EISCAT_3D AU Installation Scheme

1. EISCAT_3D AU System Overview

The EISCAT_3D AU system to be delivered consists of 229 AUs. Each AU is in a hexagonal shape, comprising of 91 antenna elements, an antenna frame, a container, connecting structural parts and RF cables, etc. The 229 AUs will be installed in three EISCAT_3D sites in Norway, Sweden and Finland.

Table 1-1 AU Deliverables

SN	Sub-array Qty	Antenna Element Qty	Container Qty	Site	Rmks
1	/	91×1	1	Sweden	First article, already installed
2	/	91×10	10	Norway	Independent array
3	109	91×109	109	Norway	Core array
4	54	91×54	54	Sweden	Half core array
5	55	91×55	55	Sweden	Half core array

The core antenna array at the Skibotn site will be composed of 109 sub-arrays. The sub-arrays will cover an area with length of 82.105m and width of 78.69m, and the total area will be about 4685m2. Each column of the core array forms a vertical passage with a width greater than 3m and a height of about 3m, which facilitates the passage of maintenance & support vehicles (width: 2m; height: 2m).

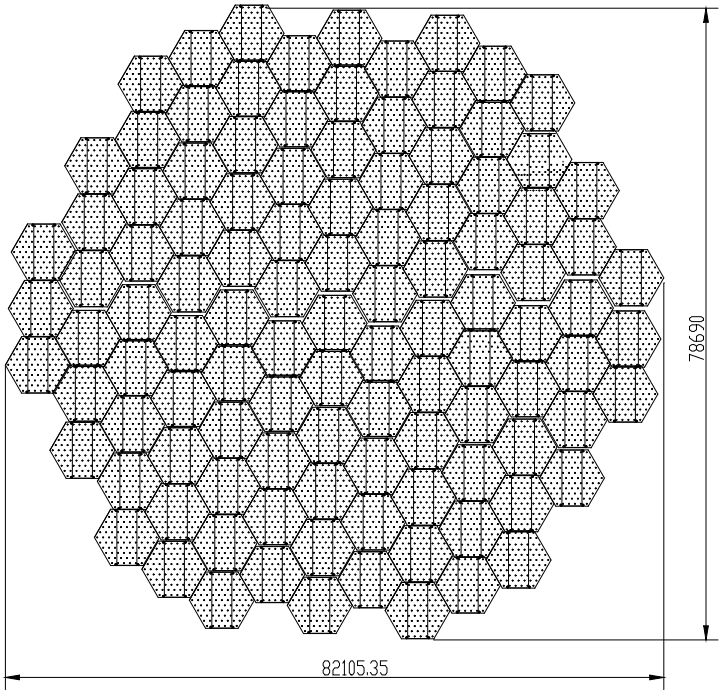


Figure 1-1 Skibotn Site Core Array (109 Sub-Arrays)

2. AU Structure Description

2.1. Structural Specifications

For the Skibotn site core array, structural specifications of the sub-arrays after being installed shall satisfy:

1) Spacing precision of the antenna elements in a single sub-array: ±3mm
2) Spacing precision of the antenna elements between sub-arrays: ±10mm
3) Normal plane precision of antenna array: 15mm (RMS)

The specifications are basically the same for sites in Sweden and Finland, while normal plane precision of antenna array can be improved to 10mm (RMS).

2.2. AU Structural Composition

Each AU is mainly composed of antenna elements, antenna frame, container, mounting base (1 & 2), upper adjustment blocks (1 & 2) and RF cables, etc. The container is placed on the ground supported by mounting bases. The 91 antenna elements are mounted on the antenna frame to form an antenna array. The array is placed on top of the container via upper adjustment blocks. The antenna elements are

connected to the interconnection boards on the container via RF cables that are arranged in the cabling racks. Overall structural layout of the AU is illustrated in Figure 2-1 below.

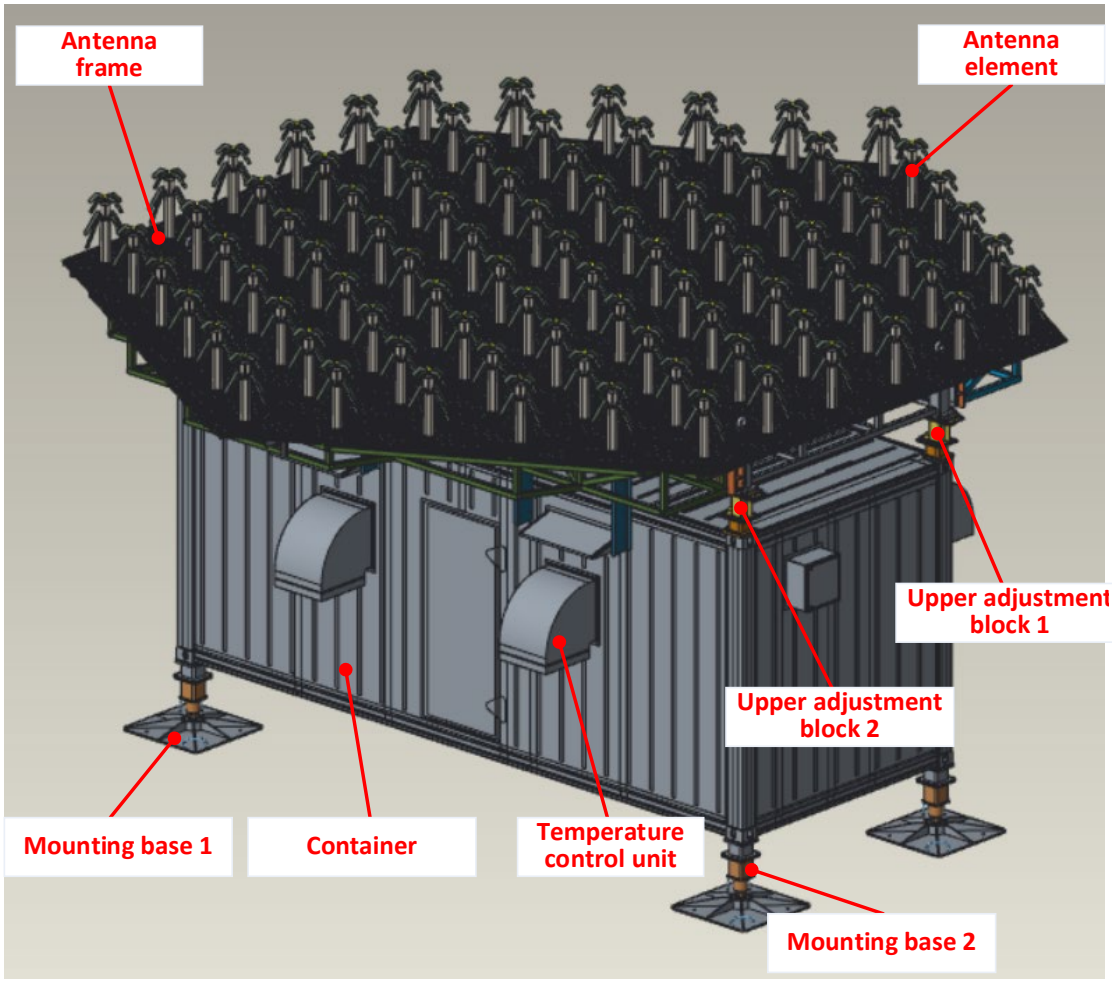


Figure 2-1 Structural Layout of AU

As illustrated in Figure 2-2, the AU antenna frame is divided into 5 blocks: 1 middle block, 2 side blocks (side block 1 / 2), and 2 single-reflection plates. These blocks are bolted to each other, and the middle block and the side blocks are positioned via the positioning pin. In addition, there are 8 sets of cable rack installation plates and cable racks mounted at the bottom of the antenna frame. The antenna frame is connected to the upper adjustment blocks (on top of the container) through the 4 flanges at the bottom of the middle block, and the middle hole of the flange is used for positioning. The RF cables on the antenna frame are pre-installed before shipment, and the cable ends are wrapped with film protection.

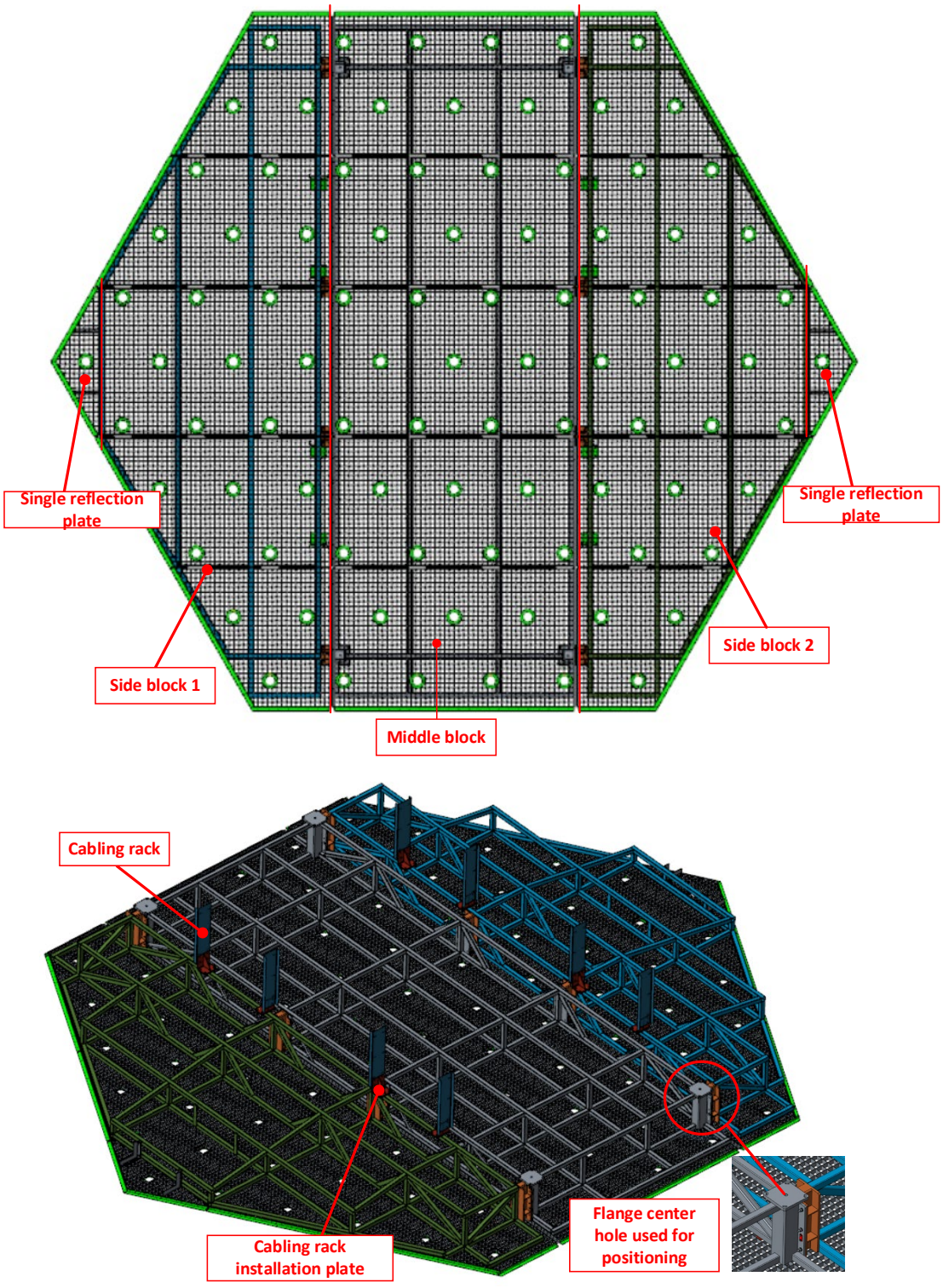


Figure 2-2 Structural Composition of AU Antenna Frame

As shown in Figure 2-3, the AU container is of standard 20GP size. Inside the container there are 7 racks, 1 power distribution box, lighting equipment and temperature control devices. The container functions as the support structures for the whole EISCAT_3D system, and also provides good shielding and thermal insulation

performance, to create good operating environment for the electronic equipment inside the container. During the transport, the external structural parts of the container such as rain cover, air inlet, air outlet and protective boxes are loaded into the container and installed on site.

