

APPENDIX B
SITING ANALYSIS

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APPENDIX B. SITING ANALYSIS

B.1 SITING OPTIONS

In Chapter 1 of the *Final Environmental Impact Statement for the Sounding Rockets Program at Poker Flat Research Range*, “Purpose and Need for the Action,” the National Aeronautics and Space Administration (NASA) indicated that it intends to maintain a high-latitude launch site in the United States (U.S.) to support research critical to the understanding of the Sun–Earth connection and upper atmosphere. However, due to concerns raised by project stakeholders during the scoping process for the Environmental Impact Statement (EIS), NASA considered several other sounding rocket launch sites that might meet some or all of the science requirements that have been identified for performing high-latitude and auroral science. The other sites considered are the Kodiak Launch Complex (KLC) in Alaska; the now-decommissioned Fort Churchill Rocket Range near Churchill, Manitoba; the Andøya Rocket Range (ARR) launch sites in Andøya, Norway, and Ny-Ålesund, Svalbard (an archipelago in the northernmost part of Norway); and the Esrange Space Center near Kiruna, Sweden. This Appendix summarizes NASA’s evaluation to determine if either site could be considered a reasonable alternative to Poker Flat Research Range (PFRR) and should thereby be evaluated in detail in the EIS.

B.1.1 Kodiak Launch Complex

The KLC on Kodiak Island, Alaska, is the only other U.S. facility at a latitude potentially compatible with the needs of the typical science missions supported by PFRR. However, the KLC is designed to launch in the southeast-to-southwest direction, over the open water of the Pacific Ocean (FAA 1996). The approved launch trajectories would prohibit reaching the northern launch azimuths necessary to obtain data that support the types of scientific missions conducted at PFRR. The large population centers north of the KLC (Anchorage and Matanuska-Susitna Valley areas) greatly increase the risk for rocket stages to impact populated areas following launch.

B.1.2 Churchill Research Range

The Churchill Research Range near Churchill, Manitoba, was a primary sounding rocket launch site for Arctic science, including auroral science, from its start in 1954 (Pfister 1967) (see **Figure B–1**). The rocket launching facilities were constructed adjacent to the Fort Churchill military base and operated by the U.S. Army and later U.S. Air Force until 1970, when management and funding became the responsibility of the Canadian National Research Council. Operations continued with limited funding until 1984, when the Canadian rocket program was canceled and funding for the Churchill Research Range terminated (Shepherd and Kruchio 2008).

