculated at 1 cm from the surface is about 20 rem/hr at 1 hour and decreases to about 2 rem/hr at 1 month. The gamma dose rate at 30 cm from the surface is about 100 mrad/hr at 1 hour and decreases to about 4 mrad/hr at 1 month.

The radioactive contamination of the ECR has also been estimated (Reference 4-1). For this estimate, the mass chain 132 which includes the relatively volatile elements Sn, Te, and I was selected. The mass chain 132 was chosen because there is great interest in using ^{132}Sn as a radioactive beam and it is expected during the first few years of CARIBU operation that much of the work will be with a ^{132}Sn beam. It is assumed that Te-132 is deposited uniformly in the ECR at the rate of 4.2 x 10^6 ions/sec, the experiment lasts long enough for saturation of the ^{132}Te activity (about 2 weeks), and secular equilibrium between ^{132}Te and ^{132}I is reached (about 2 hours). For the beta dose rate estimate it is assumed that the radioactivity is uniformly deposited over an area of 240 cm^2; a point source representation is used for the gamma dose rate estimate. The unshielded beta skin dose rate calculated at 1 cm from the surface is about 5 rem/hr. The unshielded gamma dose rate at 30 cm from the surface of the cask is about 2 mrem/hr. These dose rates decrease by a factor of about 4 after 1 week and a factor of 1,000 after 1 month.

The exhaust for the gas catcher is passed through a small HEPA filter and a charcoal filter by piping which provides a 100-second delay time before the exhaust enters the room HEPA filter for release to the environment by the building stack. The annual dose rate for this release has been estimated assuming a 100-second delay in the release but without assuming any capture of the gases by the HEPA or charcoal filters. The dose estimate considered the production of gaseous fission products (i.e., krypton and xenon) and volatile fission products (i.e., bromine and iodine) from 2.0 Ci of ^{252}Cf. Calculations were performed using the EPA CAP-88 computer program. The maximum dose rate to an individual member of the public is about 0.06 mrem/year; the maximum dose rate at the Argonne site boundary is about 0.6 mrem/year.

The radioactive contamination of the charcoal filter has been estimated (Reference 4-1). For this estimate, it is assumed that the charcoal filter has an efficiency of 100% and saturation activity of the iodine isotopes is reached. The gamma dose rate at 30 cm from the filter is about 3 mrem/hr.

Impacts on Facility Personnel, Public, and Environment

During normal activities, the radioactive material hazards from ^{252}Cf have the potential to cause injury at a radiation exposure of a few rems to facility personnel.

Under certain accident scenarios, the radioactive material hazards from ^{252}Cf have the potential to impact the public and the environment (see Section 4.2).

Hazard Controls

A combination of engineered controls and administrative controls is used as hazard control methods for the radioactive material hazards from ^{252}Cf present in the ATLAS facility.

The engineered controls include:

- the ^{252}Cf source is confined within either the shielding cask or the gas catcher,

- radiation detectors are positioned near the shielding cask and gas catcher so as to detect any anomalous readings which could indicate the presence of ^{252}Cf outside of its confinement,
- the CARIBU building ventilation system keeps the CARIBU building at a lower pressure than the rest of ATLAS to prevent the potential leakage of any radioactive material out of the CARIBU building,
- gaseous fission products in the gas catcher are captured, passed through HEPA and charcoal filtration, and delayed (by the selection of pipe size by the designed flow rate) before they are exhausted from the building stack.

The administrative controls include:

- Specific criteria for the changeout of the HEPA filter in the building ventilation system, based on differential pressure, and the changeout of the charcoal and HEPA filters in the gas catcher exhaust system, based on the buildup of radioactive material, will be given in the ATLAS Operations Procedures,
- source loading and cleanup activities involving radioactive contamination are performed under a Radiological Work Permit,
- workers involved in this activities with radioactive material have successfully completed Radiation Workers II training, and are current in that training, and
- health physics technicians will be present to determine radiological hazards before work is initiated and to monitor radiation safety during the work activities,

4.1.2.1.2. Radioactive Irradiation Targets

Hazard Description

Radioactive irradiation targets typically have an activity of 1 to 10 microCuries. The photon dose rate from these targets is less than 50 microRem/hr at 30 cm.

Impacts on Facility Personnel, Public, and Environment

The radioactive material hazards from radioactive irradiation targets have the potential to cause very minor radiation exposure to facility personnel. These hazards do not impact the public or the environment. An inventory of radioactive material is maintained following the requirements of LMS-PROC-45. All accountable radioactive sources used at ATLAS are entered into the Radioactive Material System (RMS) database. Activated ATLAS structures and accelerator components are not included in the database because, following PROC-45 requirements, the radiation hazards of these structures and components are fully analyzed in this document. Equipment surveys are required when components are removed that might have been exposed to direct accelerated beam. Radioactive material removed from the accelerator for radioactive waste disposal must be sufficiently characterized to permit disposal as radioactive or mixed waste.

Hazard Controls

Administrative controls are used as hazard control methods for activities involving radioactive irradiation targets. The use of radioactive targets with strengths larger than routine require approval by the Physics Division Radiation Safety Committee and must be handled according to the guidelines provided by the committee. Radiological Work Permits are used when required by Laboratory regulations. Additional hazard controls are prescribed by the Physics Division Radiation Safety Manual and by applicable LMS policies and procedures.

4.1.2.1.3. Radioactive Sources used for Detector Calibration, Testing and the ARIS Monitors' "Heartbeat" Function

Hazard Description

Radioactive sources are routinely used at the ATLAS facility for detector calibration and testing. The source strengths are typically 1 microCurie for open sources and 10 microCuries for sealed sources. The photon dose rate from these sources is less than 50 microRem/hr at 30 cm.

Impacts on Facility Personnel, Public, and Environment

The radioactive material hazards from detector calibration and testing as well as the usage of sources in the ARIS monitors have the potential to cause very minor radiation exposure to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

Administrative controls are used as hazard control methods for activities involving the detector calibrations sources. The use of radioactive sources with strengths larger than routine, require approval by the Physics Division Radiation Safety Committee and must be handled according to the guidelines provided by the committee. Radiological Work Permits are used when required by Laboratory regulations. Additional hazard controls are prescribed by the Physics Division Radiation Safety Manual and by applicable sections of ANL ESH Manual Chapter 5 "Ionizing Radiation Protection".

4.1.2.1.4. Beam Deposited or Induced Radioactive Material

Hazard Description

Beam induced activation at ATLAS is a serious hazard and can produce radiation fields from gamma rays corresponding to a rate of ~100 mrem/h 1 meter from the source.

An exposure rate of this magnitude would require the following improbable combination of circumstances: a worst-case beam with respect to energy and intensity is accelerated onto a tantalum beam stop or a lower-Z thick target; the beam stop is irradiated long enough to come to decay equilibrium; and the beam-stop system is disassembled within a short time from the time the beam is removed. The conditions assumed above have never come close to being experienced in the research program at ATLAS.

The activity generated by depositing beams of radioactive nuclei on slits, targets, beam stops, etc. is very small and poses a smaller hazard than the activities induced by the more intense stable beams.

The hazard associated with deposition of particles on beam line components from longest-lived radioactive nuclei such as ^{238}U is negligible. Assuming that a 5 eμA U^{30+} beam is accelerated for 2000 hours per year for 10 years, the accumulation of ^{238}U in the beam pipe will be only about 4×10^{19} nuclei, which decay at a rate of only ~ 195 decays/sec. This corresponds to a source strength of ~ 10 nCi.

The intensity of shorter-lived radioactive beams (e.g. ^{18}F, ^{44}Ti, ^{56}Co..) accelerated from the ion source to various target stations is usually very small. (*e.g.* 0.1 pnA for ^{44}Ti and 0.05 pnA for ^{56}Co have been extracted from the ion source). This is also true for radioactive beams produced by interactions of accelerated beams in gas or solid targets at the in-flight target location shown in Figure 3-4.

Assuming that a beam of 0.1 pnA of ^{44}Ti ($t_{1/2}$ = 60y) running for 30 days/year over a period of 5 years is stopped always at the same location, one obtains an activity of 75 μCi. More realistically, this activity is distributed over several beam line components with correspondingly lower activities.

The worst-case scenario is a beam of 0.05 pnA of ^{56}Co($t_{1/2}$ = 77d) running for 30 days per year. In this case the maximum activity for stopping the beam in one location would be 2.2 mCi.

Impacts on Facility Personnel, Public, and Environment

The radioactive material hazards from beam deposited or induced radioactivity have the potential to cause some radiation exposure to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

Administrative controls are used as hazard control methods for activities involving material affected by beam deposited or induced radioactivity.

Standard operating procedures at ATLAS require that equipment used in the beam line downstream from the PII exit must be surveyed by health physics personnel before removal from the facility.

The removal and disassembly of experimental targets, detectors, and accelerator system equipment from a beamline are controlled by the following protocols:

- Targets made of an inherently radioactive material (such as Pu) may only be removed from a target chamber after being surveyed by a health physics technician. When such targets are in use, a survey by a health physics technician is also required before the removal of any other component in the target chamber can take place.
- Detectors, accelerator system equipment, and all other targets may only be removed by Physics Division personnel who have successfully completed the appropriate Radiation Worker training and the Physics Division's Open Source training. Such targets and detectors will remain in the Experimental Area until a health physics technician has surveyed them.

- Targets and detectors which have been irradiated by a beam with an intensity greater than 100 pnA (10 pnA for beams of protons), and those located in a chamber known to be radioactively contaminated, may only be removed from the beamline after they have been surveyed by a health physics technician.
- The disassembly of targets and detectors follows the same rules as their removal from a beamline.
- Radiological Work Permits are used when required by Laboratory regulations.

Additional hazard controls are prescribed by the Physics Division Radiation Safety Manual and by applicable sections of ANL ESH Manual Chapter 5 “Ionizing Radiation Protection”.

4.1.2.2. Gamma and X-Ray Radiation

The hazards of gamma and x-ray radiation are present in the ATLAS facility due to (1) beam-induced ionizing photons, (2) x-rays from accelerating structures, (3) x-rays from ion sources, and (4) fission and secondary gamma radiation produced by the Cf source and its neutrons. These hazards are addressed separately.

4.1.2.2.1. Beam-Induced Ionizing Photons

Hazard Description

ATLAS beams can generate large numbers of low energy photons (gamma and x-rays) when the beam is intercepted by a target or slits and collimators. In comparison to neutrons, this hazard can be controlled easily because the attenuation length of gamma rays in concrete is only ~ 1/3 that for neutrons, and in steel it is only 1/9. Radiation surveys of ATLAS have confirmed that the radiological dose rate is primarily due to neutrons rather than photons. The risk from beam-induced photons is negligible for areas separated from the beam by neutron shielding walls.

Impacts on Facility Personnel, Public, and Environment

There are little radiological hazards to facility personnel from beam-induced ionizing photons. These hazards do not impact the public or the environment.

Hazard Controls

Specific hazard controls for beam-induced ionizing photons are not necessary since adequate radiation shielding is provided by the neutron shielding.

4.1.2.2.2. X-Rays from Accelerating Structures

Hazard Description

Parasitic electrons in the non-superconducting RFQ and superconducting resonators of the ATLAS linac can be accelerated by the RF field within a particular resonator, and generate X-rays (bremsstrahlung) when they strike the walls of the structure. For the ATLAS split-ring resonators, the X-radiation level at a distance ~ 1 meter from the surface of the beamline cryostats is in the range 1 to 100 mrem/h, depending on operating conditions. The newer quarter-wave resonators can generate higher dose rates, up to 1-10 R/hr at 3 m from the source point, with the level again depending on operating conditions. For the RFQ and PII linac, the X-ray levels are much smaller.

Impacts on Facility Personnel, Public, and Environment

The x-rays from accelerating structures have the potential to cause some radiation exposure to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

A combination of engineered controls and administrative controls is used as a hazard control method. Work areas near both the injector and the main linac are protected from x-ray radiation by concrete or steel shielding walls. However, ATLAS operations personnel need to enter the radiation area inside these shielding walls occasionally, and briefly, to monitor or adjust equipment. For these personnel, the maximum dose that could be acquired during entry is limited to 10 mrem per 8-hr day by ARIS. In addition, entry is only permitted by ARIS if the instantaneous dose rate is less than 9 mrem/h at 1 m. For the purposes of the integrated dose limit, the dose in the three accelerator areas controlled by ARIS are summed for the 8-hour period while they are occupied, thus preventing cumulative exposures for accelerator personnel who may enter different areas during their shifts.

4.1.2.2.3. X-Rays from Ion Sources

Hazard Description

The ECR ion sources are prolific sources of low-energy x-rays. The radiation produced by the ion source of the tandem is too weak to be detected with conventional radiation monitors.

Impacts on Facility Personnel, Public, and Environment

The x-rays from ion sources have the potential to cause some radiation exposure to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

A combination of engineered controls and administrative controls is used has a hazard control method. Steel fencing is used to maintain the minimum proper distance from the ECR ion sources. However, personnel need to enter the radiation area inside this fencing occasionally, and briefly, to monitor or adjust equipment. For these personnel, the maximum dose that could be acquired during entry is limited to 10 mrem per 8-hr day by ARIS. In addition, entry is only permitted by ARIS if the instantaneous dose rate is less than 9 mrem/h at 1 m. For the purposes of the integrated dose limit, the dose in the ECR areas are summed for the 8-hour period while they are occupied, thus preventing cumulative exposures for personnel who may enter both areas.

4.1.2.2.4. Fission and Secondary Gamma Radiation from Cf

Hazard Description

^{252}Cf decays by alpha particle emission (97%) and by spontaneous fission (3%) releasing fission products, neutrons, and gamma rays. The unshielded photon dose rate is 2.8 rem/hr at 30 cm. As the neutrons are captured in the shielding material, additional gamma radiation is generated.