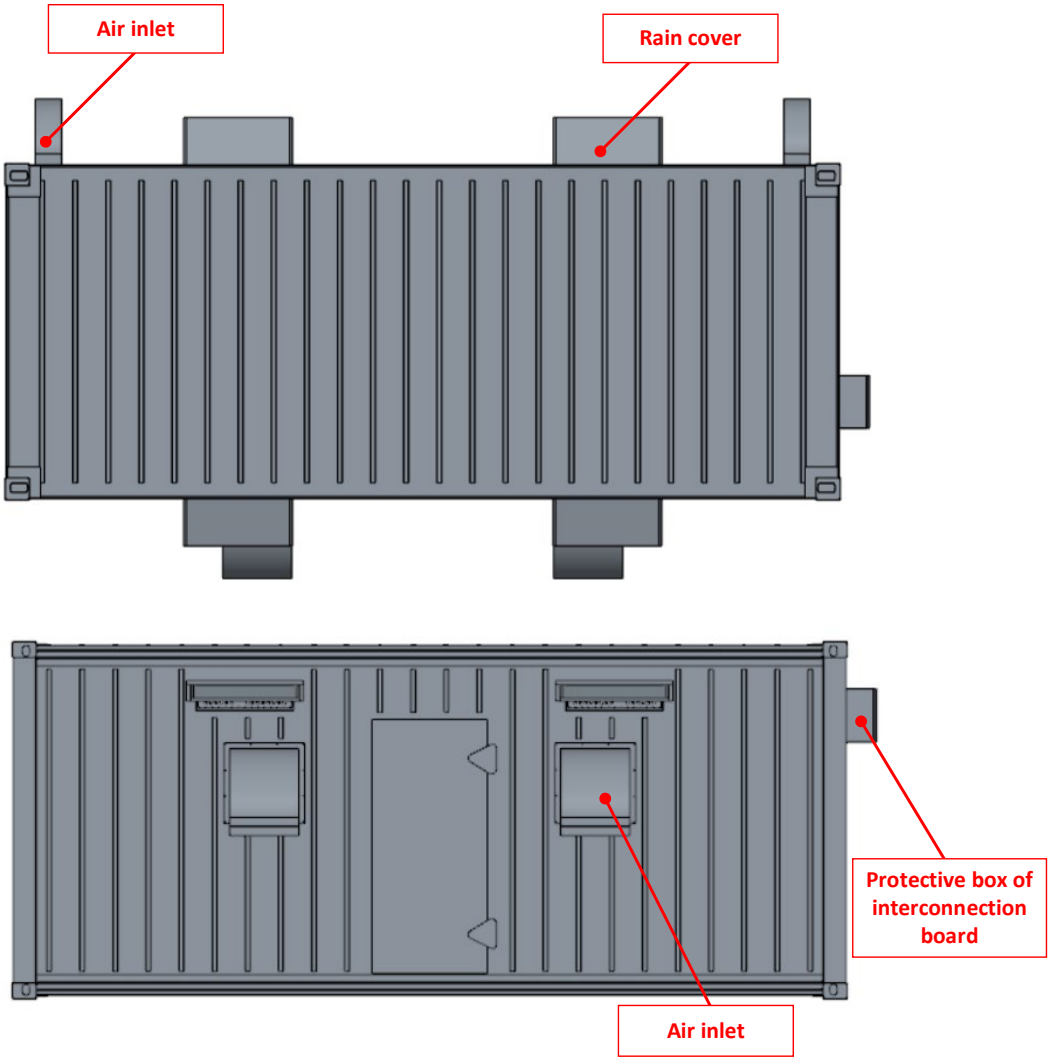


Figure 2-3 Structural Composition of AU Container

The mounting base is connected to the container bottom corner fitting via a screw lock, which can realize Z-direction height adjustment of ± 80mm, as shown in Figure 2 4. The mounting base is composed of bottom piece, plate, screw, nut, screw holder, connecting base 1 / 2 (respectively for the two types of mounting bases 1 / 2, numbered 1 / 2), lock head and related fasteners. During transport, the mounting base is disassembled into four parts: bottom piece, plate, screw adjustment section and bottom corner fitting locking section.

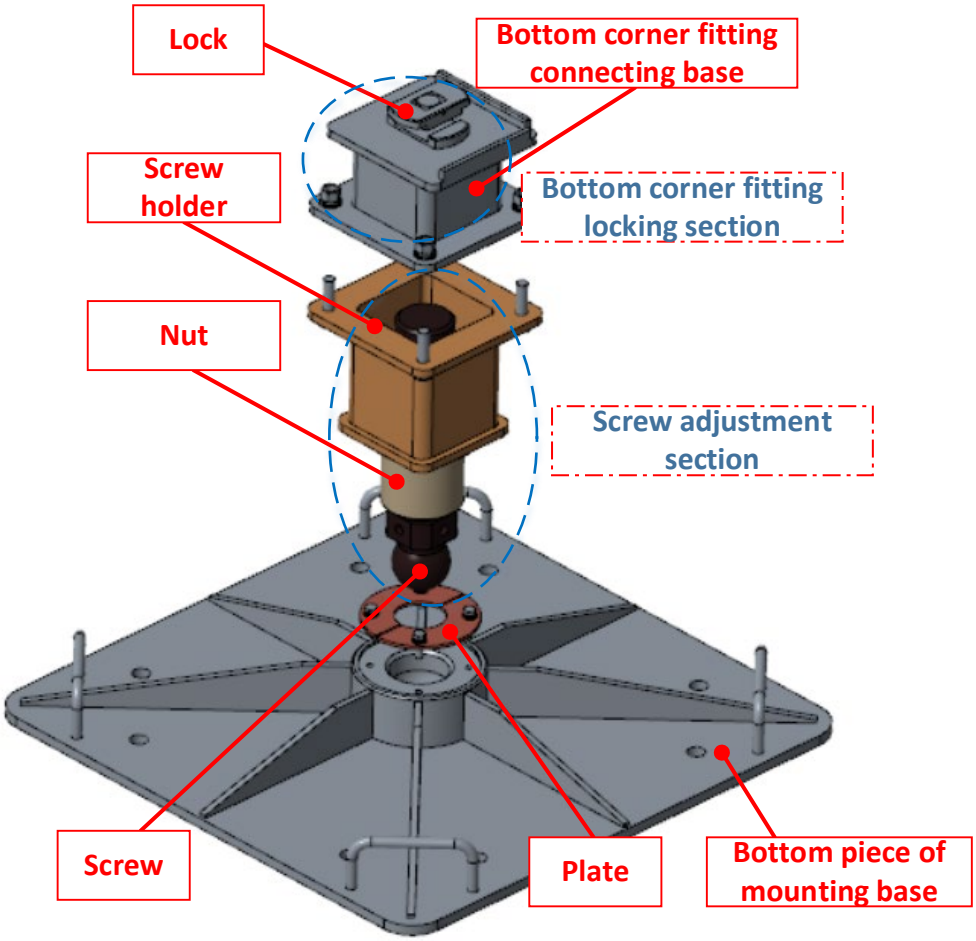


Figure 2-4 Structural Composition of Mounting Base

The upper adjustment block is also connected to the top corner fittings of the container via screw lock, which can be adjusted in the X/Y direction of ±30mm. As shown in Fig. 2-5, an upper adjustment block is composed of upper corner connector 1 / 2(respectively for the two types of upper adjustment blocks 1 / 2, numbered 1 / 2) , lock head, X-direction adjustment base, a Y-direction adjustment base and related fasteners. During transport, the upper adjustment block is disassembled into three parts: the upper corner fittings screw locking section, the Y-direction adjustment base and the X-direction adjustment plate.

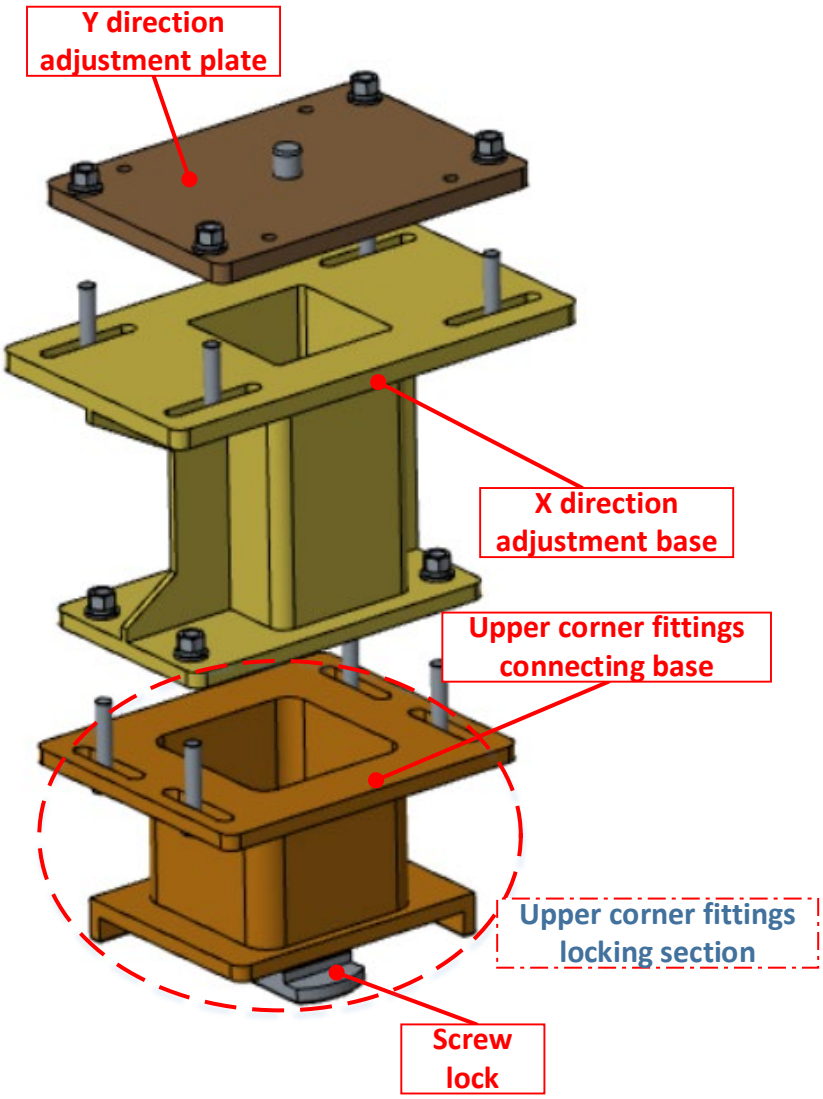


Figure 2-5 Structural Composition of Upper Adjustment Block

2.3. AU Assembling Structure

The AU sub-arrays are installed into different larger scales of sub-array combinations through misalignment assembly, as shown in Figure 2-6. Considering the possibility of structural interference during installation, a 30mm gap is reserved between adjacent sub-arrays.

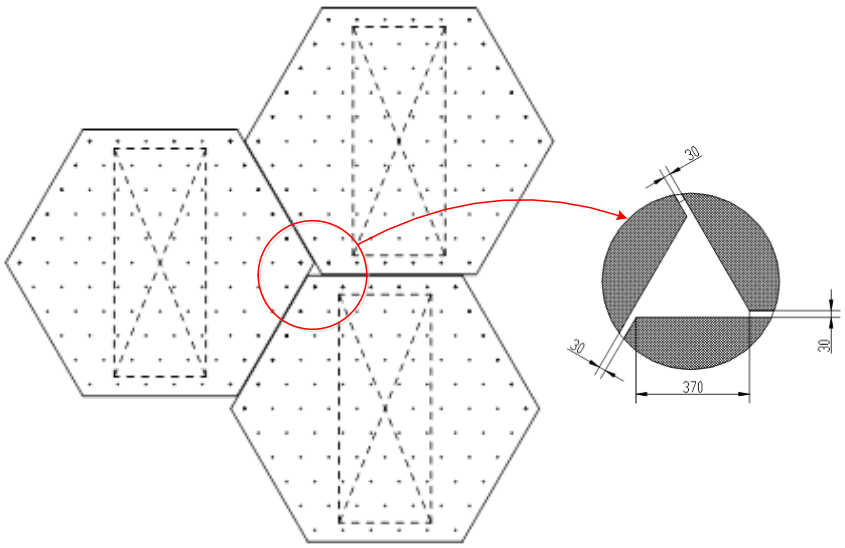


Figure 2-6 Dimensions of Space between Three Sub-arrays

After the sub-array combination is installed, it is necessary to conduct electrical connection handling along the edges of the sub-array. Electrical connection between the neighboring sub-arrays is realized by riveting pressure plate against the wire mesh, as illustrated in Figure 2-7.

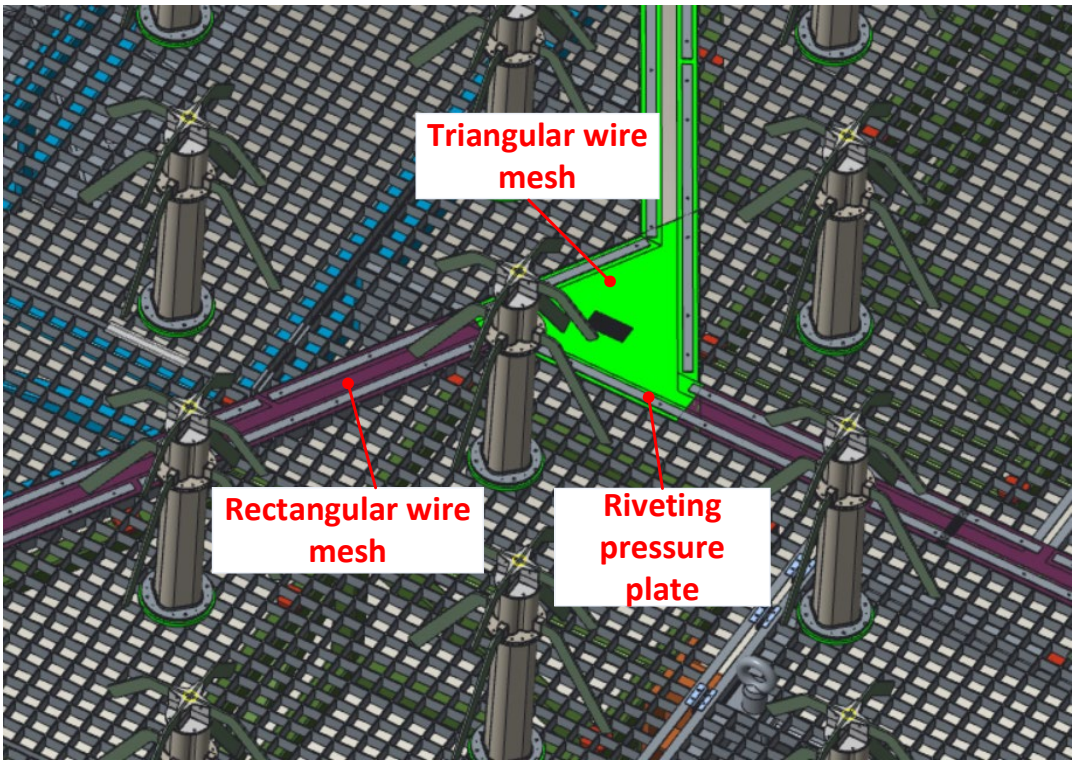


Figure 2-7 Electrical Connection Structure between Sub-arrays

3. AU Transportable Units

The AU Transportable Units (hereinafter referred to as TU) for each Eiscat_3D site are composed of Antenna frame TUs, Container TUs, Mounting base TUs I & II, Measuring tooling TUs and Assembling tooling TUs that are transported as independent units, as well as Spacing tooling TUs that are loaded in the Antenna frame TUs for transportation. Table 3-1 below lists the quantities of each type of independent TUs delivered to the Norway/Sweden/Finland sites respectively.