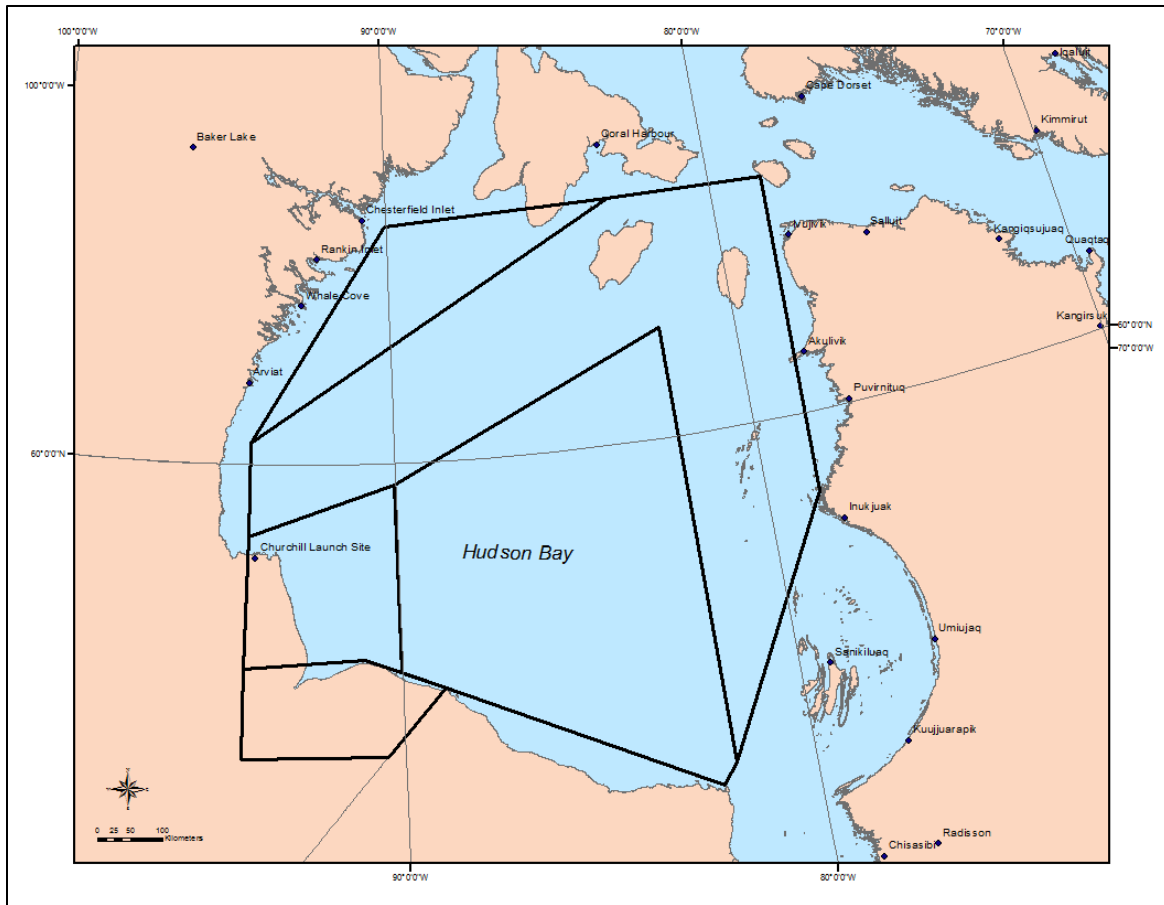


Figure B-1. Historic Fort Churchill Range Boundaries

The facilities were extensively used for northern latitude and auroral research until many U.S.-sponsored launches shifted to PFRR in the late 1960s. Launches continued at Fort Churchill through 1989, when two NASA launches occurred. Operations were then discontinued. A single launch occurred in April 1998 during an attempt to privatize the launch complex and turn it into a commercial launch site at an announced cost of \$300 million (**Astronautix 2011**).

All Fort Churchill launch and support facilities are now decommissioned and the actual remaining Fort Churchill launch facilities are designated the “Churchill Rocket Research Range National Historic Site of Canada.” The site is now home to the Churchill Northern Studies Centre, a non-profit environmental and biological research organization which occupies a number of the facilities that were used by the launch operation.

There is little, if any, ground-based support instrumentation at the launch site. Any launches carried out there would presumably be toward east into the Hudson Bay, and it would be essentially impossible to find downrange sites under the trajectories that could be used to deploy critical ground-based instruments. Churchill Research Range is also on foreign soil, which makes many operations more difficult.

For Churchill Research Range to be a viable alternative to PFRR it would need to be outfitted comparably as a permanent launch facility capable of supporting annual launch operations; temporary placement of mobile equipment is not practical on a regular basis. Accordingly, at least two, and most likely three, sheltered launchers would be required. In addition, new facilities, including a motor storage and assembly building and a payload processing building (both with bridge cranes), would be needed. Downrange science instrumentation would need to be installed at least two, and possibly three, sites on the perimeter of Hudson's Bay at considerable expense (**Hickman 2011**). Communications infrastructure would also be needed, and it is likely that at least a large portion of this infrastructure, if not all, would need to be resurrected. This would be both a cost and environmental impact of considerable undertaking (**Hickman 2011**).