The radiation shielding for the Cf source consists of approximately 10 cm of tungsten, 60 cm of borated polyethylene, and ¼ inch of iron. Computer calculations show that this shielding results in a gamma dose rate of approximately 0.8 mrem/hr at 30 cm and a neutron dose rate of approximately 0.2 mrem/hr at 30 cm.

Impacts on Facility Personnel, Public, and Environment

The gamma radiation from the Cf source has the potential to cause radiation exposures of a few rem to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

The primary hazard control used for the gamma radiation from the Cf source is radiation shielding. Administrative controls (including work procedures, Radiological Work Permits, radiation worker training, radiation monitoring, etc.) are also used for hazard control.

4.1.2.3. Neutron Radiation

The hazards of neutron radiation are present in the ATLAS facility due to:(1) neutrons produced by ion beams, and (2) neutrons produced by the Cf source. These hazards are addressed separately.

4.1.2.3.1. Neutrons Produced by Ion Beams

Hazard Description

A set of nuclear-model calculations (Reference 4-3) provides estimates of upper limits of radiation intensities and reliable results for the angular distributions of neutrons generated by all ion beams in the energy range of interest at ATLAS. These results are consistent with published experimental data with respect to dependence on ion species, beam energy, and emission angle, but the absolute values are roughly twice as large as those for the available data. Since a difference of this kind is within the accuracy of the models used, it is concluded that the model treatment gives a reasonable description of the neutron hazard for heavy-ion projectiles. The dependence of dose rate on beam energy and ion mass is given in Figure 4-1, which shows that the dose rate depends strongly on the energy per nucleon of the beam, but is relatively insensitive to ion mass.

The energy per nucleon that ATLAS is able to provide varies with ion mass as shown in Table 4-2. The maximum beam energy is about 25 MeV/u for the lightest ions (other than protons); about 18 MeV/u for medium mass ions, and about 10 MeV/u for the heaviest ions. Although it is possible to provide protons at energies up to 39 MeV, the Safety envelope and Operations envelope limit the energy to 25 MeV and 23 MeV, respectively. The facility’s mission does not include the use of protons, in general. Since becoming a national user facility in 1985, ATLAS has only provided protons at energies less than 10 MeV at very low intensities; mostly as part of a calibration procedure in support of an approved experiment which used heavy ions.

The maximum possible beam current also varies with ion mass as was shown earlier in Figure 3-14.

Since both the maximum possible beam current and energy per nucleon are larger for light ions than they are for heavier ions, beams of light ions are capable of generating greater neutron intensity than are beams of heavy ions. The radiation levels generated by beams of many of these lighter ions impinging on thick targets may be estimated reliably from the data reported in Reference 4-4, as summarized by Figure 4-2.

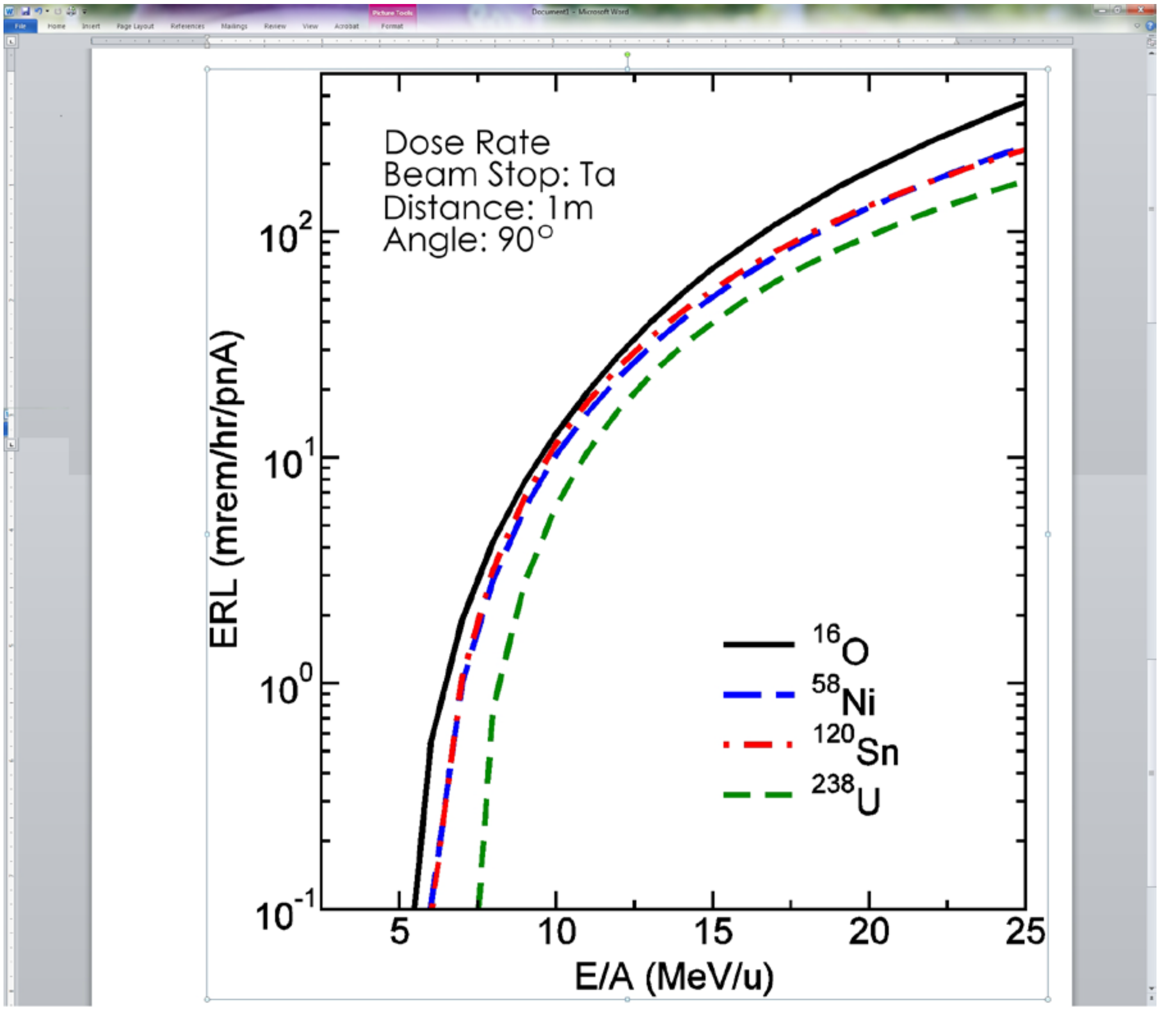

Figure 4-1. Calculation of Neutron Dose Rate One Meter from a Thick Tantalum Target.

TABLE 4-2. Energy per Nucleon.

		Energy Per Nucleon (Mev/u)	
Ion	**Mass**	**No Stripping**	**Additional Stripping***
p	1	40	N/A
He/Li	6	24.0	N/A
O	16	19.0	21.5
Ar	40	17.5	19.9
Ni	58	13.5	17.9
Se	78	12.8	16.7
Cs	132	10.4	13.4
Au	197	8.4	10.9
U	238	7.9	10.0

*Additional stripping raises the energy per nucleon, but reduces the beam intensity.

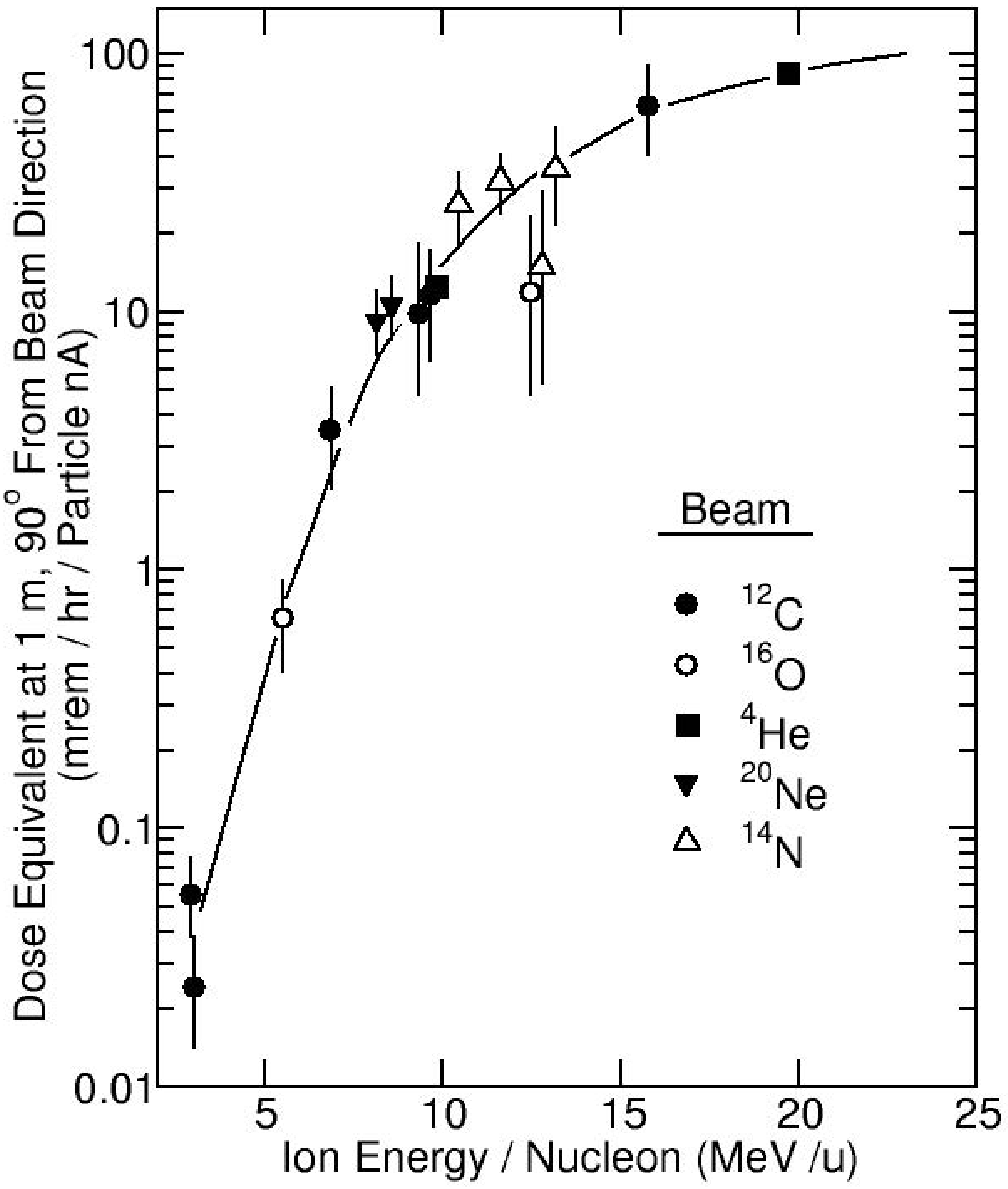

Figure 4-2. Measured Values of the Neutron Dose Equivalent Rate One Meter from a Thick Target.

Based on several years of operating experience it is expected that more than 50% of the time the neutron dose rate is less than 1 mrem/h at 1 m and it is greater than 500 mrem/h only 1% of the time. Thus, the hazard from neutron radiation is relatively small during normal operation, and the principal concern is the much greater potential hazard that might be generated by equipment failure and/or operator error.

Impacts on Facility Personnel, Public, and Environment

The neutron radiation produced by ion beams has the potential to cause radiation exposures of a few rems to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

A combination of engineered controls and administrative controls is used as a hazard control method. Portions of the ATLAS building were designed to provide shielding against the hazards of neutrons produced by beams of heavy ions and additional local shielding has been added to supplement the building shielding (Reference 3-4). Since beams of light ions produced a greater neutron intensity than beams of heavy ions, an engineered control (*i.e.*, the Beam Current Interlock System and the ATLAS Radiatioin Interlock System) and administrative controls (*e.g.*, experiment reviews and "Authorization to Operate" document) are used to assure that the neutron intensity produced by the beam of light ions does not exceed the protective capability of the shielding. In addition, ARIS restricts access to areas where radiation exposure is a potential hazard.

4.1.2.3.2. Neutrons Produced by the Cf Source

Hazard Description

^{252}Cf decays by alpha particle emission (97%) and by spontaneous fission (3%) releasing fission products, neutrons, and gamma rays. The unshielded neutron dose rate from the source is 92 rem/hr at 30 cm.

The radiation shielding for the Cf source consists of approximately 10 cm of tungsten, 60 cm of borated polyethylene, and ¼ inch of iron. Computer calculations show that this shielding results in a neutron dose rate of approximately 0.4 mrem/hr at 30 cm and a gamma dose rate of approximately 1.6 mrem/hr at 30 cm (Reference 3-4).

Impacts on Facility Personnel, Public, and Environment

The neutron radiation from the Cf source has the potential to cause radiation exposures of a few rems to facility personnel. These hazards do not impact the public or the environment under normal operation.

Hazard Controls

The primary hazard control used for the neutron radiation from the Cf source is radiation shielding. Administrative controls (including work procedures, Radiological Work Permits, radiation worker training, radiation monitoring, etc.) are also used for hazard control. Several weaker Cf sources are also in use at ATLAS. Similar controls are in place for the weaker sources.

4.1.2.4. Laser

Hazard Description

A laser ion source is used in the Canadian Penning Trap Spectrometer to provide ions of stable isotopes for calibration of the device or actual measurements. It is expected that additional experimental devices with lasers will be deployed in ATLAS in the future.