Table 3-1 AU TUs and Quantity for Three Sites

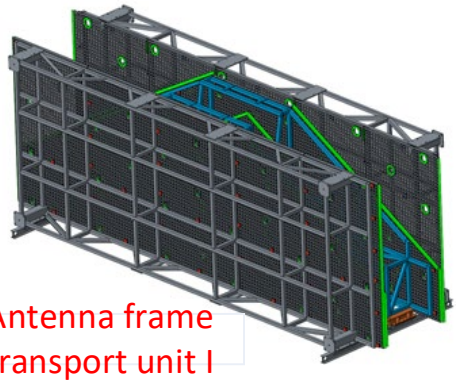
TU	Norway Qty	Sweden Qty	Finland Qty	Total Qty	Rmks
Container TU	119	55	54	228	
Antenna Frame TU	89	41	40	170+1	Including 1 special TU (1 middle block for Norway + 1 middle block for Sweden + 2 side blocks for Finland)
Mounting Base TU I	13+1	6+1	6	25+1+1	Including 1+1 smaller sized mounting base TUs
Mounting Base TU II	119	55	54	228	Loaded into antenna frame TU I (middle blocks)
Measuring Tooling TU	1	1	1	3	
Assembling Tooling TU	1	1	1	3	

3.1. AU Antenna Frame TUs

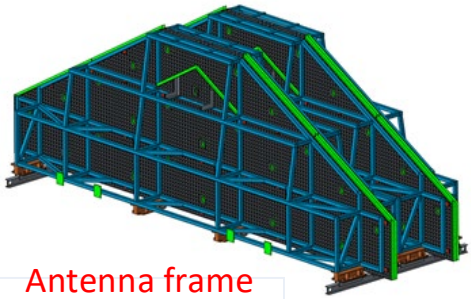
Given the height limits for land transport, the AU antenna frame TU is divided into two types: Unit I (2 middle + 2 side blocks) and Unit II (4 side blocks), as shown in Figure 3-1 below. Every three antenna frames will be assembled into four TUs (I & II) for transportation.

*Structural parts of the mounting bases (except the bottom pieces) and all the parts of the upper adjustment blocks will be loaded into and transported together with the middle blocks of TU I. This is described and illustrated in detail in the section 3.3.

*All the fasteners required for each antenna frame will also be loaded into and transported together with the middle blocks of TU I. The cabling racks will be fixed with cable strips alongside the side blocks.



Antenna frame transport unit I



Antenna frame transport unit II

Figure 3-1 Antenna Frame TU

In order to lift the antenna frame TU, special lifting devices are required, which includes 2 lifting rods and 4 lifting ropes, as shown in Figure 3-2. The lifting devices will be placed and transported in together with the antenna frame TUs.

Figure 3-2 Antenna Frame TU II in Hanging State (with 2 lifting rods and 4 lifting ropes)

Given the quantity of antenna frames at each site, there will be 1 antenna frame middle block (Norway site), 1 middle block (Sweden site), and 2 side blocks (Finland site) left without being assembled into transport I/II. During sea transport, these left blocks will be assembled into one single special TU. The special TU will then be disassembled at the destination port into 3 independent special TUs for land transport to each site. Table 3-2 below lists the quantity of transport I/II and special TU destinating to each site.

Table 3-2 Quantity of Antenna Frame TUs for Three Sites

	Rx Sub-Array Qty	Tx Sub-Array Qty	(Sea & Land) TU I Qty	(Sea & Land) TU II Qty	(Land) Special TU Qty	**(Land) Total TU Qty**
Norway Site	64	55	59	30	1 (one middle block)	**89+1**
Sweden Site	55	0	27	14	1 (one middle block)	**41+1**
Finland Site	54	0	27	13	1 (two side blocks	**40+1**

					combined)	

Each antenna frame TU destinating to each site are numbered and labeled as follows:

- **Norway Site**:
  - 48 antenna frame TUs corresponds to the 64 Rx sub-arrays, labeling N042-R ~ N089-R
  - 41 antenna frame TUs corresponds to the 55 Tx sub-arrays, labeling N001-T ~ N041-T
  - 1 special antenna frame TU (1 antenna frame middle block), labeling N090-T (SPECIAL)
- **Sweden Site**:
  - 41 antenna frame TUs, labeling S001 ~ S041
  - 1 special antenna frame TU (1 antenna frame middle block), labeling S042 (SPECIAL)
- **Finland Site:**
  - 40 antenna frame TUs, labeling F001 ~ F040
  - 1 special antenna frame TU (2 antenna frame side blocks combined), labeling F041 (SPECIAL)

Table 3-3 Antenna Frame TU Labeling and Content

Site	Serial Number	Item
Norway	N042-R ~ N089-R	Antenna frames corresponding to 64 Rx sub-arrays
	N001-T ~ N041-T	Antenna frames corresponding to 55 Tx sub-arrays
	N090-T (SPECIAL)	1 antenna frame middle block
Sweden	S001 ~ S041	Antenna frames for 55 sub-arrays
	S042 (SPECIAL)	1 antenna frame middle block
Finland	F001 ~ F040	Antenna frames for 54 sub-arrays
	F041 (SPECIAL)	2 antenna frame side blocks combined

3.2. AU Container TUs

For each AU container TU, as shown in Figure 3-4 below, all the openings will be protected with waterproof Boeing soft film and plastic thin film, and all the installation holes on the container wall are protected with sealing strip. Each container will be placed with common equipment of the same quantity, as listed in Table 3-4.

Figure 3-3 Physical Photo of the Container TU

Table 3-4 Common Equipment inside Each Container

SN	Item	Qty
1	Electrical heater	3
2	Air inlet	2
3	Air outlet	2
4	Rain cover	4
5	Protection box for interconnection board	1
6	Plastic box	2
7	Step ladder	1
8	Sealant	2
9	Fastener	1

Besides, at each site there will be a few containers dedicated for storing spare parts, tools and instrument. Serial number of each container TU and the content in it are listed in Table 3-5 below.

Table 3-5 Container TU Labeling and Content

Site	Serial Number	Item	Content (in each container)
Norway	N001-T ~ N055-T	Tx container	182 antenna elements + 182 BNC-BNC cables + Common equipment
	N056-R ~ N065-R	Independent Array container	91 antenna elements + Common equipment
	N066-R ~ N116-R	Rx container	Common equipment
	N117-R ~	Tool	Tools, auxiliary materials, spare parts,

	N119-R	container	spacing tooling+ Common equipment
Sweden	S001 ~ S053	Rx container	200 antenna elements + Common equipment
	S054 ~ S055	Tool container	Tools, auxiliary materials, spare parts, spacing tooling + Common equipment
Finland	N001 ~ N052	Rx container	200 antenna elements + Common equipment
	N053 ~ N054	Tool container	Tools, auxiliary materials, spare parts, spacing tooling + Common equipment

Labels for the container units will be attached onto the air inlet area. The labels are sealed with plastics.

3.3. AU Mounting Base TUs

The AU mounting base TUs are divided into two types: Unit I and Unit II. Each Unit I contains 36 bottom pieces of the mounting bases, as shown in Figure 3-4. The quantities of Unit I for Norway/Sweden/Finland site are 13, 6 and 6 respectively.

Figure 3-4 Physical Photo of Mounting Base TU I (36 bottom pieces of mounting bases)

However, given the total quantity of bottom pieces, there will be 8 bottom pieces (for Norway site) and 4 bottom pieces (for Sweden site) left, as illustrated in Figure 3-5, which requires 2 additional smaller-sized TUs (1 for Norway site labeled “N-SPECIAL”, and 1 for Sweden site labeled “S-SPECIAL”) for placing the pieces left.

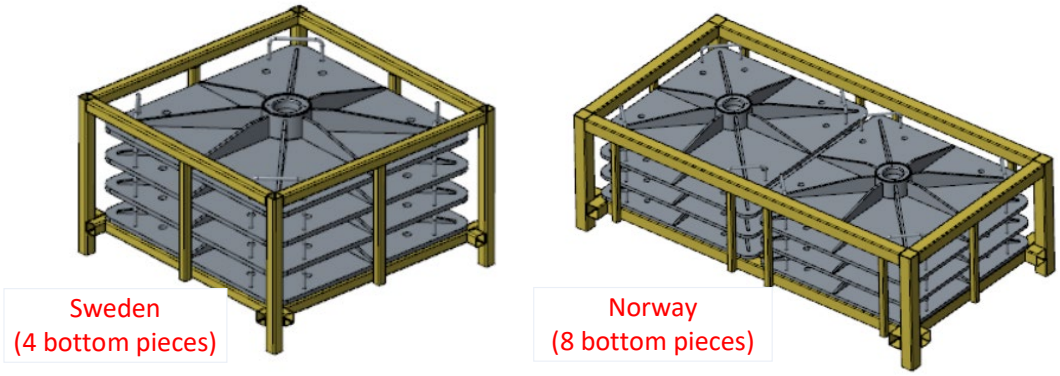


Figure 3-5 Illustrative Smaller-Sized Mounting Base TU I for Sweden & Norway Site

Table 3-6 Mounting Base TU I Labeling and Content

Site	Serial Number	Item (in each mounting base TU I)
Norway	N001 ~ N013	36 bottom pieces of mounting bases
	N014 (SPECIAL)	8 bottom pieces of mounting bases
Sweden	S001 ~ S006	36 bottom pieces of mounting bases
	S007 (SPECIAL)	4 bottom pieces of mounting bases
Finland	F001 ~ F006	36 bottom pieces of mounting bases

Apart from the bottom pieces of the mounting bases, the rest structural parts of the mounting bases together with all the parts of the upper adjustment blocks for their corresponding sub-array are placed in an iron trunk. The iron trunk will be packaged into Mounting base TU II, and loaded into the middle block of its corresponding antenna frame for transportation, as shown in Figure 3-6. The Mounting base II for each site will be labeled N001~N119, S001~S055, F001~F054 respectively.

Figure 3-6 Physical Photo of Mounting Base TU II

3.4. Measuring Tooling TUs

Each Eiscat_3D site will be equipped with 3 sets of working platforms for measuring operations that are assembled into 1 independent TU, as illustrated in Figure 3-7. The TUs for Norway, Sweden and Finland site will be labeled Norway, Sweden and Finland respectively.

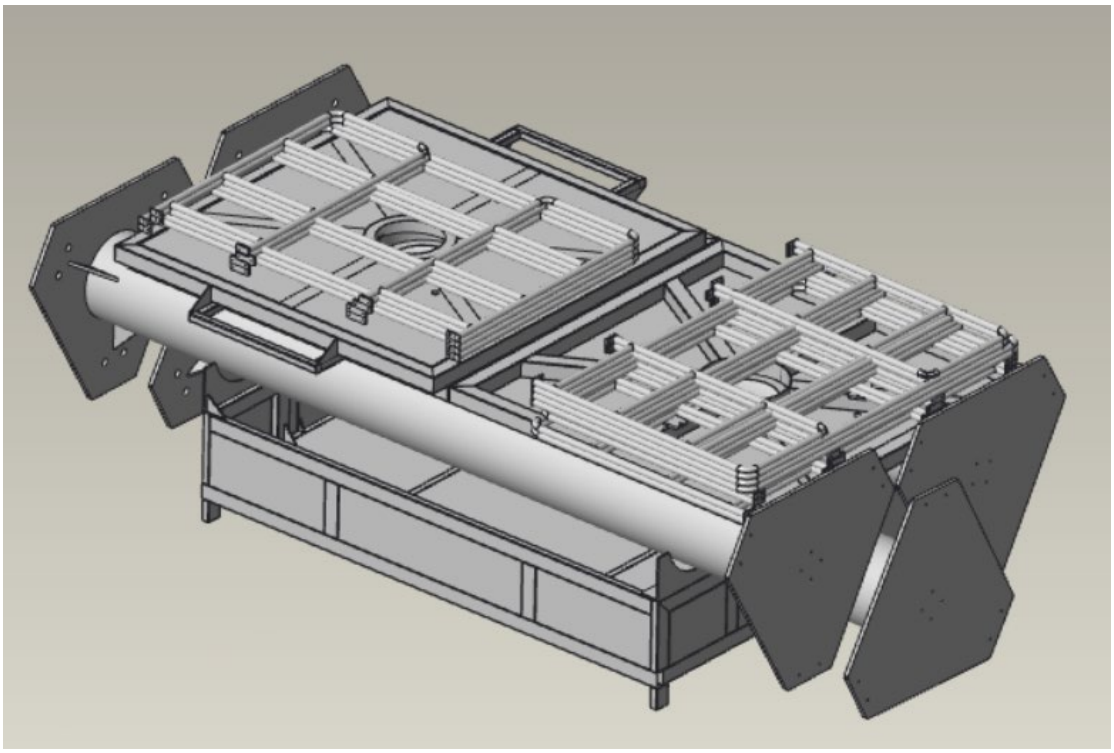


Figure 3-7 Illustrative Measuring Tooling TU

Besides, the riveting pressure plate, wire mesh and rivets required for electrical connection will be loaded into the Measuring tooling TU, as shown in Figure 3-8.

Figure 3-8 Equipment Loaded into the Measuring Tooling TU

3.5. AU Assembling Tooling TUs

Each Eiscat_3D site will be equipped with one set of assembling tooling. Figure 3-9 and Figure 3-12 shows the tooling in operation state and transport state respectively. The assembling tooling TU can be unloaded with forklift. The TUs for Norway, Sweden and Finland site will be labeled Norway, Sweden and Finland respectively.