B.1.3 Andøya Rocket Range

ARR is located in northern Norway (see **Figure B-2**). The range cooperates with the European Space Agency and supports orbital satellite, sounding rocket, and balloon operations. ARR has two launch sites for sounding rocket operations (**NASA 2005**), as follows:

- Andøya, Norway: N 69°17' E 16°01'
- Ny-Ålesund, Svalbard: N 78°55', E 11°51'

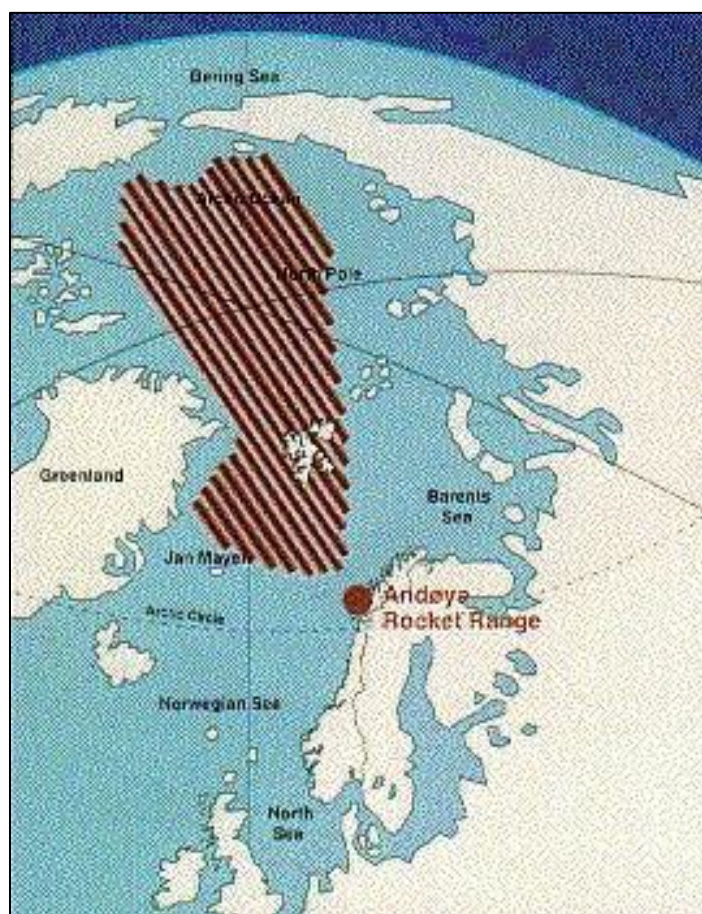


Figure B-2. Andøya Rocket Range

Launch Facilities – ARR has seven launch pads in the launch area and can, if required, launch rockets simultaneously (generally not more than two). Several launch pads are covered by heated shelters. See **Figure B–3** for a photograph of launch facilities at ARR.

The launch facility in Ny-Ålesund, Svalbard, has one covered launch pad equipped with a universal launcher.



Source: NASA 2005.

Figure B–3. Launch Facilities at Andøya Rocket Range

Support Facilities – The launch site at Andøya has offices and two payload preparation facilities, both fitted with gantry cranes, and associated infrastructure for payload systems checkout. ARR has two fixed telemetry systems and one mobile system. A Science Operation Centre is available onsite for determining optimum scientific launch conditions.