A laser system has been added to ECR-2 to develop a new technique for the ablation of solid materials into the ECR plasma. This system is still under development and is not yet considered operational, but will be used in an upcoming Accelerator Mass Spectroscopy experiment for actinide nuclei.

Impacts on Facility Personnel, Public, and Environment

Laser radiation has the potential to cause skin burns and eye damage to facility personnel who are exposed to unshielded radiation. These hazards do not impact the public or the environment.

Hazard Controls

The laser used in the Spectrometer is a Class 4 laser. The laser beam path and the laser target area are totally enclosed. The apparatus which contains the laser is qualified as a Class 1 laser enclosure; it prevents the escape of any laser radiation. Interlocks prevent accidental exposure as a result of opening panels, hatches, or doors. Additional hazard controls are prescribed in ANL ESH Manual Section 6.2 “Nonionizing Radiation Protection - Laser Safety”.

The laser used for ablation into the ECR source is a Class IV diode pumped Nd:YAG laser at 1054 nm. Maximum power is 5 mW and is pulsed with a few picosecond pulse width at a variable rate of up to 10kHz. The laser and all light pathways are fully enclosed and interlocked.

4.1.2.5. Radiofrequency and Microwave

Hazard Description

The ATLAS facility has a few systems in the accelerator (*e.g.*, gas catcher, ECR sources, RFQ, beam line resonators, and RF chopper) and the experimental equipment (*e.g.*, Canadian Penning Trap Spectrometer) which generate or use radiofrequency fields.

Impacts on Facility Personnel, Public, and Environment

At high levels or in certain conditions, radiofrequency fields can pose health hazards to personnel working in the area. These hazards do not impact the public or the environment.

Hazard Controls

The radiofrequency sources are heavily shielded to eliminate detectable leakage. The sources are tested for leakage when first assembled and are retested whenever work is done which might disrupt the shielding. Electromagnetic radiation hazard warning signs are posted and warning lights are used to indicate when the equipment is energized. Additional hazard controls are prescribed by the Physics Division's Electrical Safety Policy and Manual and ANL ESH Manual Section 6.1 " Nonionizing Radiation Protection - Radiofrequency and Microwave Radiation".

4.1.2.6. Electric Fields

Hazard Description

The ATLAS facility has accelerator and experimental equipment which makes extensive use of high voltage systems that can produce electric fields.

Impacts on Facility Personnel, Public, and Environment

The high voltage systems can generate electrical fields of sufficient strength to cause startle reactions in nearby personnel and ignition of flammable materials. These hazards do not impact the public or the environment.

Hazard Controls

The ATLAS facility incorporates a combination of engineered controls and administrative controls to control the electrical hazards present in the ATLAS facility (see Section 4.1.2.14). Additional hazard controls are prescribed in ANL ESH Manual Section 6.3 "Nonionizing Radiation Protection - Electric and Magnetic Fields".

4.1.2.7. Magnetic Fields

Hazard Description

The ATLAS facility has several systems in the accelerator (*e.g.*, gas catcher; focusing, steering, and bending magnets; and switch magnets) and the experimental equipment (*e.g.*, Canadian Penning Trap Spectrometer and Helical Orbit Spectrometer, HELIOS) which generate magnetic fields.

Impacts on Facility Personnel, Public, and Environment

A magnetic field with intensity greater than 5 Gauss could cause injuries to individuals with cardiac pacemakers or other medical electronic implants. A magnetic field with intensity greater than 30 Gauss could cause items made of ferromagnetic materials, such as hand tools, to become dangerous missiles. These hazards do not impact the public or the environment.

Hazard Controls

The gas catcher is inside radiation shielding and located on the CARIBU high voltage platform; access to the magnetic field when the magnet is energized is precluded by the access controls of the high voltage platform.

Fields of an intensity of 5 Gauss may occur in close proximity to the beam line magnets. Entrances to areas where such magnetic fields may exist are posted with signs warning of the magnetic field hazards, and yellow warning lights are installed at those magnets that are easily accessible.

The magnets for the spectrometers are large bore, superconducting solenoids typically used for magnetic resonance imaging (MRI) applications. For these magnets, the 5 Gauss field may reach 1 to 1.5 meters from the magnet; for the larger magnet used with the HELIOS, the 30 Gauss field may reach 2 to 4 meters from the magnet.

Administrative controls, rather than engineered controls, are used as hazard control methods for the hazards presented by these magnets. The magnetic field surrounding the magnet is mapped to establish the 5 and 30 Gauss lines and warning signs are positioned at those locations. A warning light is mounted on or near the magnet to indicate when the magnet is energized. Before the magnet is energized, the area will be searched to assure that no ferromagnetic objects are present. Additional hazard controls are prescribed by the Physics Division's Electrical Safety Policy and Manual and ANL ESH Manual Section 6.3 "Nonionizing Radiation Protection - Electric and Magnetic Fields".

4.1.2.8. Chemical Health Hazards

Hazard Description

Some of the materials used in ATLAS as targets and sources (e.g., beryllium, plutonium, etc.) are classified as toxic. Various chemicals which can be classified as corrosives, irritants, allergens, sensitizers, and volatile solvents are used for cleaning components of the facility.

Impacts on Facility Personnel, Public, and Environment

Toxic materials have the potential to cause severe health effects to facility personnel. Other chemical hazards have the potential to cause skin irritations to facility personnel during standard operations and accidents (*e.g*., dropping container). These hazards do not impact the public or the environment.

Hazard Controls

Administrative controls, rather than engineered controls, are used as hazard control methods for the chemical hazards present in the ATLAS facility. To minimize the potential hazards to personnel from these chemicals the quantities of the chemicals are minimized; the chemicals are properly labeled and stored when not in use; personnel are trained on the hazards of the chemicals; the appropriate personal protective equipment (*e.g.*, gloves) are used; and appropriate safety equipment (*e.g.*, eye wash stations) are positioned in the area where the chemicals are used. Additional hazard controls are prescribed by applicable sections of ANL ESH Manual Chapter 4 "Hazardous Material" and the Laboratory Management System

4.1.2.9. Combustion Hazards

Hazard Description

Various combustible materials (*i.e.*, flammable liquids, solvents, and gases; compressed oxygen; and paper and wood containers) are present in the facility and activities which could cause fires (*e.g.*, open flame, cutting, and welding operations) are conducted in the facility.

The use of flammable gases in the ATLAS facility is of particular concern. Isobutene gas is used as the ionization medium in various types of detectors for the experimental research program. Hydrogen gas is used in an ECR ion source for an experimental program for the production of high beam currents.

Impacts on Facility Personnel, Public, and Environment

Combustion hazards have the potential to cause minor burns to facility personnel during standard operations and accidents. These hazards do not impact the public or the environment.

Hazard Controls

Administrative controls and engineered controls are used as hazard control methods for the combustion hazards present in the ATLAS facility. The quantities of flammable liquids and gases permitted in the facility are limited and the materials are stored in approved storage cabinets when not in use. Permits are required for open flame or spark producing activities. Engineered controls include fire detection and fire suppression systems installed throughout the facility. Additional hazard controls are prescribed by applicable sections of ANL ESH Manual Chapter 11 "Fire Protection".

For activities involving flammable gases, applicable safety requirements are specified in the Physics Division's document "Procedures for the use of Isobutene and other Flammable Gases" and ANL ESH Manual Section 4.8 "Hydrogen Safety"

4.1.2.10. Thermal Contact Hazards

Hazard Description

The cryogenics system for the ATLAS facility uses liquid helium and liquid nitrogen. In addition, liquid helium is used in superconducting magnet spectrometers for the experimental program.

Impacts on Facility Personnel, Public, and Environment

Liquid helium and liquid nitrogen exist at very low temperatures and contact with these liquids or components containing them has the potential to cause minor cryogenic burns to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

Engineered controls (e.g., insulation of cold surfaces) are used to preclude some of the hazards presented by these cryogenic materials. Administrative controls are also employed. The appropriate personal protective equipment (*e.g*., gloves, face shield) will be used by personnel working with the cryogenic materials. Additional hazard controls are specified in the Physics Division's Cryogenics Safety Manual and in ANL ESH Manual Section 4.10 "Hazardous Materials - Cryogenic Liquid Safety".

4.1.2.11. Compressed Gases

Hazard Description

Compressed gas cylinders containing various types of gases are used in the ATLAS facility, primarily to support experiments and support activities.

Impacts on Facility Personnel, Public, and Environment

Compressed gas hazards have the potential to cause minor injuries to facility personnel during accidents (*e.g*., dropping cylinder). These hazards do not impact the public or the environment.

Hazard Controls

Administrative controls, rather than engineered controls are used as hazard control methods for the compressed gases hazards at the ATLAS facility. To minimize the potential hazards to personnel from these cylinders the cylinders are securely stored in designated locations, pressure regulators are not installed unless the cylinder is in use, and protective caps are in place when the cylinders are not in use. Additional hazard controls are prescribed in ANL ESH Manual Section 13.2 " Pressure Safety - Compressed Gas Cylinders".

4.1.2.12. Pressure and/or Vacuum Systems

Hazard Description

The pressure systems in the ATLAS facility include the sulfur hexafluoride storage tank, tandem tank and piping for the FN-Tandem Injector; and the liquid helium and liquid nitrogen systems. Numerous vacuum systems are present in the accelerator and experiment equipment of the ATLAS facility.

Impacts on Facility Personnel, Public, and Environment

Pressure and vacuum system could cause major injuries to facility personnel if these systems were to violently rupture producing damaging fragments and releasing asphyxiating gases (see Section 4.1.2.13 for a description of the asphyxiation hazards). These hazards do not impact the public or the environment.

Hazard Controls

Engineered controls used as hazard control methods for the pressure systems include: the use of coded pressure vessels (SF_6 storage tank and tandem tank, and liquid nitrogen storage tank); the use of standard, commercial design (liquid helium Dewars); and pressure relief burst disks (SF_6 storage tank and liquid nitrogen storage tank). In addition over 100 pressure relief values are positioned on the liquid nitrogen supply system to protect equipment. These valves act in series so that the failure of one valve cannot cause the system to be over-pressurized. The relief burst disks also serve to protect the system should the relief valves fail.

The vacuum systems at the ATLAS facility are located inside other components or structures which provide a measure of protection from the effects of a failure in the vacuum system itself.

4.1.2.13. Asphyxiation

Hazard Description

Asphyxiation hazards are present in the ATLAS facility due to the use of liquid nitrogen, liquid helium, and sulfur hexafluoride (SF_6). Liquid nitrogen is supplied to facility areas from a 20,000 gallon liquid nitrogen tank outside the building. Three 1,000 liter liquid helium storage Dewars are attached to the ATLAS cryogenic system, and five superconducting magnets contain up to 2,000 L of helium. A 12 m^3 tank for the tandem electrostatic accelerator is filled with SF_6 insulation gas at a pressure of about 80 psia.

Impacts on Facility Personnel, Public, and Environment

Asphyxiation hazards from liquid nitrogen, liquid helium, and sulfur hexafluoride have the potential to cause severe injuries, including death, to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

A combination of engineered controls and administrative controls is used has hazard control methods for the asphyxiation hazards present in the ATLAS facility.

The engineered controls include: (1) oxygen deficiency monitoring systems, (2) the use of standard, commercially designed liquid nitrogen Dewars, (3) the use of a coded pressure vessels for the SF_6 tandem tank and storage tank, and the liquid nitrogen storage tank, and (4) system pressure relief valves and burst disks in cryogenic systems.

The administrative controls include: caution during overhead crane operations in the vicinity of vessels containing liquid helium, liquid nitrogen, or SF_6; locating cryogenic vessels in locations that are not in traffic lanes; maintaining cryogenic distribution system free of significant contamination.

4.1.2.14. Electrical Hazards

Hazard Description

Electrical hazards due to high voltage devices, storage devices, grounding, and exposed conductors are present in the electrical equipment and power supplies at the ATLAS facility. The most significant electrical hazards are the high-voltage hazards associated with the ATLAS ion-source systems; the high voltage supplies for the booster-linac pin-diode circuits; and the more conventional electrical circuits distributed around the ATLAS facility, which are similar to conventional industrial installations.

Impacts on Facility Personnel, Public, and Environment

Electrical hazards can cause severe injuries, including death, to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

A combination of engineered and administrative controls are used as hazard control methods for the electrical hazards present in the ATLAS facility.

The engineered controls include protective enclosures (cages) which exclude personnel from the ion source platform electrical hazards; a redundant interlock system that inhibits the high-voltage supply when the cage-access gate is open; warning lights, signs, and horns; a mechanical grounding bar that automatically inhibits opening the access gate until the bar makes contact with the platform, and a manually operated grounding stick located on the entrance to the enclosing cage. In addition, dual interlock switches inhibit the ion source platform voltage when an overhead crane is located over the cage. The sources that are mounted on the platform are also biased by 10-50 kV with respect to the platform. All exposed parts biased with this voltage are enclosed in separate isolation cages. The access doors to the sources are either interlocked with sense switches and physical locks or use a capture key (Kirk Key) system that prevents operation of the bias supply when the doors are open. A grounding hook is mounted near those access doors and administrative rules require the use of those grounding hooks prior to handling any part of the source.

The administrative controls include labeling all potentially hazardous circuits with hazard warning notices; warning posters in areas where electrical hazards are present; use of appropriate personal protective equipment (*e.g.*, insulating gloves, arc flash protective helmets); compliance with lockout/tagout procedures; and the use of a hot work permit (approved by the Laboratory Director) for work on energized electrical circuits. Additional hazard controls are prescribed by the Physics Division's Electrical Safety Policy and Manual and ANL ESH Manual Section 7.1 "Work Spaces - Control of Hazardous Energy and Lockout/Tagout", Section 9.1 "General Electrical Safety", Section 9.2 "Electrical Worker Safety", Section 9.3 "Electrical Systems and Equipment".