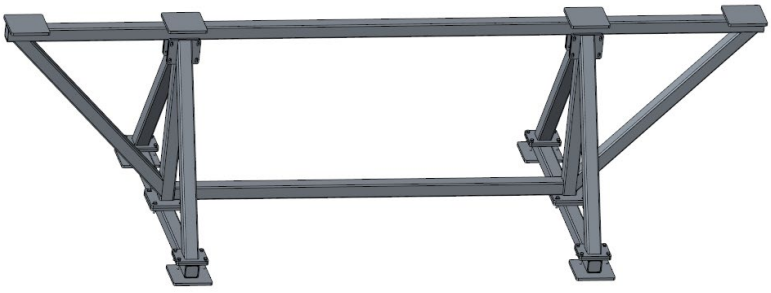


Figure 3-9 Illustrative Assembling Tooling TU in Operation State

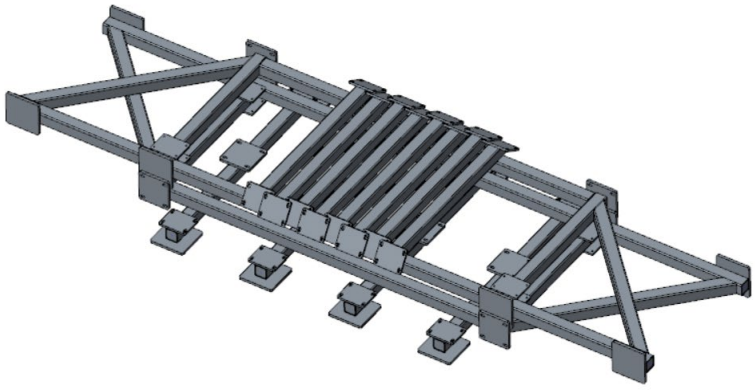


Figure 3-10 Illustrative Assembling Tooling TU in Transport State

4. Site Construction

Layout of the three sites are basically the same. However, given the slightly different ground conditions, there are differences in terms of ground design for the three sites, which satisfy the 10t/m2 load-bearing requirements and the height difference requirements within 100mm.

4.1. Skibotn Site (Norway)

4.1.1. Site Layout

The ground preparation will be the same for all sites, and the antenna core, calibration masts and RF-fence will appear the same (approximately centered in the 100x100m area). The position of houses and transformers will be adapted specifically per site. Figure 4-1 below is an illustration of the layout of Skibotn site. It shows the AU-core (the 109 core AUs), the calibration masts (M1, M2 and M3), the transformer buildings (T1~T4), the house and the garage. Physical layout of the site is shown in Figure 4-2. Its entrance is located in the northwest corner, and there is a triangular area open space on the side of the core area that can be used to store the AU equipment, etc.

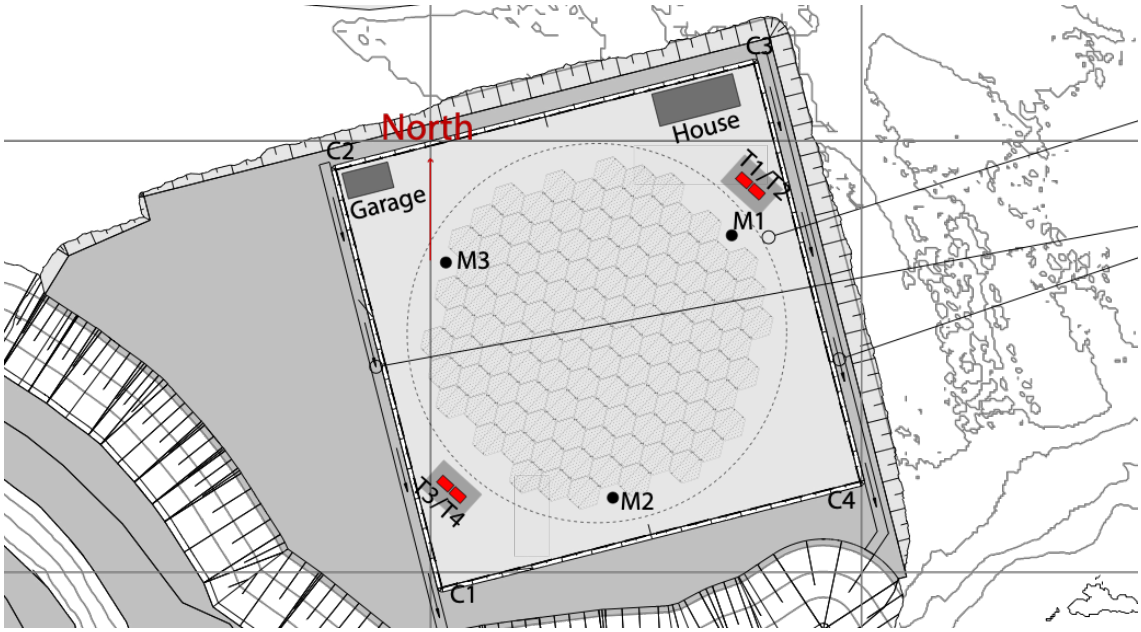


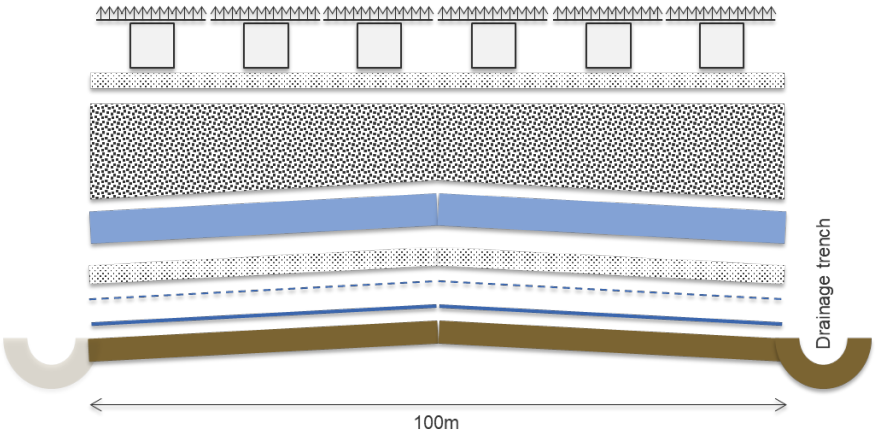
Figure 4-1 Illustrative Layout of Skibotn Site

Figure 4-2 Physical Photo of Skibotn Site

4.1.2. Site Ground Design

The groundwork design is based on very thorough geotechnical investigations and optimized for Skibotn, which has the most demanding properties of all sites.

1) This 100mm layer of 0-32 gravel provides the fine surface roughness.
2) This 0.3m-0.8m layer of compressed 20-120mm gravel provides both the 10 tons/m2 bearing and the leveling of the 1% gradient of the underlying layers.
3) This 200mm layer is made of two 100mm layers of XPS - polystyrene. Polystyrene is water-tight, it has very high compression strength and insulation properties. There are three purposes of this layer: Insulation, water drainage and balancing of load.
4) This layer of 100mm 0-32 gravel is completely insulated from any frost and will never freeze. It is added for having a well-defined surface for the XPS, and to provide a draining layer such that water pressed from the ground can slip away towards the drainage trenches.
5) This layer of combined Geo-net (plastic net) and Geo-fabric provides stability as is prevents the above layer to mix with the soil beneath.
6) The soil where with a 1% gradient within the 100x100m area for water drainage.



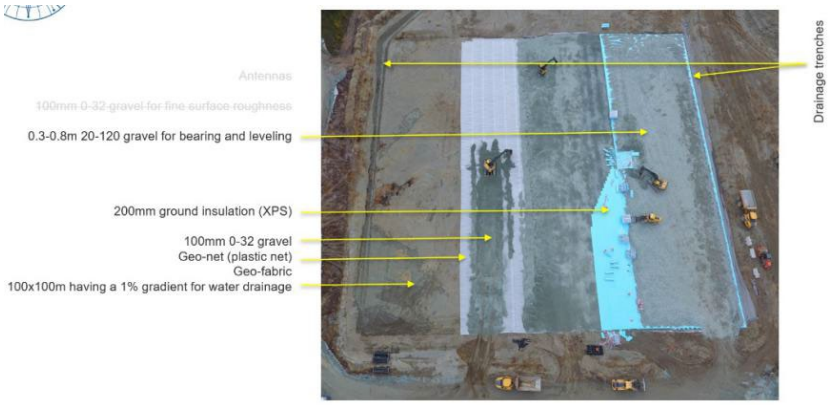


Figure 4-3 Skibotn Site Ground Design

Height measurement has been carried out at each coordinate of the Skibotn site, where m.a.s represents the height above sea level, the max height deviation between each measured point of the site is 0.151m, and the average deviation was 0.028m, and the specific measured point distribution and results were shown in Figure 4-4 and Table 4-1.

Table 4-1 Height Difference Measurement Results at Skibotn Site

SN	Item	Value	Unit
1	Max	47.245	m.a.s
2	Min	47.094	m.a.s
3	Mean height	47.171	m.a.s
4	Max deviation	0.151	m
5	Mean deviation	0.028	m

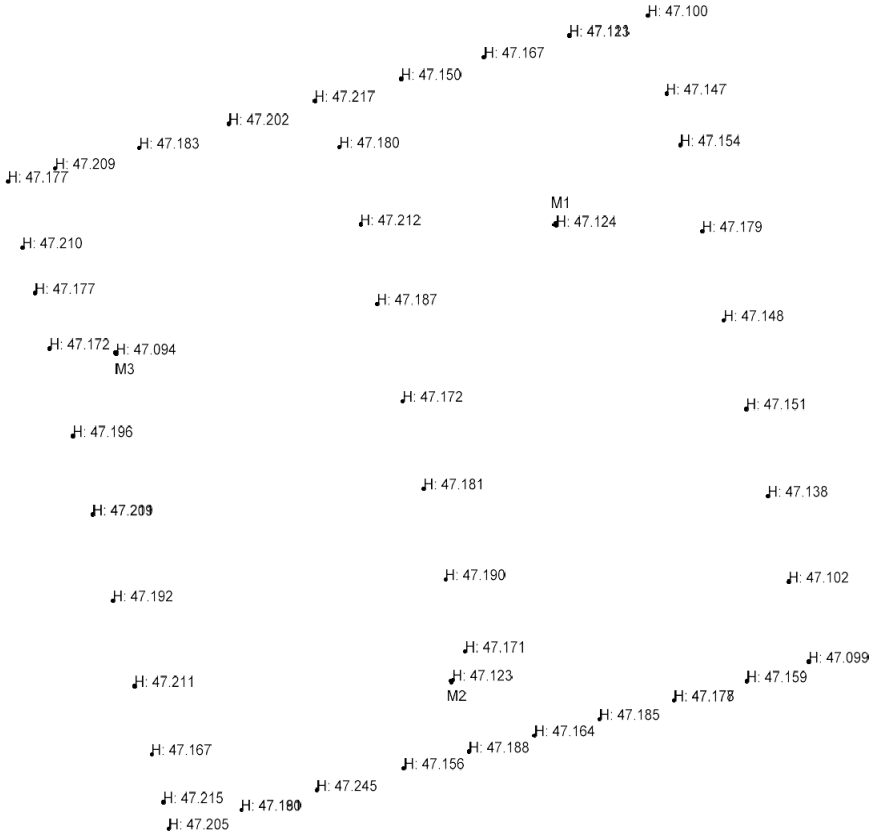


Figure 4-4 Height Difference Measurement Results at Skibotn Site

The height of calibration masts above the site ground slightly varies at the three sites.

Dimensions of the calibration mast interface are illustrated in Figure 4-5 below.