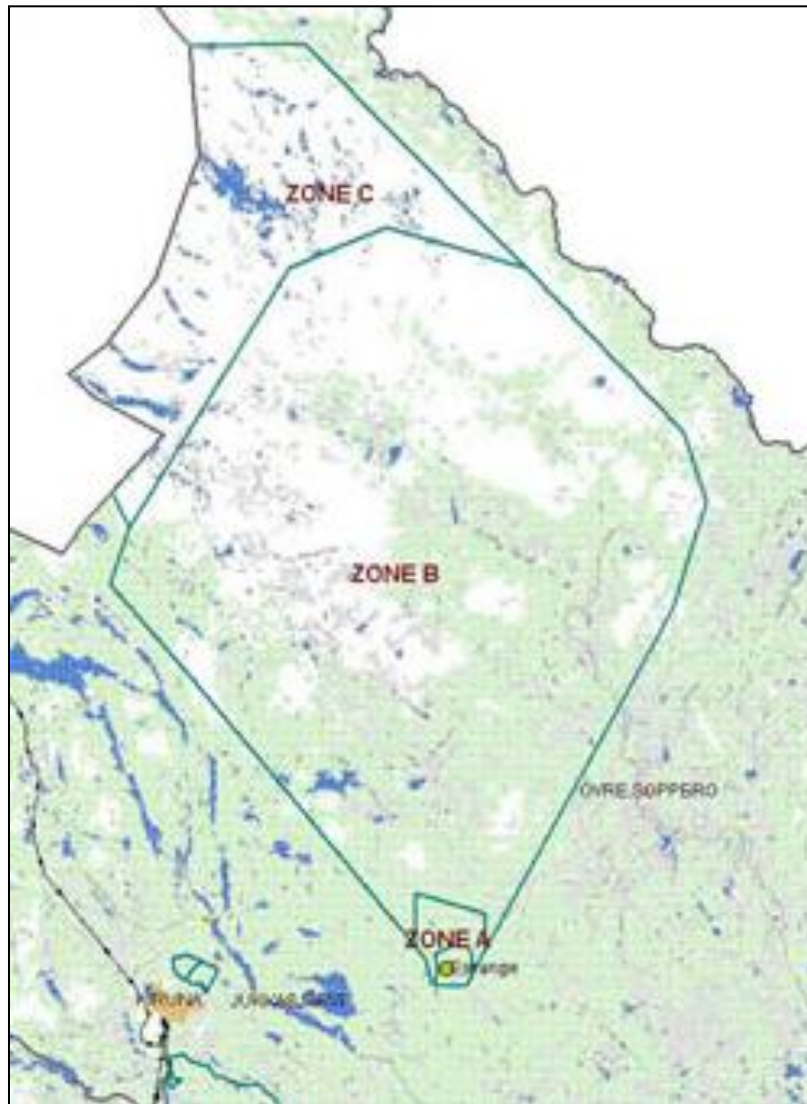
Recovery – ARR also provides recovery of the payload from the Norwegian Sea, provided that the payload is equipped with a recovery system (parachute and flotation system).

B.1.4 Esrange Space Center

Esrange Space Center is situated in northern Sweden above the Arctic Circle near Kiruna, Sweden at latitude 67° 53'N, longitude 21° 04'E. The base supports orbital satellite, sounding rocket, and balloon operations. The base is managed by the Swedish Space Corporation, which is a state-owned limited corporation under the Ministry of Industry (NASA 2005).

Launch Range – The rocket stages and payloads land in the Esrange Impact Area, a large uninhabited diamond shaped area north of Esrange Space Center in the Swedish tundra region, 120 kilometers (74 miles) long and 75 kilometers (46 miles) wide (see **Figure B–4**). The Esrange Impact Area is divided into three zones, A, B, and C, with a total area of 5,600 square kilometers (2,162 square miles). Zone A, the impact area for boosters, can be extended when rockets with long-range boosters are launched. Zones B and C are impact areas for second and

third stages, as well as payloads. Zone C is not allowed for use from May 1st through September 15th. The nominal impact point normally chosen is situated 75 kilometers (46 miles) north of the launch pads (SSC 2011).



Source: SSC 2011.

Figure B-4. Esrange Impact Area

Launch Facilities – The site includes six permanent launchers and support facilities, including environmental shelters and a blockhouse. Multiple rockets (up to 2) can be launched in succession.