4.1.2.15. Lifting Devices

Hazard Description

Building cranes are used for lifting and moving heavy items of equipment in the facility. Most of these operations involve moving equipment which contains no hazardous material. However, the building crane in the CARIBU building will be used to move and position the shielding cask containing the radioactive Cf source.

Impacts on Facility Personnel, Public, and Environment

Lifting device hazards have the potential to cause injuries to facility personnel during accidents (*e.g.*, dropping the load). In addition, an accident during lifting and moving operations could cause extensive damage to facility components.

During lifting operations involving the CARIBU shielding cask there is a concern with the potential for a release of Cf in the event of an accident. Modeling studies show the cask can tolerate a drop of at least six inches without damage; the transport procedures developed do not require the cask to be elevated more than twelve inches above a surface at any time. In addition, since the cask is sealed during those operations the radioactive material will remain within the cask even in the event of cask drop accident. Such an accident could create a situation which requires source recovery and decontamination of the inside of the cask; tasks which would present hazards to facility personnel. However, these hazards do not impact the public or the environment since no radioactive material is released.

Hazard Controls

Administrative controls, rather than engineered controls, are used as hazard control measures for the lifting hazards present in the ATLAS facility. To minimize the potential hazards building cranes are operated by trained and authorized personnel, hoisting and rigging equipment is inspected and maintained on a regular basis; and hoisting operations involving the CARIBU shielding cask will be designated as a “Critical Lift” and be planned, reviewed, and performed in accordance with the Argonne National Laboratory’s HOIST series of procedures. Additional hazard controls are prescribed in that series of procedures.

4.1.2.16. Load-Bearing Components

Hazard Description

Various load-bearing structures are used at the facility to support components of ATLAS. In general, these structures do not raise components more than a few feet above the ground surface.

Impacts on Facility Personnel, Public, and Environment

The hazards associated with load-bearing components have the potential to cause severe injuries to facility personnel during accidents (*e.g.*, collapse of the structure). In addition, an accident involving the load-bearing components could cause extensive damage to other facility components. However, these hazards do not impact the public or the environment.

Hazard Controls

Administrative controls, rather than engineered controls, are used as hazard control methods for the load-bearing components present in the ATLAS facility. Permanent structures (*e.g.*, high voltage platform) are typically designed using the engineering services of ANL's FMS Division, qualified ATLAS personnel, or a qualified outside contractor. Temporary structures (*e.g.*, test stands) are typically designed by Physics Division personnel, with the design being reviewed by a structural engineer.

4.1.2.17. Mechanical Contact Hazards

Hazard Description

Mechanical contact hazards include the hazards presented by sharp points or edges, moving parts, and pinch points. These hazards are most likely to be encountered during the maintenance of facility equipment and the assembly of experimental equipment.

Impacts on Facility Personnel, Public, and Environment

Mechanical contact hazards have the potential to cause minor injuries to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

Administrative and engineered controls are used for the mechanical contact hazards present in the ATLAS facility. To minimize the potential hazards to personnel from mechanical contact the work is generally performed by employees very knowledgeable with the systems (System Experts). Other workers are made aware of the potential hazards during the pre-job briefings. Work is performed using the appropriate personal protective equipment (*e.g.*, gloves, hard hats, work boots, etc.). Protective padding and caution tape are used to prevent contact with head-bump hazards and sharp edges. Protective guards are used to prevent contact with rotating shafts and other moving parts. Additional hazard controls are prescribed in LMS-PROC-78, Machine Guarding and Operation.

4.1.2.18. Ladders, Scaffolds, and/or Platforms

Hazard Description

Ladders, scaffolds, and platforms are used to provide facility personnel access to portions of the ATLAS facility and experimental equipment for installation and maintenance activities. In general, such work is done at heights less than six feet.

Impacts on Facility Personnel, Public, and Environment

Falls when using ladders, scaffolds, and platforms hazards have the potential to cause severe injuries to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

Administrative controls, rather than engineered controls, are used for ladder, scaffold, and platform safety in the ATLAS facility. To minimize the potential of fall hazards ladders are inspected before use, scaffold and platforms are erected by qualified personnel, and fall protection harnesses are used as appropriate. Additional hazard controls are prescribed in LMS-PROC-15 Safe Use of Scaffolds and LMS-PROC-13 Safe Use of Portable Ladders

4.1.2.19. Confined Spaces

Hazard Description

Two confined spaces exist at ATLAS; the Tandem Tank and a trench beneath the Tandem Tank.

The Tandem Tank is a large pressure vessel which is classified as a confined space. The tank is used to contain sulfur hexafluoride (SF_6) and is entered periodically for maintenance or repairs.

The trench beneath the Tandem Tank is deep enough to cause it to be classified as a confined space. It is entered periodically (twice a year) to test the Oxygen Deficiency Hazard monitors located within it. As soon as the SF_6 gas has been removed, the ODH alarm system for the tandem will be deactivated.

The new enclosed space in the booster area is not defined as a confined space. The exhaust from boil-off nitrogen will be vented by piping to outside the building as will liquid helium pressure relief valves and rupture disks. Even so, oxygen sensors will be installed in that region to monitor oxygen levels as an added backup.

Impacts on Facility Personnel, Public, and Environment

Confined spaces with unknown hazards have the potential to cause severe injuries to facility personnel. These hazards do not impact the public or the environment.

Hazard Controls

Administrative controls, rather than engineered controls, are use as hazard control methods for the confined space hazards present in the ATLAS facility. To minimize the potential hazards to personnel a confined space entry permit is required before entry of the space, the supply of asphyxiating gas is prohibited by double blocking the supply line, the atmosphere inside the tank is monitored, and an attendant who can access emergency support is posted. Additional hazard controls are prescribed in ESH-7.4 Work Spaces - Confined Space Entry and various LMS procedures.

4.1.3. Hazard Analysis Summary

Each of the hazards above were analyzed for risk level to facility personnel, the public and the environment. The risk level is based on the likelihood of occurrence (see Table 4-3) and the consequence of the occurrence (see Table 4-4), and results in a hazard being assigned a risk level of negligible, minor, or major (see Table 4-5.)

A summary of the hazard analysis is provided in Table 4-6. For normal operations, the ATLAS facility presents negligible risk to facility personnel and no risk to the public or the environment.

The hazard analysis was focused on the hazards associated with normal operations of the facility and showed that the engineered and administrative hazard controls were fully effective in controlling risks from these hazards under normal operating conditions. The next section of this SAD examines postulated accidents or incidents which could expose facility personnel, the public, and the environment to some of the identified hazards.

TABLE 4-3. Risk Likelihood Classification

DESCRIPTIVE WORD	LIKELIHOOD OF OCCURRENCE	DESCRIPTION
Anticipated	$10^{-1} > L > 10^{-2}$ per year	Incidents that may occur several times during the lifetime of the facility. Incidents that commonly occur.
Unlikely	$10^{-2} > L > 10^{-4}$ per year	Accidents that are not anticipated to occur during the lifetime of the facility. Natural phenomena of this class include: Uniform Building Code- level earthquake, 100-year flood, maximum wind gust, etc.
Extremely Unlikely	$10^{-4} > L > 10^{-6}$ per year	Accidents that will probably not occur during the lifetime of the facility. This class includes events considered design basis accidents or maximum credible incidents.

TABLE 4-4. Risk Consequence Classification.

DESCRIPTIVE WORD	CONSEQUENCES	DESCRIPTION
Negligible	May cause minor injuries that require only superficial professional medical attention. *Total effective dose equivalent is less than 1 rem.*	Minor on-site and negligible off-site impact on people or the environment.
Minor	May cause minor injuries that require professional medical attention. *Total effective dose equivalent is between 1 and 25 rem.*	Considerable on-site impact on people or the environment. Only minor off-site impact on people or environment.
Major	May cause injuries that require extensive professional medical attention. *Total effective dose equivalent is greater than 25 rem.*	Considerable on-site and off-site impacts on people or the environment.

TABLE 4-5. Risk Matrix.

	LIKELIHOOD		
CONSEQUENCE	**EXTREMELY UNLIKELY**	**UNLIKELY**	**ANTICIPATED**
MAJOR	Minor	Major	Major
MINOR	Negligible	Minor	Major
NEGLIGIBLE	Negligible	Negligible	Negligible

TABLE 4-6. Hazard Risk Level for Normal Operation after Mitigation.

HAZARD	FACILITY PERSONNEL	PUBLIC	ENVIRONMENT
Radioactivity	Negligible	None	None
Gamma and X-Ray Radiation	Negligible	None	None
Neutron Radiation	Negligible	None	None
Laser	Negligible	None	None
Radiofrequency and Microwave	Negligible	None	None
Electric Fields	Negligible	None	None
Magnetic Fields	Negligible	None	None
Chemical Health Hazards	Negligible	None	None
Combustion Hazards	Negligible	None	None
Thermal Contact Hazards	Negligible	None	None
Compressed Gases	Negligible	None	None
Pressure and Vacuum Systems	Negligible	None	None
Asphyxiation	Negligible	None	None
Electrical Hazards	Negligible	None	None
Lifting Devices	Negligible	None	None
Load-Bearing Components	Negligible	None	None
Mechanical Contact Hazards	Negligible	None	None
Ladders, Scaffolds, and Platforms	Negligible	None	None
Confined Spaces	Negligible	None	None

4.2. Accident Analysis

4.2.1. Methodology

In the previous section, various hazards present at the ATLAS facility were identified and described, control measures for those hazards were discussed, and levels of risk were assigned. In that hazard screening, it was shown that hazard control measures were effective in controlling the risk from those hazards during normal operations; however, the consequences of accidents due to human error, equipment malfunction, or natural phenomena were not addressed.

Without control measures to mitigate the consequences of exposure to those hazards, the potential consequences for facility personnel could be rated as negligible, minor, or major. Some examples illustrate this approach: the consequences of exposure to the chemical health hazards are rated negligible since the chemicals used at the ATLAS facility are primarily skin irritants; the consequences of exposure to the radioactive material used for ion production (*i.e.*, ^{252}Cf) are rated minor since the potential radiation dose is likely to be between 1 and 25 rem; the consequences of exposure to electrical hazards is rated as major since the exposure to high voltage could result in death.

The approach can also be applied to rate the consequences of the hazards for the public and the environment. Most of the hazards present at the ATLAS facility do not pose any threat to the public or the environment. The consequences of an accident resulting in an off-site release of the radioactive material used for ion production (*i.e.*, ^{252}Cf) are rated as minor since the potential radiation dose without mitigation at the nearest site boundary is estimated to be less than 25 rem.

The hazard consequence ratings for the hazards present at the ATLAS facility without mitigation are given in Table 4-7.

For a hazard which has a consequence rating of major or minor, a more detailed analysis of the hazard and the applicable hazard control methods is necessary. The analysis considers the consequences of accidents due to human error, equipment malfunction, natural phenomena, or external events. The objective of the analysis is to assure that the engineered and administrative controls provide sufficient mitigation of the hazard's consequence and likelihood to achieve a negligible risk classification for the hazard.

For those hazards which have a consequence rating of negligible, no further analysis is necessary. The engineered and administrative controls for those hazards are considered to be adequate.

TABLE 4-7. Potential Consequences of Hazards Without Effective Consequence Mitigation Measures

HAZARD	FACILITY PERSONNEL	PUBLIC	ENVIRONMENT
Radioactivity	-	-	-
Radioactive Material for Ion Production	Minor	Minor	Minor
Radioactive Irradiation Targets	Negligible	None	None
Radioactive Material for Detector Calibration	Negligible	None	None
Beam Deposited or Induced Radioactive Material	Negligible	None	None
Gamma and X-Ray Radiation	-	-	-
Beam-Induced Ionizing Photons	Negligible	None	None
X-Rays from Accelerating Structures	Negligible	None	None
X-Rays from Ion Sources	Negligible	None	None
Fission and Secondary Gamma Radiation from Cf	Minor	None	None
Neutron Radiation	-	-	-
Neutrons Produced by Ion Beams	Minor	None	None
Neutrons Produced by Cf Source	Minor	None	None
Laser	Negligible	None	None
Radiofrequency and Microwave	Negligible	None	None
Electric Fields	Negligible	None	None
Magnetic Fields	Negligible	None	None
Chemical Health Hazards	Negligible	None	None
Combustion Hazards	Negligible	None	None
Thermal Contact Hazards	Negligible	None	None
Compressed Gases	Negligible	None	None
Pressure and Vacuum System	Minor	None	None
Asphyxiation	Major	None	None
Electrical Hazards	Major	None	None
Lifting Devices	Negligible	None	None
Load-Bearing Components	Negligible	None	None
Mechanical Contact Hazards	Negligible	None	None
Ladders, Scaffolds, and Platforms	Negligible	None	None
Confined Spaces	Negligible	None	None

4.2.2. Accident Initiators

Various types of events could initiate accidents at the ATLAS facility. Such events include: operational accidents, facility accidents, natural phenomena, and external events.

Operational accidents refer to human errors during operation or maintenance and equipment or component failures. The likelihood of occurrence of operational accidents is classified as Anticipated.

Facility accidents refer to general events in Building 203 which could impact the safety of the ATLAS facility. Such events include the loss of electric power and fire. The likelihood of occurrence of facility accidents is classified as Anticipated.

Natural Phenomena includes earthquakes and tornados. Severe events which could produce forces which exceed the design criteria of the CARIBU addition to Building 203 are credible. The likelihood of occurrence of such severe natural phenomena is classified as Extremely Unlikely.