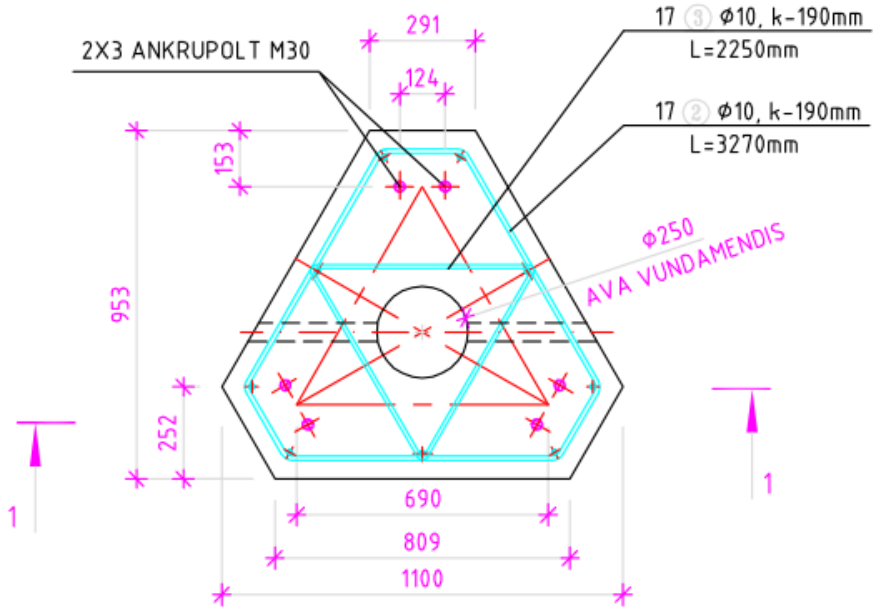


Figure 4-5 Dimensions of Calibration Mast Interface

4.2. Kaiseniemi Site (Sweden)

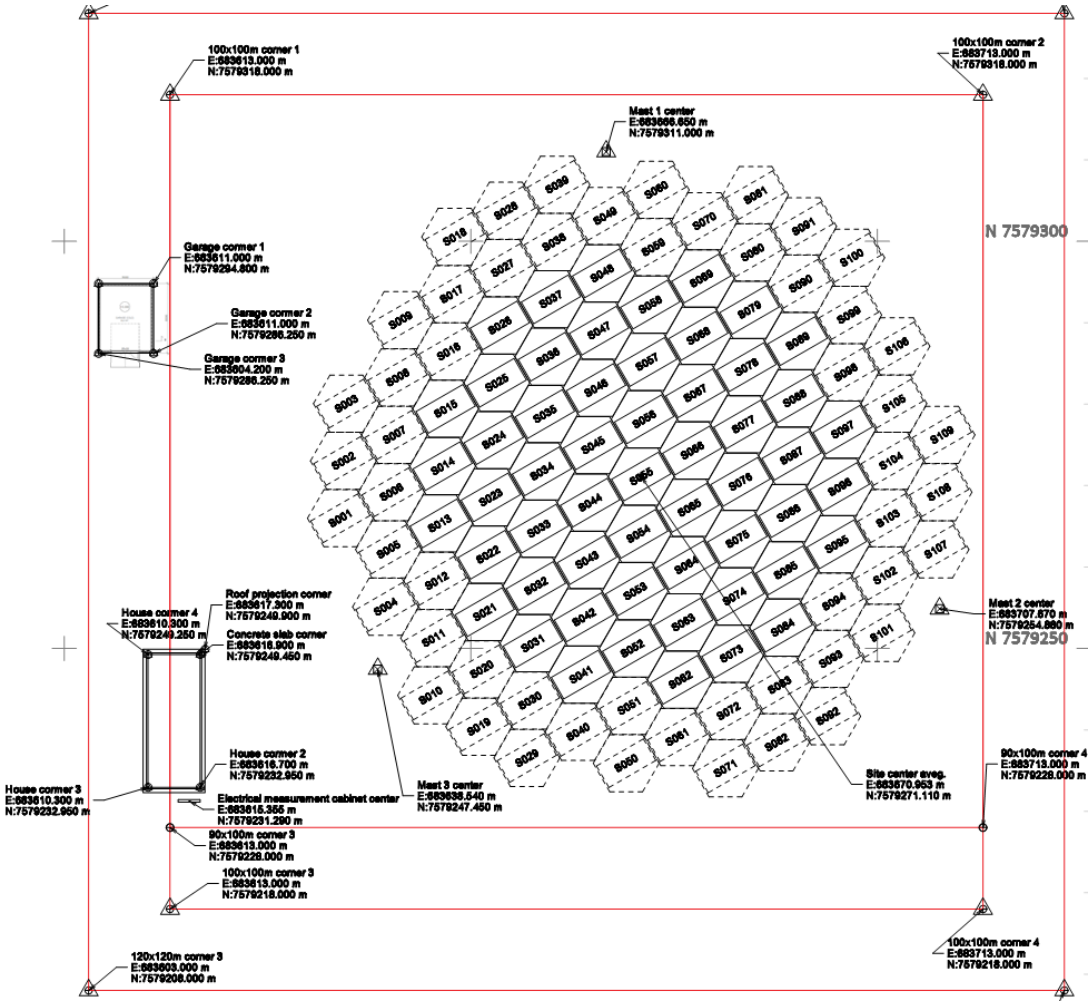


Figure 4-5 Illustrative Layout of Kaiseniemi Site

As illustrated in Figure 4-6, the sub-arrays in solid line are the 55 sub-arrays to be installed for the site.

4.3. Karesuvanto Site (Finland)

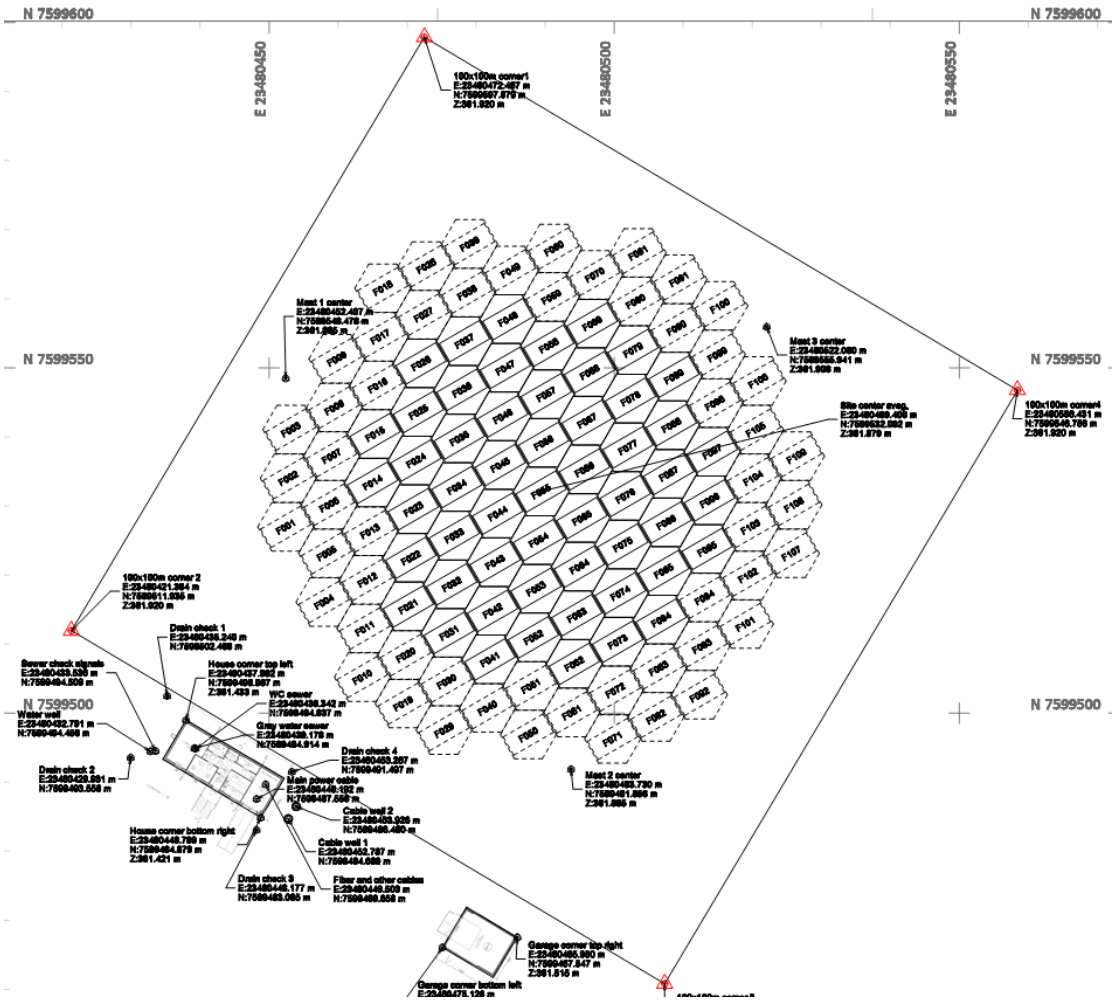


Figure 4-6 Illustrative Layout of Karensuvanto Site

As illustrated in Figure 4-7, the sub-arrays in solid line are the 54 sub-arrays to be installed for the site.

Figure 4-7 Physical Photo of Karensuvanto Site

Calibration masts of the Kaiseniemi site and Karensuvanto site are the same, as shown in Figure 4-9 below.

Figure 4-8 Physical Photo of Calibration Masts in Karensuvanto Site

5. Installation Procedures and Operations

5.1. Installation Principles

According to the structural characteristics of the sub-arrays, under the premise of ensuring the accuracy of the array installation, in order to maximize installation efficiency, the installation operations at each site shall follow the following principles:

1) In order to reduce the cumulative error of the assembly of adjacent sub-arrays, the installation of containers will roll out by stages with the sub-array at the center as the reference. For each stage, when the containers have been in place, installation of antenna sub-arrays will be performed right afterwards.
2) Use the three calibration masts interfaces already prepared on the site, as well as high-precision measurement devices to realize surveying and positioning of mounting bases of all containers, and positioning and adjustment of upper adjustment blocks on top of the reference container. Use the spacing tooling to realize fast positioning and placement of the upper adjustment blocks and the total station for calibration and correction of their positions.
3) The sub-array will be divided into antenna frame and container for the hoisting. Before hoisting of the containers, pre-installation of the container will be performed, which includes: installation and adjustment of adjustable mounting bases on the ground. Also, before hoisting of the antenna frames, pre-installation will be performed, which includes: assembly of antenna frame, antenna elements and RF cables on the ground. Operations on the ground and hoisting will be conducted independently to maximize installation efficiency.
4) To ensure installation efficiency, the operating range of the crane shall at least cover 2 rows (ideally 3 rows) of sub-arrays (length ≥16m in vertical direction). Where the foundation bearing capacity permits, use large-tonnage cranes as

much as possible to avoid frequent movement of cranes. For instance for Skibotn site, 70t crane is preferred, which covers 3 rows of sub-arrays.

5) Two pre-installation sites will be set up, one within the site area, one outside the site area. Also, two cranes of smaller tonnage will be used for transfer of AU equipment and pre-installation of the antenna frame respectively.
6) It is important to reasonably plan the layout of AU equipment and its entry into the site, to avoid waste of time caused by shortage of materials and waiting for AU to enter in the site, and to minimize on-site transfer work.

5.2. Installation Workflow

Figure 5-1 describes the overall workflow of AU installation at the site.

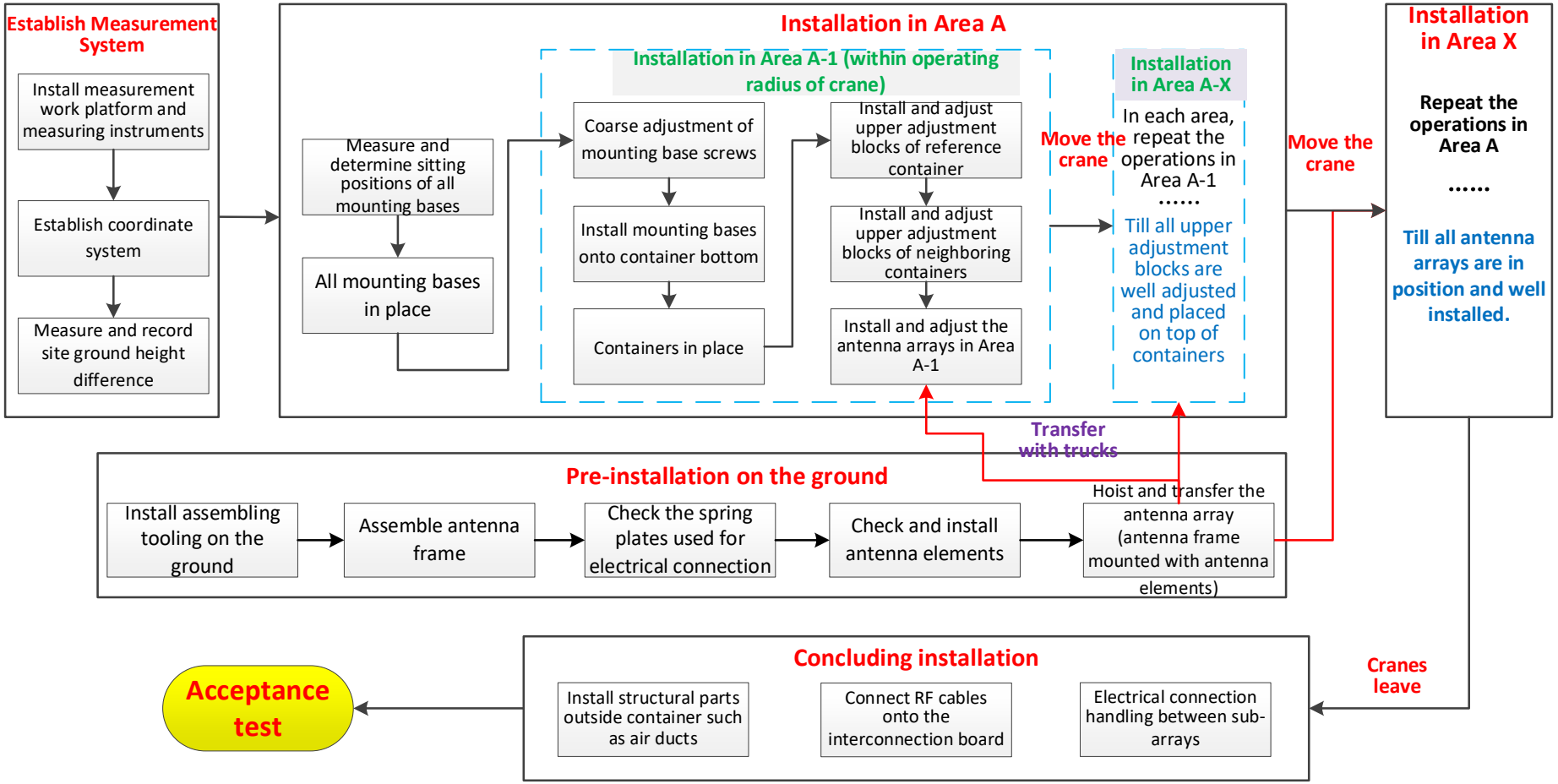


Figure 5-1 AU Installation Workflow

The entire AU installation work are divided into 5 major parts: 1) establish measurement system 2) pre-assembly of antenna frame on the ground 3) installation by sub-areas 4) concluding installation work 5) acceptance test. For installation at each site, measurement coordinate system shall be established first. Pre-installation of the antenna frame on the ground and installation of the antenna frame & container are carried out simultaneously. The installation shall be carried out by sub-areas following the pre-set installation plan. The antenna frame after pre-installation will be transferred to the site area and hoisted for installation. Once installation in all sub-areas finishes, remove the cranes. The installation personnel will carry out installation of structural parts outside the container (such as air inlet/outlet, rain cover, etc.), RF cables, and spring plates for electrical connection between sub-arrays. When all the installation completes, acceptance tests will be conducted, in accordance with the test procedures.

5.2.1. Establish Measurement System

The ground preparation will be the same for all sites, and the antenna core, calibration masts and RF-fence will appear the same (approximately centered in the 100x100m area). The position of houses and transformers will be adapted specifically per site.

Take the Skibotn site as an example. Figure 5-2 shows the overall site area with four corners (HJ1, HJ2, HJ3, HJ4), the AU-core (the 109 core AUs), the calibration masts (M1, M2 and M3), the installation area centered in the 100x100m area (C-100m×100m), the center of the installation area (C-Master) and other landmarks. Table 5-1 lists the geographical coordinates of the mentioned landmarks.