Support Facilities – There are two large rocket preparation buildings equipped with gantry cranes. A ground observation station, Kiruna Esrange Optical Platform System (KEOPS), is located onsite (SSC 2011). Downrange observations can be made from two different sites within the impact area north of the launch site. Additionally, a network of ground-based scientific instrumentation has been established in northern Scandinavia. One is the Swedish Institute of Space Physics. Another installation is the European Incoherent Scatter (EISCAT) Facility,

comprising a system of stations in Norway, Sweden, and Finland. In Sweden is a climate research center, which supports scientific research in Arctic regions and location of ground-based instrumentation (SSC 2011).

Recovery – Recovery of payloads is a common requirement, with approximately 50 percent equipped with recovery systems. Recovery missions are generally successful.

Rocket motors are not recovered immediately following the launch. People visiting the impact area during non-winter months occasionally find the motors and are offered a small reward for finding the motor. It is then typically recovered.

B.2 SITE SELECTION PROCESS

The NASA Sounding Rockets Program (SRP) defined several criteria to determine if there are any reasonable alternative launch sites to PFRR for meeting the purpose and need for NASA's action. These criteria included:

Criterion 1: Site and Range Must Meet the Research Needs of the Scientific Community

The site and range must provide scientists the ability to meet the research goals identified in Chapter 1 of the EIS, including studies of aurora and the sun-earth connection. Since the stated purpose and need for this action is only for high-latitude science, this effectively restricts launch sites to those that would permit rocket flights within the northern (or southern) high-latitude areas of the Earth. For much of the expected future scientific needs of the NASA SRP, this area is further restricted to the auroral areas around the Earth's magnetic poles.

Figure B-5 illustrates the area around the magnetic pole where the aurora intensity is greatest and the northern launch sites that have historically been used for sounding rocket research. Most aurorae occur in a band known as the auroral zone, which is typically 3 to 6 degrees in latitudinal extent and extends around the magnetic pole. The auroral zone is typically 10 to 20 degrees from the magnetic pole. During a geomagnetic storm, the auroral zone will expand to lower latitudes. Auroral research with sounding rockets is typically performed during periods of high activity and intense auroral displays. During these periods, the launches from PFRR can be made such that the payload transverses both sides of the auroral oval, which increases the scientific data returned.

The site should also have practical range characteristics that are necessary to directly support the collection of scientific data or substantially enhance the science that might be achieved. As a "land" range, PFRR has the advantage of having villages downrange with commercial aircraft access and the ability to establish permanent or semi-permanent monitoring stations. Prior to a launch, support staff can be safely deployed to these sites for weeks at a time, which is critical when awaiting a natural phenomenon, such as the aurora. PFRR's access to an array of established, ground-based research instruments (*e.g.*, magnetometers, all-sky cameras, and lidars) enables researchers to gauge optimum scientific conditions before deciding to launch. PFRR also has a database of observations from ground-based instruments that provides the environmental context into which the rocket measurements may be interpreted.



Figure B-5. General Graphic Depiction of the Auroral Oval

In addition to providing information vital to the understanding of optimal launch conditions, the downrange instrumentation often provides a significant contribution to the research objectives. For example, scientists can observe the aurora with ground-based optics and other instrumentation to put in context the measurements taken by the in situ instruments on board the payload during the flight. A good example is the measurement of neutral winds, which is an important aspect of auroral studies. This can only be done reliably using ground-based optics to track artificial clouds made in the ionosphere and employing triangulation to obtain wind speed and direction (triangulation requires three geographically separated sites) (**Hickman 2010**).

The range should also facilitate the recovery of the payload as desired for scientific reasons. Whether desired for re-use of an instrument (as in the case of a telescope-type payload) or analysis of samples collected (as in the case of an air sampler payload), the ability to recover proves to be a major advantage of PFRR for some missions.

Evaluation

Kodiak Launch Complex – the site is designed to launch in the southeast-to-southwest direction, over the open water of the Pacific Ocean (FAA 1996). The approved launch trajectories would prohibit reaching the northern launch azimuths necessary to obtain data that support the types of scientific missions conducted at PFRR. Therefore, the KLC is eliminated as a reasonable alternative and will not be discussed further in this appendix.