An external event is an event not directly associated with the ATLAS facility which could impact its safety. Typically, such events include explosions, fires, toxic chemical releases which occur at nearby facilities or transportation routes; none of those circumstances apply to the ATLAS facility. The facilities surrounding ATLAS, including those in Building 203, have been evaluated for their potential to cause such an impact on ATLAS in the event of an accident; no such potentials were found to exist. However, the crash of a liquid nitrogen delivery truck into the CARIBU addition to Building 203 is considered a credible event. The likelihood of occurrence of such a truck crash is classified as Extremely Unlikely.

4.2.3. Postulated Accidents

4.2.3.1. Radioactive Material for Ion Production

The hazards associated with radioactive material used for ion production were addressed in section 4.1.2.1.1. The most severe hazard is presented by the ^{252}Cf source. Accidents or events which damage the source could result in local radioactive contamination or release of the radioactivity outside the facility.

Minor damage to the source could be caused by: rough handling during transport or difficulties during source deposition which result in material flaking off the source; improper orientation or alignment during the attachment of the source to the source holder or operator error during the insertion (or withdrawal) of the source into the gas catcher which could result in contact with the shielding cask gate or other internal components; and excessive flaking of source material during operations due to high deposition density.

This minor damage to the source would result in radioactive contamination of the internal portions of the shielding cask and gas catcher by the ^{252}Cf. The radiation shielding precludes access to this contamination during operations; however, access to the contamination will be possible during maintenance activities. Because of the hazards presented by the source and fission product contamination, maintenance activities will be performed under a radiological work permit which requires a health physics technician to conduct a radiation survey before the activities can begin. Based on the radiation survey, the actual radiological hazards will be determined and the appropriate protective measures implemented to perform the work safely.

Major damage to the source could conceivably result from the effects of fire or severe natural phenomena (*i.e.*, earthquake or tornado).

Building 203 and the CARIBU addition have extensive fire detection and fire suppression (*i.e.*, sprinklers) systems. A fire starting within Building 203 and spreading to the CARIBU addition is not considered credible given the fire protective systems and the absence of large amounts of combustible materials in the areas. To examine the consequences of a fire within the CARIBU addition, it is postulated that a fire of unspecified origin occurs in the electrical cables near the high voltage platform. The analysis of such a fire shows that the equilibrium temperature of the shielding cask containing the ^{252}Cf source is approximately 72 ^{o}C, substantially below temperatures which could damage the polyethylene shielding or the source itself (Reference 4-5).

In the event of a severe earthquake or tornado, the CARIBU addition may experience extensive damage. To examine the consequences of such damage, it is postulated that a large roof I-beam weighing approximately 1,100 pounds falls eleven feet onto the shielding cask. The analysis of such an event shows that I-beam dents, but does not punch through, the one-half inch steel shell which encloses the shielding material (Reference 4-6).

The most significant potential for damage to the ^{252}Cf source is a truck crashing into the CARIBU addition. This situation is a credible event having the maximum potential for causing an off-site release of radioactive material; it is addressed in section 4.2.4 “Maximum Credible Incident”.

The safety system which mitigates the hazards associated with accidents involving the ^{252}Cf source is the radiation shielding provided for the shielding cask and the gas catcher, including its contamination confinement and heat absorption capabilities.

4.2.3.2. Fission and Secondary Gamma Radiation from Cf

The hazards associated with the fission and secondary gamma radiation from the ^{252}Cf source were addressed in section 4.1.2.2.4. The radiation shielding provided for the source is designed to limit the radiation dose rate to 1 mrem/hr at 30 cm. Accidents or events could damage the shielding or reduce the effectiveness of the shielding resulting in dose rates above the designed dose rate.

Minor damage to the shielding could be caused by rough handling during transport or during the mating of the shielding cask to the gas catcher. Errors during the assembly of the shielding could cause voids or streaming pathways to be created in the shielding.

The effectiveness of the radiation shielding will be evaluated during the initial testing of the shielding using ^{252}Cf sources less intense than the 2 Curie source. The radiation monitoring system in the CARIBU addition will confirm the effectiveness of the shielding during operations. Health physics technicians will perform radiation surveys of the shielding whenever an activity which could have compromised the shielding effectiveness has occurred and when the shield cask–gas catcher mating or unmating operation is conducted.

The safety systems which mitigate the hazards associated with accidents involving the gamma radiation from the ^{252}Cf source include: the radiation shielding provided for the shield cask and the gas catcher; and the radiation monitoring system for the CARIBU addition (NARIS).

4.2.3.3. Neutrons Produced by Ion Beams

The hazards associated with the neutron radiation produced by ion beams were addressed in section 4.1.2.3.1. The facility shielding was originally designed for the neutron radiation produced by beams of heavy ions and its effectiveness has been proven by over 20 years of operation. The most severe hazard is presented by the neutron radiation produced by beams of light ions.

A credible incident involving a light ion beam could occur when an experimenter enter a target area to optimize the alignment and detector arrangement. For this postulated incident it is assumed that the ECR ion source of the Positive Ion Injector will be used to provide a full beam of 3 pμA of ^{16}O at 10 MeV/u. The operator uses several beam attenuators to provide a pilot beam of 0.00025 pμA; at this beam current, the radiation levels in the target area are below 5 mrem per hour and the Operations Envelope permits access to the area.

Through a failure to follow procedures or poor communication between the experimenter and the operator, the operator removes one of the beam-limiting attenuators. This is a fairly slow process requiring approximately 30 seconds. The beam current increases by a factor of 1000, the largest single attenuation factor available, to 250 pnA. The experimenter is now in a radiation field of approximately 5 rem per hour.

There are several redundant systems that will mitigate the consequences of such an accident:

- the ARIS high-level area neutron monitors will exceed their programmed limits for neutrons and the beam will be inhibited in approximately five seconds,

- the ARIS low-level radiation monitors will respond and inhibit the beam within 1 second, and

Thus the total dose to the experimenter is expected to be below 2 mrem.

Another consequence mitigation measure is the characteristics of the ATLAS accelerator. For such high beams, the sudden added load of the high beam current requires careful tuning and adjusting of the accelerator parameters. If the high beam is suddenly injected, without further tuning and attention, this will likely cause quenching of some of the superconducting solenoids, and result in beam loss within the accelerator enclosure at lower energies and before the full intensity has been reached.

The safety systems which mitigate the hazards associated with accidents involving the neutron radiation from the ion beams include: the radiation shielding provided for the beam line; the radiation interlock system (ARIS); and the Beam Current Interlock System.

4.2.3.4. Neutrons Produced by Cf Source

The hazards associated with the neutron radiation produced by the ^{252}Cf source were addressed in section 4.1.2.3.2. The material on accident analysis provided in section 4.2.3.2 regarding the gamma radiation from the ^{252}Cf source is applicable to the neutron radiation for the source.

4.2.3.5. Pressure and Vacuum System

The hazards associated with pressure and vacuum systems were addressed in section 4.1.2.12. The primary concern with these systems is the possibility of violent rupture of a system containing liquid nitrogen or liquid helium.

The risk of a violent rupture of a liquid nitrogen system is small. The characteristics of the liquid nitrogen system which reduce the risk are:

- the volume of liquid nitrogen in individual vessels is small (less than 50 liters),
- the maximum rate of heat transfer into the liquid nitrogen caused by a failure of the insulation vacuum is small because of the presence of superinsulation around the vessels and piping,
- the heat of vaporization of liquid nitrogen is relatively large, and
- all vessels have adequate pressure relief.

The risk of a violent rupture of a liquid helium system is small. The liquid helium system was analyzed for pressure protection; pressure relief valves and burst disks were installed throughout the system to provide adequate protection. However, two potential hazards remain: trapped liquid helium in distribution lines, and accident-induced pressure in beam-line cryostats.

With respect to trapped liquid helium, all parts of the liquid helium distribution system have adequate pressure relief, with one exception. Through a design error, there is one tube in a distribution line that does not have pressure relief between three valves. It would be possible to close all of these valves while liquid helium is in the line, creating a trapped volume. The hazard potential is minimal because the amount of potentially trapped liquid helium is small (~0.5 kg), the tube in question is surrounded by four concentric layers of stainless-steel piping, only a limited number of highly trained people access this system, and the three valves all have tags attached stating they must be kept in the "open" position.

The potential rupture hazard for the beam-line cryostats needs to be examined mainly because of the relatively high probability of vacuum incidents (such as the accidental opening of a beam-line valve) which flood the insulation-vacuum region of the cryostat with air. A test conducted in 1980s showed that vacuum failures of this kind are not a safety hazard for the cryostats used in the ATLAS linac. However, it is physically possible, although highly improbable, to have a more rapid inrush of air because of a major mechanical accident in which a large opening is created in the vacuum wall of the cryostat itself.

The safety implications of a catastrophic rupture of the vacuum wall of a beam-line cryostat have been analyzed. Two volumes in the cryostat contain significant amounts of liquid helium: the entrance manifold holds about 6 kg of helium, and the exit manifold holds about 3.5 kg of helium. When the rate of air inflow is very large, the rate of heat input into the helium in the manifold is limited by the heat-transfer coefficient at the helium-vacuum interface. For an instantaneous loss of vacuum, the rate of pressure increase is small enough that the pressure relief capabilities of the entrance and exit manifolds are adequate.

However, several bellows attached to this manifold might not have the required safety for a worst case vacuum accident. A rupture of a bellows would not pose a safety hazard because: the manifold is enclosed within a secondary barrier, a large-volume thick-walled stainless steel cryostat with excellent pressure relief, and the amount of helium in the manifold is small.

The greatest concern for the violent rupture of a cryogenic system involves those structures that contain significant quantities of cryogenic fluids. These include:

- the three 1,000 liter liquid helium storage Dewars of the cryogenic system
- the two superconducting magnets, the 7 Tesla CPT magnet and the HELIOS magnet
- two superconducting solenoids and the superconducting switching magnet in the ATLAS beamline.

The safety systems which mitigate the hazards associated with accidents involving the liquid cryogens include pressure relief valves and burst disks, and the use of standard, commercially designed Dewars for liquid helium.

4.2.3.6. Asphyxiation

Asphyxiation hazards were addressed in section 4.1.2.13. These hazards could be caused by nitrogen, helium, and sulfur hexafluoride.

Nitrogen

The worst case accident for asphyxiation by nitrogen is that one of the main transfer lines from the 20,000 gallon liquid nitrogen tank outside the building could be severed at a location where the lines are approximately 10 to 15 feet above floor level. The three lines are located in the Tandem Vault, the Booster-Linac Room and the Experimental Areas III and IV. Because of their rigidity, these lines could each be severed only by a large force such as the overhead cranes used in the areas.

The crane near the line in the Tandem vault cannot reach the line and such an accident would be extremely improbable.

The crane near the line in the Booster-Linac room is used regularly, and there is a finite probability for such an accident in this location. To determine the effects of such an accident, an experiment was conducted which simulated such an event. The results of the experiment showed that even under this worst case condition, the oxygen content 45 inches above the floor was never less than 18 - 19%.

The crane in the Experimental Areas III and IV is used regularly, and the possibility of an accident occurring is in this area is credible when nitrogen is present in the system. The liquid nitrogen system in the Experimental Area presents a potential hazard only under certain specific circumstances. So far, it has been used only when Gammasphere was located at ATLAS. At all other times, the line has been inactive. When inactive, liquid nitrogen is prevented from entering the area by the closure of three upstream valves - two manual and one normally closed valve which is electronically controlled. The latter can only be opened when it receives power from the oxygen deficiency monitoring system in place in the area and when the system does not sense an oxygen deficiency. Therefore, when the monitoring system is inactivated, the valve is automatically placed in a closed position.

Helium

The worst case accident for asphyxiation by helium is the possibility that one of the three 1,000 liter liquid helium storage Dewars attached to the ATLAS cryogenic system or one of the superconducting magnets would rupture and release its contents suddenly.

The storage Dewars were built commercially by Cryenco to their standard storage-Dewar design, except for the neck, which is exceptionally large (6 inch diameter) in order to accommodate several helium-distribution lines. The Dewars are in different areas.

Similarly, the superconducting magnet vessels were commercially constructed to standard designs.

The most probable scenario for a sudden release of the liquid helium stored in a Dewar is that the vacuum wall of the Dewar is ruptured and the in-rushing air generates a large heat load on the inner vessel. A rupture of the vacuum wall could be caused by a massive blow from power equipment such as an overhead crane. An accident of this kind is very improbable because the cranes are rarely used in the neighborhood of Dewars.

A Dewar rupture caused by an ice blockage in its neck is extremely improbable because of the Dewar's design and because operation of the accelerator requires the whole helium distribution system to be maintained free of significant contamination. As has been proven during many years of operation, power failures and accidents to attached equipment (refrigerators, etc.) do not generate enough heat or pressure input to cause an explosive situation in a Dewar, because relief valves provide protection to those systems and to the Dewars.

The helium exiting from a ruptured Dewar or either of the superconducting magnets would rise to the ceiling of the high bay area in which it is located. The only exception to this situation is the area around the K Dewar; that area is protected by the presence of an oxygen deficiency sensor installed immediately above that Dewar.

Sulfur Hexafluoride (SF_6)

During operation, the 12 m^3 tank of the tandem electrostatic accelerator is filled with SF_6 insulation gas at a pressure of about 80 psia. When the interior of the tandem tank is opened for maintenance, the SF_6 is stored in liquid form in a high-pressure tank located in the service area above the tandem vault. Although SF_6 is not toxic, the large volume of inert gas associated with the tandem constitutes an asphyxiation hazard. At ATLAS, this hazard is present in three locations: the tandem tank, the tandem vault and the service area above the tandem vault.

The tandem tank and its piping are inherently safe against a sudden rupture. The tank is a coded pressure vessel with a certified maximum working pressure of 300 psig, and is operated at about 20% of this value.