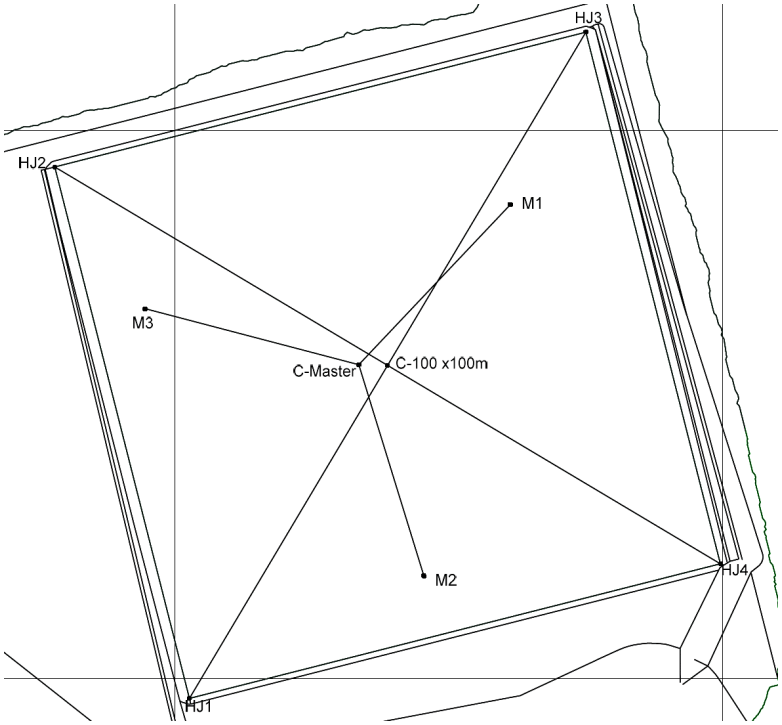


Figure 5-2 Landmarks on Skibotn Site

Table 5-1 Lat/Long Coordinates of Each Landmarks on the Site

Landmark	Latitude	Longitude
HJ1	69.3395113766018	20.313484780565062
HJ2	69.34038724338732	20.313089136852706
HJ3	69.34053586661868	20.315571779203715
HJ4	69.339650287856	20.315990409664383
M1	69.34026916304947	20.3151747971131
M2	69.33967440491473	20.314620524725406
M3	69.34015157701513	20.313438723886303
C-Master	69.340031975574	20.314402919669533
C-100×100	69.3400280895371	20.314529355542912

Based on the layout of the Skibotn site, select calibration mast M3 as the coordinate origin (0,0), the connection line between calibration mast M3 and M2 as the X axis,

and its vertical direction as the Y axis, to establish the coordinate system. The direction of M3 pointing to M2 is the positive direction of the X axis. Number each sub-array in accordance with the layout drawing of the site, and obtain through coordinate conversion the theoretical coordinates of the seating positions of all mounting bases of the 109 sub-arrays. Record the numbers and coordinates of all the mounting bases.

Therefore, it is necessary to install a total station at M3, and a lens at M1 and M2. Observe the actual coordinate values of M1 and M2 via the total station, and establish the actual measurement coordinate system, which will function as the measurement basis for the AU installation.

5.2.1.1. Install Measuring Working Platform and Instruments

Given the sub-array height of about 4.5m, to ensure clear line of sight to the three calibration masts, the total station installation height shall be at least 5.2m. For that end, it is necessary to install a measuring working platform on the calibration mast. The working platform enables mounting of the total station or lens, and provides a safe platform for the measurement personnel to operate the measuring instruments. See Figure 5-3 for illustration of the measuring working platform.

The working platform is composed of four parts: support, platform frame, bracket and guardrail. The support is connected to the calibration masts via 6 bolts and leveled with bolts. The bottom of the bracket is directly bolted to the support, and the top of bracket reserves the interface for installing the total station. The platform frame is also bolted to the support, and the platform is surrounded by guardrails.

While installing the measuring working platform, use the mounting base TU tooling to raise the support, and hoist the platform frame to connect with the support, and hoist the “frame + support” assembly and place it on the calibration mast. Level and adjust the assembly and install the surrounding guardrails and bracket.

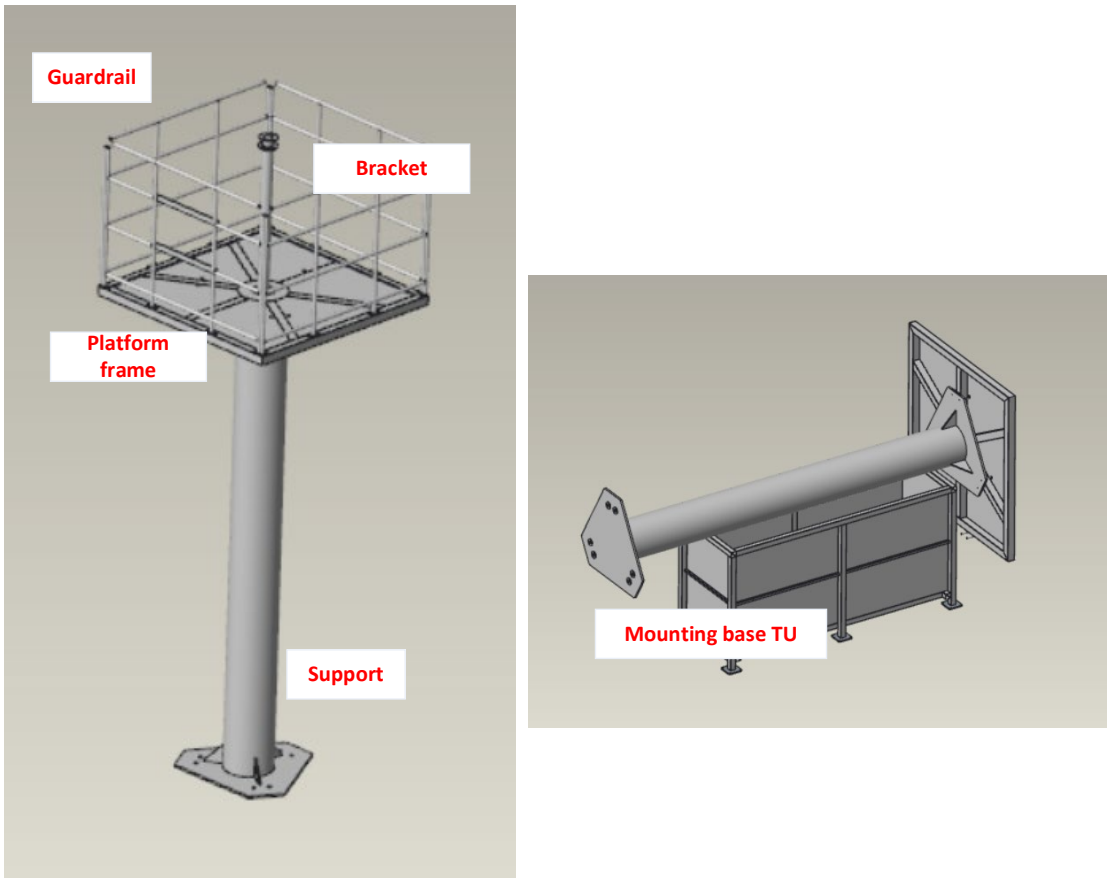


Figure 5-3 Composition of Measuring Working Platform

5.2.1.2. Establish the Coordinate System

After installation of the measurement working platform and the total station, the measurement personnel stands on the platform of calibration mast M3, operates the total station to observe the lens on M1 and M2, determines the actual measurement coordinate value, and records it. According to the three coordinate values, the center position of the antenna array can be determined. Then calculate the theoretical coordinate positions of all mounting bases based on the site layout drawing and fill in Table 5-2.

Table 5-2 Surveying and Measurement Data

Mounting base No.	X-direction theoretical value (mm)	Y-direction theoretical value (mm)	X-direction actual value (mm)	Y-direction actual value (mm)	Z-direction actual value (mm)	Screw stretch (mm)

N001-1						
N001-2						
N001-3						
N001-4						
…						
N109-3						
N109-4						

5.2.1.3. Measure Site Ground Height Difference

Select the center of seating positions of all containers for horizontal height difference measurement, and determine the lowest point and the highest point. The measurement position does not need to be accurate. Measure and record in a table. Take the lowest point as 0, and calculate the relative height difference.

5.2.2. Pre-Installation on the Ground

The ground pre-installation and installation of the antenna array are carried out simultaneously. There are two separate areas set up for the pre-installation, equipped with two smaller-tonnage crane. The ground pre-installation of the antenna array is decomposed into four parts: assembling tooling installation, antenna frame assembly, electrical connection spring plate check, and antenna element testing and installation.

5.2.2.1. Assemble the Assembling Tooling

After the assembling tooling is transported to the planned pre-installation site, assemble the assembling tooling as illustrated below. Figure 5-4 shows the tooling after assembly.

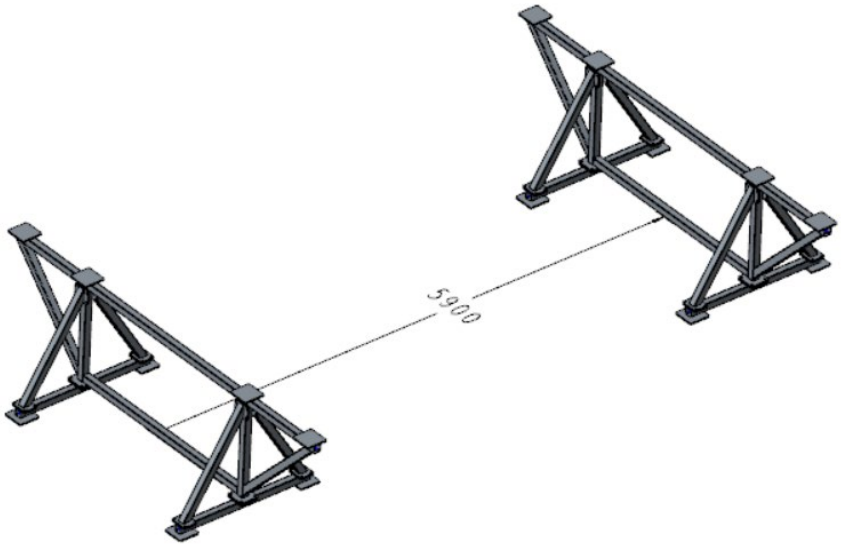


Figure 5-4 Assembling Tooling After Assembly

Besides, the 4 sets of transport tooling for mounting bases can be combined to function as the assembling tooling. Dimensions and layout of the 4 sets of transport tooling are illustrated in Figure 5-5.

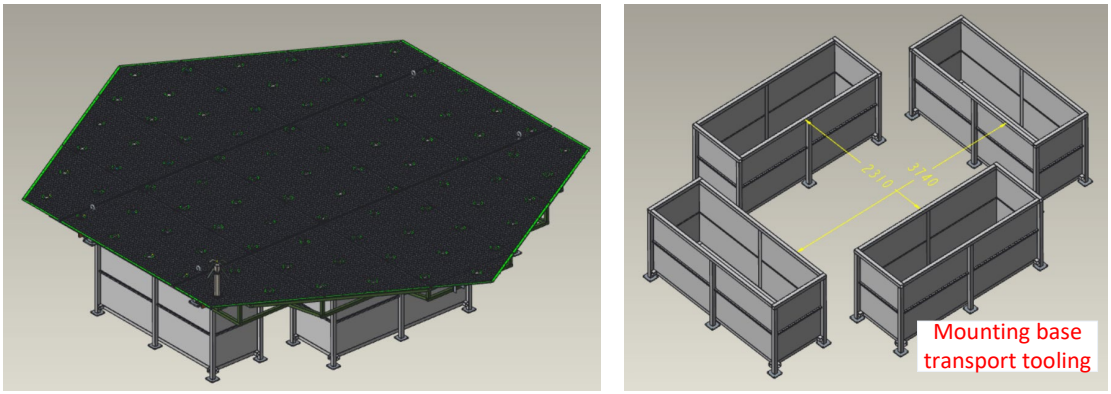


Figure 5-5 Transport Tooling Combined into Assembling Tooling

5.2.2.2. Assemble the Antenna Frame

1) Move to the antenna frame transportable units, first remove the connection bolt between the antenna frame and the tooling, then remove the cabling rack, and finally remove the single reflection plates in the side blocks. Make sure that the numbering of the middle block and side blocks are matched.

2) Hoist the middle block of the antenna frame away from its transport tooling, pull the side pipe of the middle block via two slings, and safely place it on the two pads. Manually push the middle block from vertical to horizontal state,

and the four flanges touch the ground.

3) Remove the slings, install 4 groups of M24 ring screws in the middle block, then connect 4 slings with the ring screws. Hoist and place the middle block on the middle position of the assembling tooling.
4) Hoist and place the side block of the antenna frame on the pads, and manually push the side block from vertical to horizontal state. Remove the slings and make sure the hook of the 4 slings is safely stuck in the 4 flanges. Safely hoist the side block and place it on the assembling tooling. Make sure that the direction marks on one end of the side block matches the middle block. The installation personnel then manually push the side block flange to approach the middle block flange, until the positioning pin on the two flanges enters the positioning hole. Then connect the bolts between the flanges, and remove the top sling after the connection is completed.
5) Repeat step 4 to install the other side block of antenna frame.
6) The installation personnel walks under the middle block and connect the bolts between the rest flanges.
7) Install the two pieces of single reflection plate. Make sure that the orientation of the antenna elements on the single reflection plate is consistent with those on the side blocks.

Make sure that during hoisting, especially when the middle block and side blocks are hoisted away from the transporting tooling to rotate 90 degrees, it is necessary to protect the blocks with soft wood or rubber, so that the zinc layer of antenna frame surface and the spring plates for electrical connection are not destroyed.

Figure 5-6 Antenna Frame after Assembly

5.2.2.3. Check Electrical Connection

After completion of assembly of the antenna frame, it is necessary to check whether the spring plates for electrical connection between each frame block are in contact. Figure 5-7 shows the spring plates after being installed. If the spring plates are not in contact, loose the spring plates and then move the plates along the waist-shape hole for adjustment. If the plates are bent or damaged, replace with spare parts.