Fort Churchill – During periods of high auroral activity, the site is well with the auroral oval, and at times available scientific conditions may be similar to those that can be obtained at PFRR; however it is at a much lower geographic latitude than PFRR (58.76 degrees versus 65.08 degrees), making it much less suitable for those experiments that depend on high geographic latitude, such as the study of Polar Mesospheric Clouds and Polar Mesospheric Summer Echoes (Conde 2012).

By contrast, Fort Churchill's geomagnetic latitude is three degrees higher than PFRR, which could be considered a detriment for many auroral studies. Assuming that launches would fly generally in a northerly direction, it would place the rockets well north of the aurora in many cases. Even at PFRR scientists often face the challenge that if the aurora is active, it can be too far south to permit a launch. This challenge would be much worse at Churchill.

The same problem arises with any science mission targeting active aurora. Magnetic activity moves the aurora equatorward, so that PFRR is actually about as far north as researchers want to be to study bright and active auroral phenomena.

Fort Churchill could in fact have advantages for a very limited number of experiments for which it may be advantageous to fly eastward, along the auroral oval, which cannot be done from PFRR due to concerns regarding safety (discussed in more detail below) as well as the limitation for crossing the Canadian border.

Norway and Sweden – During periods of high auroral activity, these sites are at high geographic latitudes, but the magnetic latitudes, which determine the location relative to the auroral oval, are much lower than those at PFRR for the site at Andøya and the site at Esrange Space Center and much higher than those at PFRR for the site at Svalbard. PFRR provides access to the auroral oval that is not easily reached from these northern Scandinavian sites (Larsen 2011).

Depending on the type of science and the range/altitude of the experiment, only PFRR would be suitable as it is further north magnetically, which affects the location of the auroral substorms. The more disturbed the substorm, the further south it moves, and if the scientists want to study a particular phenomenon, Norway may not be suitable (Hickman 2010). There is good ground-based instrumentation support in the vicinity of all three ranges, including science radars and optical instrumentation. However, these sites have the same limitation as Fort Churchill in that locations for instrumentation under the rocket trajectories are not available for rockets launched over the ocean (Larsen 2011).

For typical SRP launches from Norway or Sweden, much of the flights would be over water and ship-based observations would be necessary. While not impossible, the cost of ship-based

observations at multiple sites would substantially raise the costs of equivalent science and introduce added uncertainty to the launch windows given the concerns related to long-duration (*e.g.*, for weeks at a time) ship-borne operations in areas with highly variable weather conditions.

A key limitation of the Swedish range is its size; thereby limiting launches to single-stage and smaller two-stage rockets. The inability to launch the most frequently employed vehicles for recent heliophysical research (*e.g.*, Terrier-Improved Orion, multi-stage Black Brants [BBs]) from the Sweden site precludes it from being considered a reasonable alternative to PFRR.

Conclusion – Based on the evaluation of the “Scientific Need” criterion, only Churchill Research Range in Canada can achieve the majority of auroral and high-latitude science identified as needed by NASA in Chapter 1 of the EIS. However, its lack of downrange observatories would limit the types of missions conducted.

Although well-suited for conducting certain types of auroral research, the characteristics of the launch sites in Norway and Sweden do not permit them to fulfill the science objectives identified in the purpose and need of the EIS, and are therefore not considered reasonable alternatives to PFRR.

Criterion 2: Site and Range Would Allow Operations to be Conducted Safely

NASA strictly follows range safety requirements that are consistent with other Federal agencies and require that the safety risks to people, aircraft, and structures be extremely low, as described in Chapter 2 of the EIS. The practical implication for unguided sounding rockets is that the downrange areas over which the sounding rocket motors and stages travel and land must be remote with very few people. Thus, sounding rockets must be launched over water or, when over land, in areas where the population is very low.