In the tandem vault, outside the tandem tank, the asphyxiation hazard stems mainly from the large density of SF_6 gas (about 5 times greater than air), which would cause the SF_6 to stratify to the lower portion of the room. The most probable way that this hazard could be initiated is by the breaking of a pipe or port on the tandem tank. A breakage that could cause an SF_6 leak rate great enough to be potentially lethal would require a considerable force or impact, such as could be delivered by the overhead crane. An accident such as postulated here is very improbable because the crane, which is slow moving, is used rarely and then only for handling rather small objects such as beam-line components. Because of limited headroom, the crane cannot be used to transport large objects into the building from the truck door at the north end of the vault. If all of the gas in the tandem tank were released suddenly, the tandem vault would be filled with SF_6 to a depth of 7 ft.

The SF_6 storage tank or its piping could rupture. The storage tank is a coded pressure vessel that usually operates at a pressure of about 400 psi and has pressure relief at 650 psi by means of 2 parallel burst disks that exhaust outside the building. Sudden rupture of the system is very unlikely because there is no large source of energy such as a crane or a lift truck used in the area, there are few penetrations of the pressure vessel, and work activity in the area is infrequent. Fire cannot easily rupture the tank because it is insulated with non-flammable material, there is little flammable material in the area, and the area is equipped with smoke sensors and sprinklers.

The safety systems which mitigate the asphyxiation hazards include an oxygen deficiency monitoring system in the accelerator operations area; an active oxygen deficiency monitoring in the experimental area when liquid nitrogen is present; system pressure relief valves; the use of standard, commercially designed Dewars for liquid helium; and the use of coded pressure vessels for the SF_6 tandem tank and storage tank, and the liquid nitrogen storage tank.

4.2.3.7. Electrical Hazards

Electrical hazards were addressed in section 4.1.2.14. The primary electrical hazards are the high-voltage systems associated with the ion sources of the positive ion injector and the tandem.

Each of these sources is mounted on a platform with a maximum voltage greater than 200 kV and several other lesser voltages. For each system, a metal cage encloses the whole voltage platform, and a cage mounted on the platform encloses the components associated with the lesser voltages.

The safety systems associated with the steel cage around a voltage platform provide five levels of protection:

- the cage itself,
- a redundant interlock system that inhibits the high-voltage supply when the cage-access gate is open,
- warning lights, signs, and horns,
- a mechanical grounding bar that automatically inhibits opening the access gate until the bar makes contact with the platform, and
- a manually operated grounding stick located on the entrance to the enclosing cage.

In addition, dual interlock switches inhibit the ion source platform voltage when the overhead crane is located over the cage.

The safety system which mitigates the hazards associated with accidents involving high voltage electricity includes the high voltage platform cages with their safety systems, including the cage-gate interlock system.

4.2.4. Maximum Credible Incident

The maximum credible incident (MCI) for the ATLAS facility is postulated to occur in the CARIBU building as a result of an accident involving a truck delivering liquid nitrogen to Building 203 skidding on the turn in front of the CARIBU building and sliding into the building. The impact of the truck sliding into the building is assumed to cause the high-voltage platform to collapse in a non-uniform manner such that the gas catcher (which contains the radioactive Californium source) separates from the beam tube and drops to the floor level. The collapse of the high-voltage platform is assumed to result in mechanical damage to the Californium source. The separation of the gas catcher from the beam tube causes the Californium source to be exposed to the local environment; but the source remains located within the gas catcher at a distance of approximately 110 centimeters from the open end of the 5 centimeters diameter gas catcher-beam tube interface. The impact of the truck is also assumed to remove a section of the north wall of the CARIBU building resulting in an opening which is 2 meters high and 10 meters long.

The accident is assumed to result in a fire from the gasoline spilled from the truck with subsequent ignition of electrical cables and a computer work station. The gasoline spill is assumed to involve fifty gallons of gasoline and cover the entire floor area of the building uniformly. The value of fifty gallons is a conservative estimate; if the spill were greater than thirty-three gallons, the excess gasoline would flow out of the building, especially if a large opening were made in the building by the truck impact. One hundred electrical cables are assumed to run the full length of the CARIBU building along its centerline. The value of one hundred cables is taken as a bounding estimate of the amount of electrical cabling likely to be present in the building. A computer work station with combustible partitions and miscellaneous combustible papers and items is assumed to be located at the west end of the CARIBU building along its centerline. The computer work station is used to represent miscellaneous combustible materials (e.g., papers, manuals, furniture, etc.) located in the building.

The analysis of the building fire was performed using the computer program CFAST (Consolidated Model of Fire Growth and Smoke Transport), developed by the Building and Fire Research Laboratory of the National Institute of Standards and Technology (References 4-7and 4-8). The CFAST program has been evaluated by the Department of Energy (Reference 4-9) and has been approved for use in safety analyses of DOE facilities as part of the “tool box” of high-use safety software codes.

The analysis of the fire considered: (1) the temperature history of the outer surface of the gas catcher at the interface between it and the beam tube due to conduction heating by the local environment and radiation heating by the fire flames and hot gases, and (2) the temperature history of the hot upper layer of the fire atmosphere when the gas catcher interface was located within that layer. For this analysis, it is assumed that the gas catcher-beam tube interface has shifted to the center of the building and has dropped closer to the floor due to the collapse of the high-voltage platform. The analysis showed that the maximum temperature to which the Californium source would be exposed is less than 500 °C (Reference 4-10). Hence, although the Californium source is assumed to have been damaged by the collapse of the high-voltage platform, thermal damage of the source does not occur.

The dose calculation equation is

$$D = (\chi/Q) \times (BR) \times (Q) \times (RF) \times (DCF)$$

where

D = committed effective dose equivalent over a fifty year period [rem]
χ/Q = atmospheric diffusion parameter [sec/m^3]
BR = breathing rate [m^3/sec]
Q = radioactive source [Curie]
RF = release fraction [-]
DCF = dose conversion factor [rem/Curie]

The atmospheric diffusion parameter, χ/Q, for the MCI dose calculation refers to the airborne concentration of radioactive material at the nearest site boundary. Because of the location of the new Theory and Computing Science (TCS) Building, the term “site boundary” is ambiguous. Since Argonne is leasing the land for the TCS Building to a private organization, the “legal” site boundary remains about 152 meters from the CARIBU building. However, the construction security fence which separates the TCS Building area from the Argonne site and hence restricts public access to the Argonne site is located about 104 meters from the CARIBU building. When the TCS Building is completed it is expected that a new site boundary at a distance of about 150 meters from the CARIBU building will be defined. However, for the purposes of this dose calculation, the nearest site boundary is considered to be located 100 meters from the CARIBU building.

The treatment of atmospheric diffusion for the dose calculation utilizes information already generated for another Argonne organization by Nexus Technical Services Corporation (Reference 4-11). Nexus calculated the values of χ/Q at the Exclusion Area Boundary and at a distance of 100 meters for five nuclear facilities at ANL by applying the procedure given in NRC Regulatory Guide 1.145 “Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants” to meteorological data gathered at the ANL site from the period of 11-01-04 through 10-31-07 representing 17,520 hours of data. Using the calculated values of χ/Q an overall cumulative probability distribution was constructed and used to determine the χ/Q value that is exceeded 5 percent of the time. The reported values of the 95th percentile χ/Q for a distance of 100 meters from each facility are:

Facility	χ/Q @ 100 meters [sec/m^3]
Bldg 200, MA & MB Wings	4.205×10^{-3}

Bldg 205, G & K Wings	4.277×10^{-3}
Bldg 212, AGHCF	4.240×10^{-3}
Bldg 315, Vault 40	4.277×10^{-3}
Bldg 331	4.100×10^{-3}
Bldg 331 (Excluding building wake effects)	4.277×10^{-3}

As noted by Nexus, differences in the χ/Q values for these facilities are only affected by the building's minimum cross-sectional area. The Nexus analysis did not include the CARIBU building to Building 203. However since the same meteorological data was used for all of the analyzed buildings, the χ/Q value at 100 meters for the CARIBU building, excluding building wake effects, should be the same as that for Bldg 331 at 100 meters, specifically, 4.277×10^{-3} [sec/m^3].

The breathing rate, BR, for the dose calculation is 3.33×10^{-4} [m^3/s]. The breathing rate is recommended by ICRP-30 for adults engaged in light activity (Reference 4-12).

The source term, Q, for the dose calculation is taken to be 2.0 Curie of ^{252}Cf. The source term is based on the following:

1. the amount of material at risk is 2.0 Curie of Cf-252,
2. the fraction of the material which is damaged during the accident is 1.0, and
3. the material being released during the accident is not reduced by confinement or filtration (i.e., an unmitigated release).

Note that the amount of ^{252}Cf described in the scientific papers for the CARIBU Project is 1.0 Curie. The value of 2.0 Curie has been selected for the purposes of accident analysis to allow the use of the 2.0 Curie limit in the Accelerator Safety Envelope for the ATLAS Facility. It is not expected that the actual amount of ^{252}Cf will ever be as much as 2.0 Curie.

As mentioned in Section 3.2.2.1 "Cf Source", the Californium source could contain a mixture of Californium isotopes. If the source material is 65% ^{252}Cf, the source will contain 2 Ci of ^{252}Cf and 0.116 Ci of ^{250}Cf. Accordingly, a second source term of 0.116 Ci of ^{250}Cf is included in the dose calculation.

The release fraction, RF, for the dose calculation is taken to be 0.001. The release fraction is based on the following:

1. the airborne release fraction is 0.001, and
2. all of the released material is respirable.

The basis for the airborne release factor of 0.001 is that it is a value appropriate for mechanical damage to a non-volatile solid as reported in DOE-STD-1027-92 (Reference 4-13). The CFAST analysis of the postulated CARIBU building fire demonstrated that the Californium source could be exposed to a temperature of at most 500 ^{o}C, substantially lower than the Californium melting point of 900 ^{o}C. Accordingly, an airborne release fraction of 0.001 is a valid assumption.

The dose conversion factor, DCF, for ^{252}Cf is 1.57 x 10^{+8} rem/Curie and the dose conversion factor for ^{250}Cf is 2.06 x 10^{+8} rem/Curie. The basis for the dose conversion factor is ICRP-30 for ^{252}Cf and ^{250}Cf in a form having a Y lung clearance class (Reference 4-14).

The dose calculation for ^{252}Cf using the values of the parameters described above is:

$$D = (\chi/Q) \times (BR) \times (Q) \times (RF) \times (DCF)$$
$$D = (4.277 \times 10^{-3}) (3.33 \times 10^{-4}) (2.0) (0.001) (1.57 \times 10^{+8})$$
$$D = 0.447 \text{ rem}$$

and for ^{250}Cf is:

$$D = (4.277 \times 10^{-3}) (3.33 \times 10^{-4}) (0.116) (0.001) (2.06 \times 10^{+8})$$
$$D = 0.034 \text{ rem}$$

The calculated dose at a distance from the CARIBU building of 100 m for the postulated MCI is 0.481 rem.

This MCI is for an unmitigated release at ground level. It is assumed that no HEPA filtration of the radioactive material is provided by the building ventilation system. It is assumed that the fire burns without suppression by the building sprinkler system. Since the estimated offsite impact is less than 1 rem effective dose equivalent, the MCI is considered to have a negligible offsite impact

5. BASIS FOR ACCELERATOR SAFETY ENVELOPE

5.1. Introduction

Basic safety requirements that are applicable to the safe operation of the ATLAS facility are provided by Laboratory documents (*e.g.*, the Laboratory Management System, including LMS-PROC-188 Accelerator Safety), Physics Division documents (*e.g*., Radiation Safety Manual and Electric Safety Policy and Manual), and ATLAS facility documents (*e.g*., ATLAS Operations Procedures). Additional safety requirements that are focused specifically on accelerator safety are provided in the Accelerator Safety Envelope and the Operations Envelope.

The Accelerator Safety Envelope (ASE) defines the set of physical and administrative bounding conditions for safe operation of the ATLAS facility; the ASE is based on the engineered and administrative controls identified in the SAD as being necessary for the safe operation of the facility. The ASE is reviewed and approved by the DOE Argonne Site Office (ASO). Any activity violating the ASE must be terminated immediately and DOE /ASO must be promptly notified of the violation.

The Operations Envelope (OE) specifies a set of controls that are selected by the ATLAS facility management to assure that the conditions of the ASE are not exceeded. The OE is reviewed and approved by the Physics Division Director. Any violation of the OE must be promptly reported to the Division Director.

The engineered and administrative controls addressed in the ASE and OE include:

- Radiation Shielding
- Engineered Safety Systems (include interlock testing)
- Beam Parameter Limits
- Radiation Source Limits
- Facility Access
- Accelerator Operations Staff
- Experiment Reviews and Approvals

The controls are based on the hazard controls and safety systems identified in Chapter 4 “Safety Analysis”.

The Accelerator Safety Envelope and Operating Envelope are provided in a document at the Appendix of this SAD.

5.2. Radiation Shielding

Radiation shielding requirements are necessary to protect personnel from the radiation produced by ATLAS beams and sources.

The following requirement is specified in the ASE:

- A shielding configuration control program must exist to maintain dose during normal and abnormal operations within the specified Radiation Dose Limits. The ATLAS shielding program must be described in the ATLAS Operating Procedures or similar controlled-copy document. The Physics Division Radiation Safety Committee must review all changes to the shielding configuration.

The following requirement is specified in the OE:

- The Physics Division's Shielding Policy requires that shielding be used as necessary to limit the radiation exposure of the general public as well as facility employees and users. Any changes in the ATLAS shielding configuration shall be reviewed by the Division's Radiation Safety Committee.