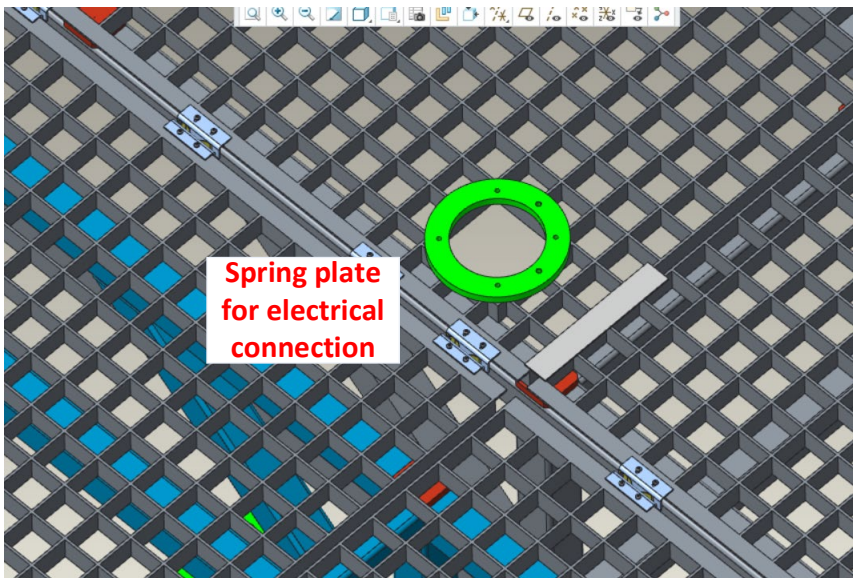


Figure 5-7 Check Spring Plate for Electrical Connection

5.2.2.4. Check and Install Antenna Elements

While the antenna frame is being assembled, carry out transfer, unpackaging and testing of the antenna elements, to make sure that no damage has been caused to the antenna elements during transportation, which might affect the electrical performance.

After the antenna elements are tested to be qualified, mount the antenna elements onto their respective positions on the antenna frame. Meanwhile, the installation personnel stand below the antenna frame to connect the RF cables to the antenna elements. After removal of the RF cable end protective film and protective sleeve, it is necessary to observe whether there is water or water vapor inside, if so, then use the hair dryer for drying treatment, and ensure that the inside of the connector is dry and waterless before it can be connected with the antenna elements.

5.2.2.5. Transfer the Pre-Installed Antenna Frame (Mounted with Antenna Elements)

After pre-installation of the antenna frame, connect four slings to the four ring screws on the middle block of antenna frame, and hoist the frame (mounted with antenna elements) onto the flatbed truck and transfer it to the installation position along the pre-set path. Since the antenna frame after assembly is 8.1 meters long, make sure that the transportation path width is greater than 10 meters.

5.2.3. Installation by Sub-Areas

Measure and determine seating positions of mounting bases of all AU containers in Area A. Transfer and place the bottom pieces of the mounting bases as measured. Then start installation of containers and antenna arrays in Area A-1 following the pre-set route by completing the 6 steps of operations. Repeat the operations in Area A-1 till all antenna arrays and containers in Area A are in place. Then repeat the operations in Area A to complete installation in Area B as planned, till all antenna arrays and containers in the core array are in place.

5.2.3.1. Measure and Determine Seating Positions of Mounting Bases

After establishing the measurement system, start surveying and mapping of the seating positions of the mounting bases. The surveying personnel moves the reference marker, and the measurement personnel use a total station to observe the marker and determine the position coordinates. The coordinates will be informed to the surveying personnel to keep moving the marker to approach the theoretically required position, till differences between the actual measurement value and the theoretical value are within the range of ±1mm. Then use the surveying tooling to mark the positions the ground, and record the X/Y/Z three-way coordinates out of the actual measurement position in Table 5-2.

Figure 5-8 illustrates the tooling needed for surveying. The tooling is composed of a metal disc and a pin. The metal disc is placed in the surveying position. Once the position is determined, fix the disc into the pin top to stay fixed on the ground. When the bottom piece of the mounting base is in place, its center 10mm hole will be just in line with the pin, which facilitates observation by the measurement personnel.

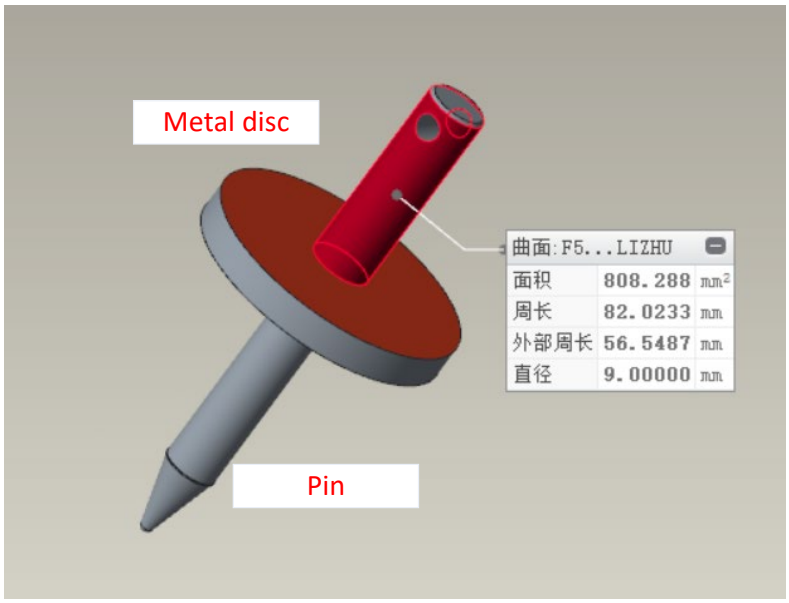


Figure 5-8 Tooling for Surveying and Mapping

Compare the Z-direction data recorded with the site ground height difference values previously measured, and obtain the minimum height of seating positions of all

mounting bases. Set the screw protrusion as 20mm at the point with the minimum height, and calculate the protrusion of mounting bases of corresponding antenna arrays.

5.2.3.2. Place the Bottom Pieces of Mounting Bases

After ground surveying, hoist the bottom pieces of mounting bases out of the transporting tooling and place them on the forklift, before being transferred to their seating positions. The bottom piece weighs 95kg, thus can be taken by 4 personnel for more accurate seating. Note that when placing the bottom piece, align the control center hole with the loft pin, and pull the pin out after its landing. The work can be conducted multi-line in parallel, depending on the number of installation personnel. Figure 5-9 shows the bottom pieces after being placed.

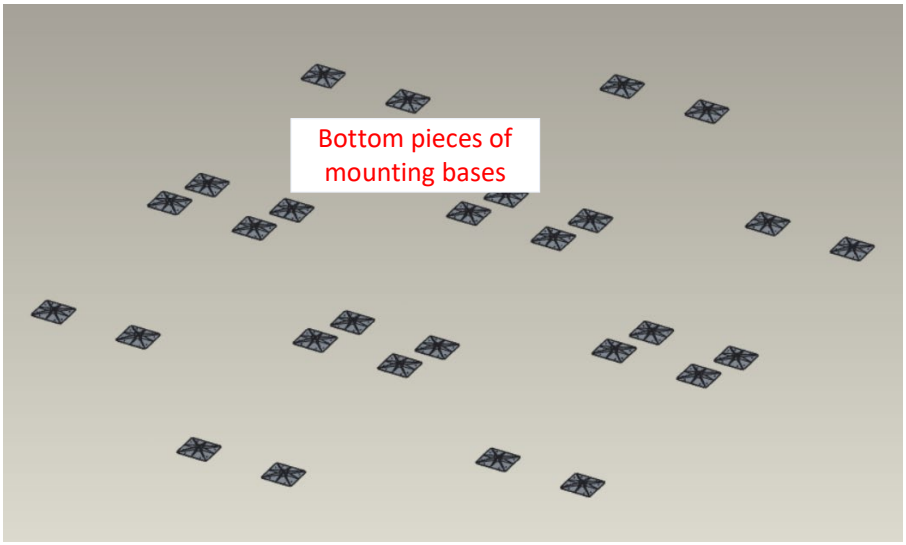


Figure 5-9 Bottom Pieces after being Placed

5.2.3.3. Install AU in Area A-1

After bottom pieces of the mounting bases have been placed in Area A, start the installation in Area A-1. In Area A-1, select one container as the reference container, for instance, in Skibotn site Area A-1 select the column 11-13 near the M1, the reference container is numbered N088, and the A-1 area is shown in Figure 5-10.

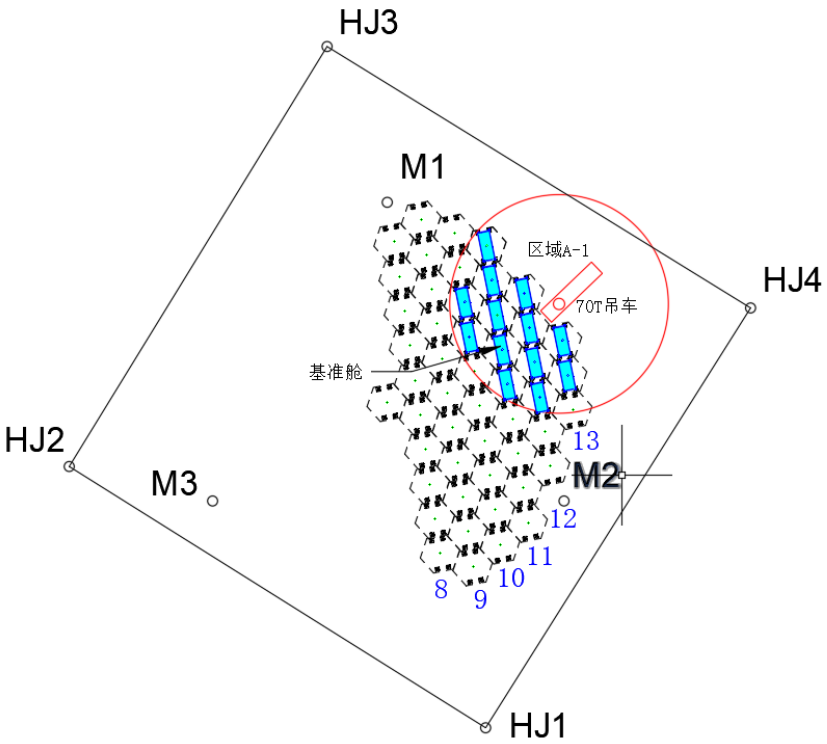


Figure 5-3 Area A-1 in Skibotn Site

5.2.3.3.1. Coarse Adjustment of Mounting Base

1) Disassemble mounting base TU II from the antenna frame TU to be installed in area A-1, and transfer them to near A-1 with forklift.

2) Lay foam in selected areas, take out the parts in the mounting base TU and place them on the ground, as shown in Figure 5-11. Adjust the screw and make the screw ball head facing upwards.

Figure 5-11 Coarse Adjustment of Mounting Base Screws

3) Adjust according to the number of sub-arrays, use a marker pen on the side of the adjustment screw segment to make corresponding markings.

4) Based on the data in Table 5-2, manually rotate the screw, measure the protrusion length with a tape, and control it within the range of 1mm.

5) Apply the aviation grease evenly on the screw ball head.

5.2.3.3.2. Install Mounting Bases onto Container Bottom

To install the mounting bases onto container bottom, first hoist the container and place it on the tooling (composed of two sets of mounting base TU tooling, with a spacing of 3.6m, as shown below), so that the four corner fittings of the container are accessible. Install the mounting bases.

1) Transfer the two sets of mounting base TU tooling with forklift to Area A-1, and place them as illustrated below.

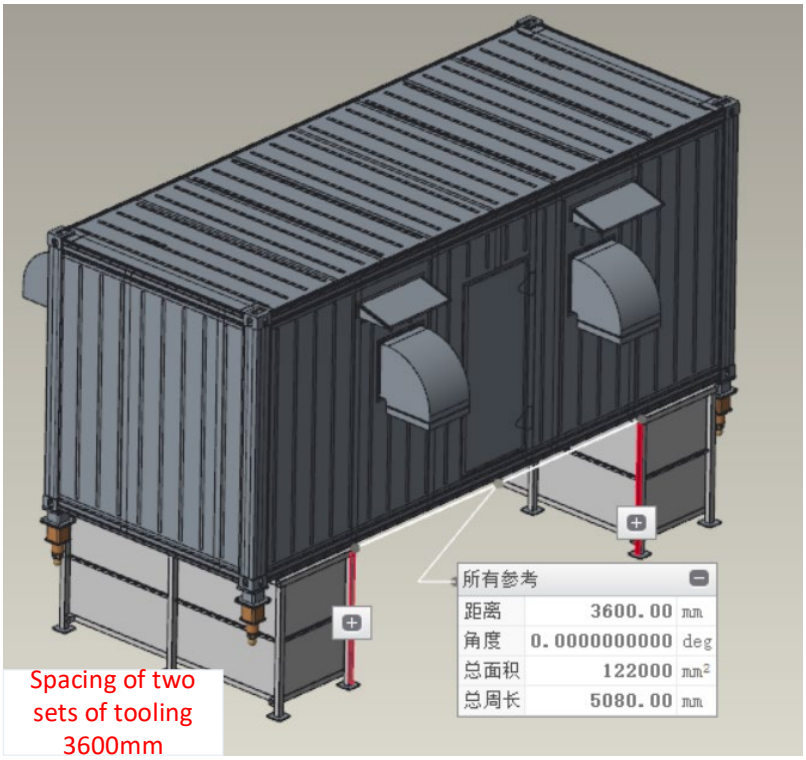


Figure 5-12 Place the Container on the Mounting Base TU Tooling

2) The installation person climbs onto the container top and attach the lifting devices to the four corners. Hoist the container and place it on the tooling. Mark the container bottom corner fittings with pen.

3) Fix the bottom corner fitting locking section to the corner fitting, after the limit edge is fitted to the two sides of the corner piece, then rotate the middle lock head by 90 degrees, tighten the double nut with a socket ratchet wrench. Make sure the two types of screw locking section of bottom corner fittings match with their corresponding corner fittings.

4) Connect the screw section and the screw locking section via flange bolt. Make sure that the marks of the screw section and the marks on the corner fittings match.