Evaluation

Fort Churchill – Employing the same methodology as it uses in developing Flight Safety Plans and Risk Assessments for sounding rocket missions, NASA evaluated the potential for the Fort Churchill Range to safely support the flight of its BB-class of vehicles (BBIX, BBX, BBXI, and BBXII). These vehicles were chosen as they are the highest performing in the SRP’s fleet and are most likely to be specified by auroral scientists in the future.

The analysis, which employed the same risk acceptance criteria that is utilized for mission planning at PFRR, indicated that the BBIX could be flown safely at a wide range of azimuths, however the BBX, BBXI, and BBXII required much more easterly azimuths (greater than 30 degrees from true north for the BBXI and greater than 60 degrees for BBX) (**Computer Sciences Corporation 2012**). To provide context, typical missions flown from PFRR fly azimuths in the 5 degree (from true north) range. The analysis of the most powerful vehicle, the BBXII, returned a range of acceptable launch azimuths (greater than 35 degrees); however, it was limited to a launcher setting that would provide a lower payload apogee, which could have some effect on its meeting both safety and scientific requirements. In all cases, trajectories were over the Hudson Bay, which avoided the populated Hudson Bay shoreline.

Conclusion – In summary, when compared to PFRR, Fort Churchill would provide only a very limited set of permissible northerly azimuths for the SRP’s highest performing vehicles; thereby, limiting the range of scientific opportunities available. Therefore, when safety considerations are weighed, Fort Churchill’s ability to support PFRR-like science is marginal at best.

Criterion 3: Site and Range Would Provide Practical and Cost-Effective Facilities and Infrastructure

The site and range must provide practical and cost-effective facilities and infrastructure that enhance the ability of the SRP to support the scientific and research community. Even the optimum location from purely a scientific perspective may not be practical if the logistics of conducting a launch, including installation of launchers, downrange support equipment, and facilitation of recovery, are not practical. Budgets within the SRP have always been quite limited, and its goal has always been to obtain the most scientific return at the lowest possible cost.

Evaluation

Fort Churchill – The practicality of PFRR stands out in comparison to Churchill Research Range as it does not contain any active launch infrastructure. Moreover, its remaining facilities have been retrofitted to support ecological research. While it is still technically possible to launch from Fort Churchill using mobile launchers, employing the “mobile campaign” approach as a long-term solution does not meet NASA’s needs as a PFRR site alternative, especially when considered within the context of its geographic limitations (that affect the scientific value), safety restrictions (that limit equivalent northerly azimuths), and lack of downrange support infrastructure. The cost of building new permanent launch and support facilities at a new site on foreign soil, such as at Fort Churchill, would be above the future budgets of the SRP, requiring severe curtailment of its activities, thereby not meeting NASA’s purpose and need. Due its lack of infrastructure, Churchill Research Range is eliminated as reasonable alternative launch site to PFRR.

B.2.1 Overall Evaluation of Launch Sites

Based on the three criteria which were science, safety, and available facilities, PFRR is the only site that fully meets all program requirements. Other existing U.S. launch sites cannot achieve the needed science objectives. Churchill Research Range could in principle meet some science needs; except it does not permit northward launches and its geomagnetic latitude would preclude it from providing the same level of scientific opportunities as PFRR. Furthermore, the practical details and costs associated with equipping the launch area and downrange sites with the needed scientific observation equipment would make this an impractical alternative for future scientific missions as currently envisioned. Other northern launch sites in Norway and Sweden are practical and will continue to be used for some NASA SRP missions, but because of their geographic location relative to the auroral zone, and certain range characteristics, they cannot achieve the science that is obtainable at PFRR. Based on this evaluation process, PFRR is the only site that fully meets the purpose and need for the SRP and the only site considered reasonable for the *PFRR EIS*. Therefore, the EIS only addresses alternative approaches for continuing NASA’s SRP mission at PFRR.

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