5.3. Engineered Safety Systems

The radiation interlock systems (ARIS, NARIS, or functionally equivalent systems), and the Beam Current Interlock System help assure that the radiation dose limits of ATLAS facility personnel, including experimenters, are not exceeded. Systems that control and monitor potential airborne radioactivity within the CARIBU building help assure the radiological safety of facility personnel

The following requirements are specified in the ASE:

- A validated, engineered radiation safety system, consisting of ARIS as well as other active control devices, shall be in place and operational to the extent defined and described by this SAD.
- Calibration and testing requirements for ATLAS interlocks must be documented in the ATLAS Operating Procedures to ensure proper system operation.
- Calibration and testing requirements for those systems which control and monitor the potential airborne activity within the CARIBU building (including the building ventilation system, the building exhaust filtration system, the stack monitoring system and the CARIBU Vacuum line filtration system) must be documented in the ATLAS Operating Procedures to ensure proper systems operation.

The following requirement is specified in the OE:

- The engineered safety systems, ARIS (or its successor system,) and the ATLAS Beam-Current Monitor, must be functional for beam to be accelerated through the ATLAS facility. All personnel working at ATLAS must be trained to properly understand the functioning and use of the ARIS system.

5.4. Beam Parameter Limits

Beam parameter limits are necessary to assure that beam produced radiation is not so intense as to exceed the capacity of the radiation shielding.

The following requirement is specified in the ASE:

- Beams of the hydrogen isotopes ^{2}H and ^{3}H will not be accelerated by ATLAS to an energy of more than 0.4 MeV, except as results from minor impurities in other source materials.
- The energy of all beams from ATLAS will be less than 25 MeV/u.
- No operation shall be authorized to proceed with an Estimated Radiation Level ERL of the beam greater than 30 rem/h nor with a radiation field 1 m from any source in excess of 100 rem/hr.

The following requirements are specified in the OE:

- The energy of all ATLAS beams will be lower than 23 MeV/u.
- The energy of all beams accelerated by PII alone will be below 2.5 MeV/u.

5.5. Radiation Source Limits

A limitation is placed on the maximum radioactivity of the ^{252}Cf source to assure that it is not so intense as to exceed the capacity of the radiation shielding and to assure that the potential consequences of the Maximum Credible Incident do not exceed a small fraction of 25 rem at the site boundary.

The following requirement is specified in the ASE:

- The radioactivity of the ^{252}Cf source used for ion production at the ATLAS facility will not exceed 2.0 Curies.

The following requirement is specified in the OE:

- The radioactivity of the ^{252}Cf source used for ion production at the ATLAS facility will not exceed 1.75 Curies.

5.6 Facility Access

Controls on facility access help assure that the radiation dose limits are not exceeded for ATLAS facility personnel, including experimenters.

The following requirement is specified in the ASE:

- No entry is allowed to any area with radiation levels greater than 5 rem/h. Entry with levels below this, but exceeding the Operations Envelope, will require specific Radiological Work Permits.

The following requirements are specified in the OE:

- Access to the potential radiation areas of the facility is controlled when the accelerator is in an operational mode. The "facility" includes the fenced-in earth berms and part of the roof of the building housing ATLAS.
- Access to different parts of the facility is not permitted when the measured radiation level is greater than the specified "access limit" dose rate at one meter of 9 mrem/h for the ECR Deck, Tandem, 40^{O} Bend, Booster and ATLAS Linac Tunnel; or 5 mrem/h for Experimental Areas, or the integral of the dose rate measured in any area exceeds the "integrated dose limit" of 10 mrem at one meter while the area is occupied during the preceding 8-hour period.
- For primary beams with A lighter than 12 delivered to an ARIS-monitored area, access to that area is permitted only with a Radiological Work Permit and after the required experimental review.
- For all beams, access to any area adjacent to a beam area is permitted without a prior radiation survey only if the ERL of the beam is less than 100 mrem/h. For example, this includes lockable or interlockable areas that are not directly along the beam path but adjoining it, such as Target area III, at times when beams of high ERL are transported past the ATLAS high-energy cup. For any beam above this value of ERL all adjacent areas must be locked until a radiation survey has been performed and the health physicist has established access conditions, taking into account the beam current at the time of survey and the maximum approved value. For non-lockable adjacent areas, the Health Physicist assigned to the Physics Division will always establish access limitations on the basis of radiation surveys.
- The Access Gate of a beam area downstream of the accelerator will be locked if the Estimated Radiation Level ERL of the beam is greater than the "locked-state level" of 100 mrem/h. Entry to such an area may be allowed if a survey has verified that the Radiation Level is no higher than 5 mrem/h at 1 m. at that beam energy and intensity. Entry may continue at increased intensities so long as the Radiation Level remains below 5 mrem/h at 1 m. as scaled from the previous survey.

- Access to areas with radiation levels above the established limits, or bypass of any safety interlock, when conditions absolutely require it, is permitted only under the conditions specified in an approved procedure after a thorough review, and under a Radiological Work Permit.
- When the Estimated Radiation Level ERL of the beam in the area is less than the "locked state level", the operator may grant access to the experimental areas. For these low hazard beams the experiment spokesperson is responsible for monitoring the area status. Trained users are authorized to execute "low level" area sweeps (to search for and remove personnel). Completing such a sweep will place the experimental area in a "Restricted Access - Not Occupied" state. The user is responsible for monitoring the 8-hour integrated dose level and preventing it from reaching the Dose Limit.

5.7. Accelerator Operations Staff

Requirements on the training and qualification of ATLAS operators are necessary to assure that they can operate the facility in accordance with the specified safety requirements.

The following requirement is specified in the ASE:

- Minimum operating staff training and qualification requirements must be described in ATLAS Operating Procedures or similar controlled-copy document.

No requirement is specified in the OE.

5.8 Experiment Reviews and Approvals

No requirement is specified in the ASE.

The following requirements are specified in the OE:

- When helium is used as a support gas, the accelerator will not be tuned to a charge-to-mass ratio of 1/2 or 1/4 without an experiment-by-experiment review by an ad-hoc committee appointed by the Division Director.
- All experiments involving low-intensity beams having atomic weight greater than 11; an expected value of ERL less than 5 rem/hr in the ATLAS Linac Tunnel and the Experimental Area and less than 2 rem/hr in the 40^o bend region; and not producing a radiation field exceeding 15 rem/h 1 m from any source in any direction are considered standard operations and will be reviewed by the Operations Manager, the Division ESH/QA Engineer, the Physics Division Radiation Safety Committee, and other committees as necessary.
- All experiments involving the acceleration of beams with atomic mass less than 12 (except deuterium or tritium) which have an expected ERL less than 5 rem/h and are not expected to produce a radiation field exceeding 15 rem/h 1 m from

any source in any direction will require a separate documented review by the Physics Division Radiation Safety Committee. The review for each such experiment will include: a) a consideration of possible worst-case incidents, b) a reexamination of requirements for reentry into beam areas where a secondary beam is present and areas adjacent to them, c) an examination of the potential for excessive radiation in non-interlockable areas, and d) the imposition of additional administrative constraints, if needed. The committee's report to the Division Director will include a recommendation for approval (along with any additional administrative constraints) or disapproval. The Division Director must authorize each such experiment separately. • All experiments using beams with an Estimated Radiation Level ERL above 5 rem/h or which are expected to produce a radiation field exceeding 15 rem/h 1 m from any source in any direction will require a separate documented review by an ad-hoc committee called by the Division Director. This committee will include at least one member from outside the Physics Division. The review for each such experiment will include: a) a consideration of possible worst-case incidents, b) a reexamination of requirements for reentry into beam areas where a secondary beam is present and areas adjacent to them, c) an examination of the potential for excessive radiation in non-interlockable areas, and d) the imposition of additional administrative constraints, if needed. The committee's report to the Division Director will include a recommendation for approval (along with any additional administrative constraints) or disapproval. Subject to this review, the health physics technician(s) will be available at all times and will check radiation levels at least once per 8 hour shift. For such experiments the entire ATLAS facility will be operated under a Radiological Work Permit and access to the facility will, if determined to be necessary by the Facility Manager, be limited in the personnel allowed to enter. t. The Division Director must authorize each such experiment separately.

- All experiments using beams of deuterium or tritium will require a separate documented review by an ad-hoc committee called by the Division Director. This committee will include at least one member from outside the Physics Division. The review for each such experiment will include: a) a consideration of possible worst-case incidents, b) a reexamination of requirements for reentry into beam areas where a secondary beam is present and areas adjacent to them, c) an examination of the potential for excessive radiation in non-interlockable areas, and d) the imposition of additional administrative constraints, if needed. The committee's report to the Division Director will include a recommendation for approval (along with any additional administrative constraints) or disapproval. Subject to this review, the health physics technician(s) will be available at all times and will check radiation levels at least once per 8 hour shift. For such experiments the entire ATLAS facility will be operated under a Radiological Work Permit and access to the facility will be limited to personnel essential for operating ATLAS or the experiment. The Division Director must authorize each such experiment separately.

- Except for the beam-target location and the region upstream from the Booster linac, the primary accelerated beam must not be able to strike any material lighter than steel unless such use is approved by the Physics Division Radiation Safety Committee or an ad-hoc committee appointed by the Division Director.

6. QUALITY ASSURANCE

DOE Order 414.1D "Quality Assurance (Reference 6-1) specifies the quality assurance requirements which are applicable to non-nuclear facilities at Argonne.

The Laboratory's quality assurance policy is established in Chapter 12 "Quality Assurance Policy" of the ANL Policy Manual (Reference 6-2). Directions for the implementation of quality assurance measures are provided in the ANL Quality Assurance Procedures Manual (Reference 6-3). The Laboratory's quality assurance program is described in the ANL Quality Assurance Requirements and Description (Reference 6-4).

Some of the activities conducted at the ATLAS facility merit further attention because of their importance in assuring the quality of ATLAS operations and experiments. These activities include:

- Training of facility personnel, operators and experimenters assures that personnel are aware of the hazards of the workplace and have the knowledge to perform their activities in accordance with approved procedures.

- Technical reviews of experiments and facility modifications by standing and ad-hoc committees assure that the experiments and equipment can meet the intended objectives while performing in a safe manner without violations of the approved safety guidelines and envelopes.

- Peer reviews of experimental results assure that experimenters follow good scientific practices with regard to data collection and analysis.

- Equipment design is performed by qualified individuals having a strong understanding of science and technology since the uniqueness of the equipment precludes the use of industrial codes and standards.

- Equipment testing is used to assure that new and modified equipment can meet its performance requirements in a safe manner.

- Management and independent assessments, along with DOE/ASO oversight, provide facility and Division management with assurance that activities are being planned and conducted in a proper manner.

- Work planning and control is now a more structured process which adds value by requiring hazard analyses, subject matter expert reviews, and detailed procedures (References 6.5, 6.6, and 6.7).

7. POST-OPERATIONS PLANNING

The ATLAS facility, since its inception in 1985, has continually been upgraded to provide a state-of-the-art facility for nuclear research and this process is expected to continue for the foreseeable future. Argonne's proposal for the Advanced Exotic Beam Laboratory (ABEL) at ANL, one of the next generation of research accelerators, utilizes many portions of the existing ATLAS facility. The post-operations phase of the ATLAS facility's history is unlikely to occur for many years.

7.1. Facilitating Future Decommissioning, Decontamination, and Dismantlement

The modular nature of the ATLAS not only simplifies the upgrading of the system, but also facilitates the future decommissioning, decontamination, and dismantlement of the system. For example, the FN Tandem is one of the modules. It is being retired as part of the current ATLAS upgrade. It is likely that the tandem tank will be used to store the existing SF_6 for approximately one year. Following removal of the SF_6, funding will be requested for disposal of the tandem components, including the tank. Radioactive materials will be disposed of as low level radioactive waste if no use is found for them.

The beam parameter limitations not only provide safety protection for the facility workers, but also limit the production of radioactive material.

The agreement to return the Cf source to ORNL for recovery and reuse allows ANL to avoid the problems associated with the storage and disposition of the source.

The maintenance of records of ATLAS facility activities, operations, and experiments will provide information that could be useful for post-operations planning. The maintenance of as-built and as-modified system drawings, especially for electrical circuitry, will provide information that will be very useful for post-operations activities.

7.2. Transition Period Planning

Planning of those activities to be conducted during the transition period between facility shutdown and the beginning of decontamination/dismantlement operations is a crucial element of post-operations planning. During the transition period, the facility's experienced and knowledgeable staff can be used to efficiently and safely eliminate hazards (*e.g*., de-energize electrical circuits) and dispose of hazardous materials (*e.g.*, cryogenic liquids). The staff can also provide valuable assistance in characterizing the facility and planning the decontamination and dismantlement activities. The surveillance and maintenance of the facility during the transition period is an activity that could be performed by the facility staff.

The ATLAS facility will remain under DOE Order 420.2C during the post-operations activities. Accordingly, the facility's Accelerator Safety Envelope (ASE) will be revised, as appropriate, to reflect the changing conditions of the facility.

7.3. Decommissioning, Decontamination, and Dismantlement Planning and Performance

During this portion of the post-operations period, it is expected that the control of the former ATLAS facility will pass from the Physics Division to Facilities Management and Services Division.

The planning and performance of the decommissioning, decontamination, and dismantlement of the former ATLAS facility will be in accordance with the DOE and ANL requirements that are in place at the time of post-operations. These requirements will include the health, safety, and environmental protection requirements that are appropriate for a facility undergoing decontamination and dismantlement.

8. REFERENCES

1-1. Title 10, Code of Federal Regulations, Part 820 “Procedural Rules for DOE Nuclear Activities”

1-2. Title 10, Code of Federal Regulations, Part 835, “Occupational Radiation Protection”

1-3. Title 10, Code of Federal Regulations, Part 851, “Worker Safety and Health Programs”

1-4. DOE Order 420.1C, “Facility Safety”

1-5. DOE Order 420.2C, “Safety of Accelerator Facilities”

1-6. ANL Environment, Safety, and Health Manual

1-7. Laboratory-Wide Argonne Procedure LMS-PROC-188, Rev.0, “Accelerator Safety,” Effective Date: May 1, 2012

3-1. Safety Assessment Document; The Physics Division ATLAS Accelerator; 2009

3-2. Argonne National Laboratory; NWM-NSB-101 “Documented Safety Analysis Common Chapters; Revision OA; 04/26/07

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9. ACRONYMS AND DEFINITIONS

ALARA	As Low As Reasonably Achievable
ANL	Argonne National Laboratory
ARIS	ATLAS Radiation Interlock System
ASCE	American Society of Civil Engineers
ASE	Accelerator Safety Envelope
ASRC	Accelerator Safety Review Committee
ATLAS	Argonne Tandem-Linac Accelerator System
Average Radiation Dose Rates	The radiation dose rate as measured in the facility by ARIS detectors is integrated over at least a one second time interval. Beam inhibits due to levels of radiation associated with dose rates in excess 0.1 rem/hr are based on a one second average. Beam inhibits because of radiation levels less than 0.1 rem/hr but that are incompatible with existing area access states are based on a 30 second average.
Beam-stop	Any object that can be struck by the beam and is thick enough to stop the beam (Faraday cups, beam-defining slits, valves, etc.)
CARIBU	CAlifornium Rare Ion Breeder Upgrade
DOE	Department of Energy
E/A	Energy per mass number of the accelerated ion. A quantity expressing the ratio of beam energy (E), in millions of electron-volts (MeV) and the atomic mass number (A). The unit of this quantity is MeV/u, where u implies unit mass number. The atomic mass number A, an integral number as used in this document, is also called the ion mass number and the nucleon number
ECR	Electron Cyclotron Resonance
EPA	Environmental Protection Agency
ERL	Estimated Radiation Level. The dose rate (in mrem/h at 1 m) generated by the

	beam striking any unshielded surface 90º from the beam direction. This dose rate is estimated by calculations and confirmed by measurement with the same beam species and at the applicable full energy, and extrapolating it to the maximum beam current for a given experiment. This dose rate is calculated at 90° because it is an angle readily accessible for measurements at ATLAS in all cases.
HELIOS	Helical Orbit Spectrometer
JHQ	Job Hazard Questionnaire
LMS	Laboratory Management System
LN$_2$	Liquified Nitrogen Gas (liquid nitrogen)
MCI	Maximum Credible Incident
MeV	Million Electron Volts. A measure of particle energies. One eV is equal to the amount of energy one electron acquires by accelerating (from rest) through a potential difference of one volt. 1 eV = 1.602 x 10^{-19} Joule
NARIS	New (CARIBU) Radiation Interlock System
NFPA	National Fire Protection Association
NRC	Nuclear Regulatory Commission
ODH	Oxygen Deficiency Hazard
OSHA	Occupational Safety and Health Administration
PC	Performance Category
PII	Positive Ion Injector
pnA	Particle nanoampere. The electrical current in nanoamperes (10^{-9} A) that would be measured if all beam ions were singly charged. 6.25×10^{9} ions/second
RWP	Radiological Work Permit
SAD	Safety Assessment Document
Secondary Beam	A beam of exotic nuclei produced at ATLAS through a nuclear reaction of a primary beam with a target. Following the production, the secondary beam is transported by the accelerator system and focused on a target for an experiment.
SSC	Structure, Systems, and Components
TLD	Thermoluminescent Dosimeter

TMS	Training Management System
USDA	United States Department of Agriculture

APPENDIX

ACCELERATOR SAFETY ENVELOPE
for the
ARGONNE TANDEM-LINAC ACCELERATOR SYSTEM (ATLAS)

(November 2013)

1. Radiation Shielding

   1.1. A shielding configuration control program must exist to maintain dose during normal and abnormal operations within the specified Radiation Dose Limits. The ATLAS shielding program must be described in the ATLAS Operating Procedures or similar controlled-copy document. The Physics Division Radiation Safety Committee must review all changes to the shielding configuration.

2. Engineered Safety Systems

   2.1. A validated, engineered radiation safety system, consisting of ARIS as well as other active control devices, shall be in place and operational to the extent defined and described by this SAD.

   2.2. Calibration and testing requirements for ATLAS interlocks must be documented in the ATLAS Operating Procedures to ensure proper system operation

   2.3 Calibration and testing requirements for those systems which control and monitor the potential airborne activity within the CARIBU building (including the building ventilation system, the building exhaust filtration system, the stack monitoring system and the CARIBU Vacuum line filtration system) must be documented in the ATLAS Operating Procedures to ensure proper systems operation.

3. Beam Parameter Limits

   3.1. Beams of the hydrogen isotopes 2H and 3H will not be accelerated by ATLAS to an energy of more than 0.4 MeV, except as results from minor impurities in other source materials.

   3.2. The energy of all beams from ATLAS will be less than 25 MeV/u.

   3.3. No operation shall be authorized to proceed with an Estimated Radiation Level ERL of the beam greater than 30 rem/h nor with a radiation field 1 m from any source in excess of 100 rem/hr. (See Note)

4. Radiation Source Limits

   4.1. The radioactivity of the ^{252}Cf source used for ion production at the ATLAS facility will not exceed 2.0 Curies.

5. Facility Access

   5.1. No entry is allowed to any area with radiation levels greater than 5 rem/h. Entry with levels below this, but exceeding the Operations Envelope, will require specific Radiological Work Permits.

6. Accelerator Operations Staff

   6.1. Minimum operating staff training and qualification requirements must be described in ATLAS Operating Procedures or similar controlled-copy document.

Note: The rationale for describing the ASE in terms of a radiation level (vs. a bounding current) is that the radiation level is dependent on the parameters of the ion species being accelerated. There are numerous ion species of varying mass that are accelerated with different energies, charges, and currents to fit the need of the experimenter. A limiting current or energy limit for a particular beam species that would be associated with a particular ERL may not be appropriate for another beam species. Specifying the envelope in terms of a radiation level will allow normalization of the radiation effect of the various ion species for comparison to a common evaluation guideline. The evaluation guideline has been shown to be a safe bounding value based on the analysis documented in ATLAS Report RA-5, "Radiation Shielding Considerations at ATLAS", K. E. Rehm, July 9, 1991 and ATLAS Report RA-7 Maximum Radiation Does Rates From the ATLAS Facility, R.C. Pardo, August 7, 2002. Radiation levels of the ion species with various parameters are based on operational experience and extrapolation of empirical data.

OPERATIONS ENVELOPE
for the
ARGONNE TANDEM-LINAC ACCELERATOR SYSTEM (ATLAS)

(November 2013)

1. Radiation Shielding

   1.1. The Physics Division's Shielding Policy requires that shielding be used as necessary to limit the radiation exposure of the general public as well as facility employees and users. Any changes in the ATLAS shielding configuration shall be reviewed by the Division's Radiation Safety Committee.

2. Engineered Safety Systems

   2.1. The engineered safety systems, ARIS and the ATLAS Beam-Current Monitor, must be functional for beam to be accelerated through the ATLAS facility. All personnel working at ATLAS must be trained to properly understand the functioning and use of the ARIS system.

3. Beam Parameter Limits

   3.1. The energy of all ATLAS beams will be lower than 23 MeV/u.

   3.2. The energy of all beams accelerated by PII alone will be below 2.5 MeV/u.

4. Radiation Source Limits

   4.1. The radioactivity of the ^{252}Cf source used for ion production at the ATLAS facility will not exceed 1.75 Curies.

5. Facility Access

   5.1. Access to the potential radiation areas of the facility is controlled when the accelerator is in an operational mode. The "facility" includes the fenced-in earth berms and part of the roof of the building housing ATLAS.

   5.2. Access to different parts of the facility is not permitted when the measured radiation level is greater than the specified "access limit" dose rate at one meter of 9 mrem/h for the ECR Deck, Tandem, 40^0 Bend, Booster and ATLAS Linac Tunnel; or 5 mrem/h for Experimental Areas, or the integral of the dose rate measured in any area exceeds the "integrated dose limit" of 10 mrem at one meter while the area is occupied during the preceding 8-hour period.

   5.3. For primary beams with A lighter than 12 delivered to an ARIS-monitored area, access to that area is permitted only with a Radiological Work Permit and after the required experimental review.

5.4. For primary beams with mass between 11 and 23 delivered to an ARIS-monitored area, access to that area is permitted only for energies E/A under 10 MeV/u.

5.5. For all beams, access to any area adjacent to a beam area is permitted without a prior radiation survey only if the ERL of the beam is less than 100 mrem/h. For example, this includes lockable or interlockable areas that are not directly along the beam path but adjoining it, such as Target area III, at times when beams of high ERL are transported past the ATLAS high-energy cup. For any beam above this value of ERL all adjacent areas must be locked until a radiation survey has been performed and the health physicist has established access conditions, taking into account the beam current at the time of survey and the maximum approved value. For non-lockable adjacent areas, the Health Physicist assigned to the Physics Division will always establish access limitations on the basis of radiation surveys.

5.6. The Access Gate of a beam area downstream of the accelerator will be locked if the Estimated Radiation Level ERL of the beam is greater than the "locked-state level" of 100 mrem/h. Entry to such an area may be allowed if a survey has verified that the Radiation Level is no higher than 5 mrem/h at 1 m. at that beam energy and intensity. Entry may continue at increased intensities so long as the Radiation Level remains below 5 mrem/h at 1 m. as scaled from the previous survey.

5.7. Access to areas with radiation levels above the established limits or bypass of any safety interlock, when conditions absolutely require it, is permitted only under the conditions specified in an approved procedure after a thorough review, and under a Radiological Work Permit.

5.8. When the Estimated Radiation Level ERL of the beam in the area is less than the "locked state level", the operator may grant access to the experimental areas. For these low hazard beams the experiment spokesperson is responsible for monitoring the area status. Trained users are authorized to execute "low level" area sweeps (to search for and remove personnel). Completing such a sweep will place the experimental area in a "Restricted Access - Not Occupied" state. The user is responsible for monitoring the 8-hour integrated dose level and preventing it from reaching the Dose Limit.

6. Experiment Reviews and Approvals

6.1. When helium is used as a support gas, the accelerator will not be tuned to a charge-to-mass ratio of 1/2 or 1/4 without an experiment-by-experiment review by an ad-hoc committee appointed by the Division Director.

6.2. All experiments involving low-intensity beams having atomic weight greater than 11; an expected value of ERL less than 5 rem/hr in the ATLAS Linac Tunnel and the Experimental Area and less than 2 rem/hr in the 40^{o} bend region; and not producing a radiation field exceeding 15 rem/h 1 m from any source in any direction are considered standard operations and will be reviewed by the Operations Manager, the Division ESH/QA Engineer, the Physics Division Radiation Safety Committee, and other committees as necessary.

6.3. All experiments involving the acceleration of beams with atomic mass less than 12 (except deuterium or tritium) which have an expected ERL less than 5 rem/h and are not expected to produce a radiation field exceeding 15 rem/h 1 m from any source in any direction will require a separate documented review by the Physics Division Radiation Safety Committee. The review for each such experiment will include: (a) a consideration of possible worst-case incidents, (b) a reexamination of requirements for reentry into beam areas where a secondary beam is present and areas adjacent to them, (c) an examination of the potential for excessive radiation in non-interlockable areas, and (d) the imposition of additional administrative constraints, if needed. The committee's report to the Division Director will include a recommendation for approval (along with any additional administrative constraints) or disapproval. The Division Director must authorize each such experiment separately. 6.4. All experiments using beams with an Estimated Radiation Level ERL above 5 rem/h or which are expected to produce a radiation field exceeding 15 rem/h 1 m from any source in any direction will require a separate documented review by an ad-hoc committee called by the Division Director. This committee will include at least one member from outside the Physics Division. The review for each such experiment will include: (a) a consideration of possible worst-case incidents, (b) a reexamination of requirements for reentry into beam areas where a secondary beam is present and areas adjacent to them, (c) an examination of the potential for excessive radiation in non-interlockable areas, and (d) the imposition of additional administrative constraints, if needed. The committee's report to the Division Director will include a recommendation for approval (along with any additional administrative constraints) or disapproval. Subject to this review, the health physics technician(s) will be available at all times and will check radiation levels at least once per 8 hour shift. For such experiments the entire ATLAS facility will be operated under a Radiological Work Permit and access to the facility will be limited to personnel essential for operating ATLAS or the experiment. The Division Director must authorize each such experiment separately.

6.5. All experiments using beams of deuterium or tritium will require a separate documented review by an ad-hoc committee called by the Division Director. This committee will include at least one member from outside the Physics Division. The review for each such experiment will include: (a) a consideration of possible worst-case incidents, (b) a reexamination of requirements for reentry into beam areas where a secondary beam is present and areas adjacent to them, (c) an examination of the potential for excessive radiation in non-interlockable areas, and (d) the imposition of additional administrative constraints, if needed. The committee's report to the Division Director will include a recommendation for approval (along with any additional administrative constraints) or disapproval. Subject to this review, the health physics technician(s) will be available at all times and will check radiation levels at least once per 8 hour shift. For such experiments the entire ATLAS facility will be operated under a Radiological Work Permit and access to the facility will, if determined to be necessary by the ATLAS Director,be limited in the personnel allowed to enter. The Division Director must authorize each such experiment separately.

6.6. Except for the beam-target location and the region upstream from the Booster linac, the primary accelerated beam must not be able to strike any material lighter than steel unless such use is approved by the Physics Division Radiation Safety Committee or an ad-hoc committee appointed by the Division Director.