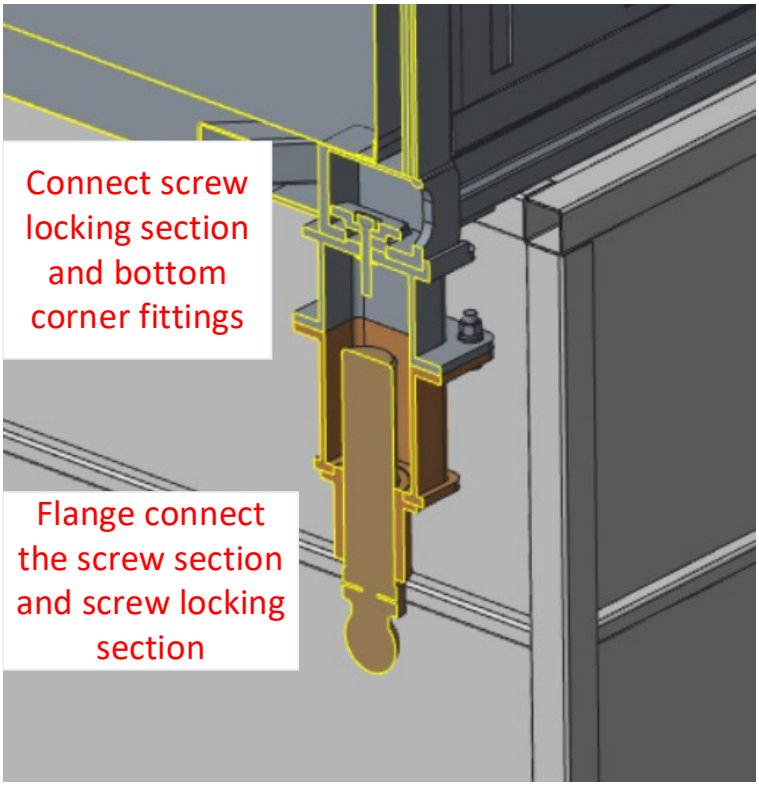


Figure 5-13 Install Mounting Base onto Container Bottom Corners

5.2.3.3.3. Place the Container

After the mounting bases are mounted to the container bottom corners, hoist the container to its corresponding installation position. Four personnel pull the sling rope till the ball heads of the four mounting bases are aligned with the hemispherical holes on the bottom piece of the mounting base, and slowly lower the container to ensure that the ball heads safely fall into the holes. When falling in, make sure that at least two sets of the bottom pieces do not move.

After the container lands, check whether it shakes. If yes, adjust the corresponding mounting base screw to ensure that all screw ball heads are in contact with the bottom piece of mounting base. Figure 5-14 shows the container after landing. Repeat the procedures till all containers in Area A-1 complete landing. Then install the baffle plate of the mounting base.

Figure 5-14 Container in Place

5.2.3.3.4. Install and Adjust Upper Adjustment Blocks of Reference Container

When all the containers in Area A-1 are in place, the installation person climb up to the reference container top via the 3.5m mobile ladder, to install and adjust the upper adjustment blocks in X/Y/Z directions. Wherein the Z direction adjustment is performed via the screw of the mounting base, to achieve horizontal height adjustment of the support flange surface, while the X/Y direction adjustment is performed by moving the its own structural parts, the specific steps are as follows.

1) Fix the screw locking section on the corner fittings, after the two sides of the limit edge and the two sides of the corner fittings are fitted, then rotate the lock tongue 90 degrees, use the socket ratchet wrench to tighten the double nut.
2) Connect the Y-direction adjustment plate with the X-direction adjustment seat bolt as one, and place the Y-direction adjustment plate in the middle theoretical position, and the bolt is not tightened for the time being.
3) Fit the X-direction adjustment seat to the screw locking section flange, place it in the middle theoretical position, and the bolt is not tightened for the time being.

Figure 5-15 Install Upper Adjustment Block

4) Place the four reference markers on the positioning pin in the middle of the Y-direction adjustment plate, as shown in Figure 5-16. The measurement personnel observes the reference marker to determine the horizontal height difference, and the installation personnel rotates the screw of the mounting bases with a 65-opening large wrench according to the horizontal height difference, controls the 4-corner horizontal height difference within 2mm, and ensures that there is no false leg phenomenon in the 4 mounting bases.

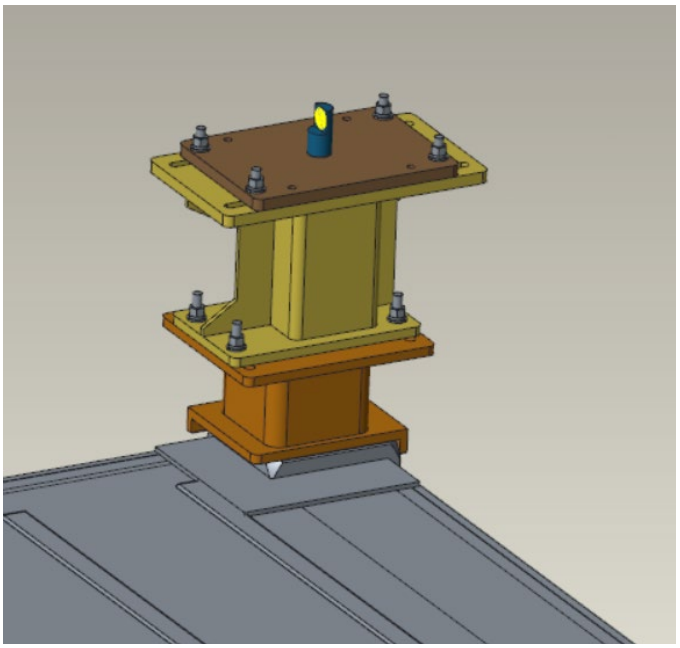


Figure 5-4 Reference Markers for Installation of Upper Adjustment Blocks

5) If there is a situation where it is not possible to adjust to the required accuracy, a 1mm compensation gasket is added to the corresponding Y to the adjustment plate, as shown in Figure 5-17, to ensure the required level of height difference. After the horizontal adjustment of the reference container is completed, the lowest point is taken as the horizontal height adjustment reference value.

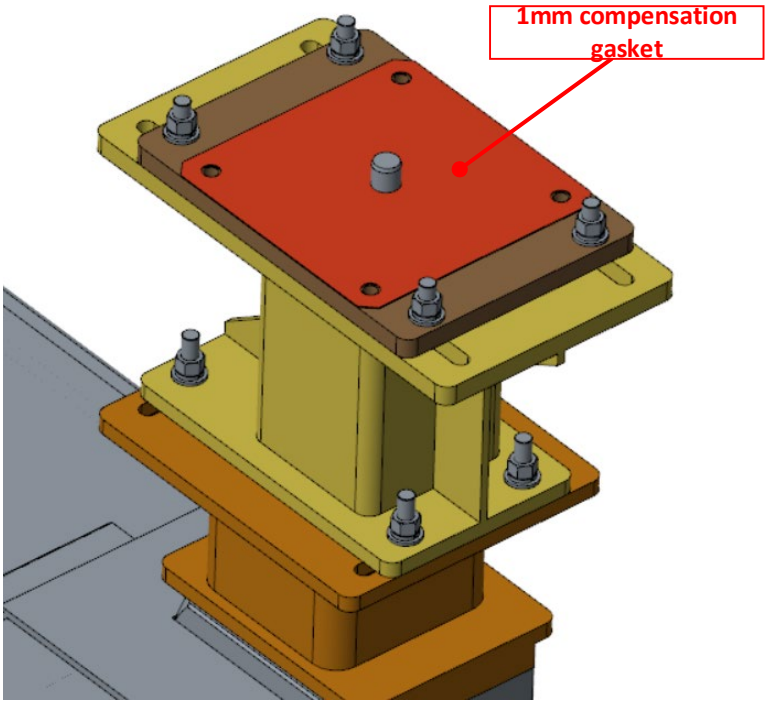


Figure 5-5 1mm Compensation Gasket

6) Select one upper adjustment block in the reference container as the X/Y direction reference, the X/Y direction is fixed in the theoretical middle position, and all bolts are tightened. Mount the reference marker on the center positioning pin of the Y-direction adjustment plate. Measure and determine the actual coordinate values with the total station, and compare with the theoretical coordinate values, then correct the remaining adjustment block coordinates according to the difference, and record all the corrected coordinate values in Table 5-3.

Table 5-3 Measurement Data Record for Upper Adjustment Blocks

Area	Center point of upper adjustment blocks	X-direction theoretical value (mm)	Y-direction theoretical value (mm)	X-direction correction value (mm)	Y-direction correction value (mm)	X-direction actual value (mm)	Y-direction actual value (mm)	Z-direction actual value (mm)
A-1 (N088, reference)	N088-1							
	N088-2							
	N088-3							
	N088-4							
	N089-1							
	N089-2							
X-X	N001-3							
	N001-4							

7) After determination of the reference, perform positioning of the upper adjustment blocks within a single sub-array via spacing tooling 1 and 2, until the center positioning hole of the spacing tooling 1 and 2 is matched with the center positioning pin of the Y-direction adjustment plate, and the threaded positioning

pin of the threaded hole on the Y-direction adjustment plate is fitted with the flange hole on the spacing tooling. After the positioning is completed, re-measure with the total station to ensure that the difference with the theoretical value is within 1mm. Fill the actual values in Table 5-3. Figure 5-18 shows how spacing is performed.

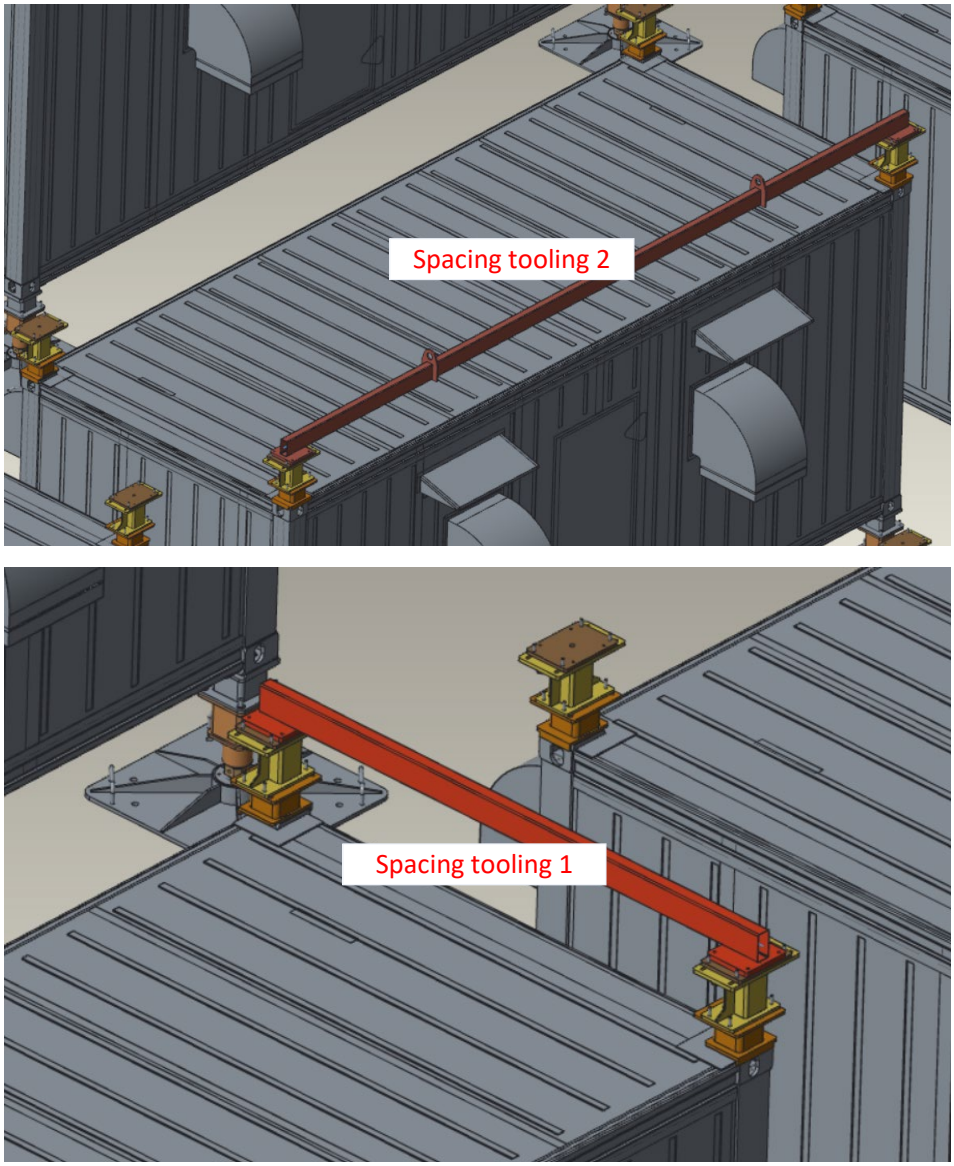


Figure 5-18 Positioning of Upper Adjustment Blocks in One Sub-Array

5.2.3.3.5. Install and Adjust Upper Adjustment Blocks in Adjacent Containers

After placement of the upper adjustment blocks on the reference container, start installation and adjustment of the upper adjustment blocks of remaining containers in Area A-1.

1) Repeat the steps in 5.2.3.3.5 to install the upper adjustment blocks of adjacent containers, with bolts mounted but not tightened.

2) Place the 4 reference markers on the positioning pin in the middle of the Y-direction adjustment plate. The measurement personnel observes the reference marker to determine the horizontal height difference, and the installation personnel accordingly rotates the screw of the mounting bases, controls the 4-corner horizontal height difference within 2mm, and ensures that there is no false leg phenomenon in the 4 mounting bases. If it is not possible to adjust to the required height difference, add a 1mm gasket as compensation.

3) Perform positioning of the upper adjustment blocks in adjacent containers in the same column of the reference container, using spacing tooling 3. Then use spacing tooling 2 to complete positioning of the other 2 upper adjustment blocks. Re-measure with a total station the positions of the other adjustment blocks and record in Table 5-3.

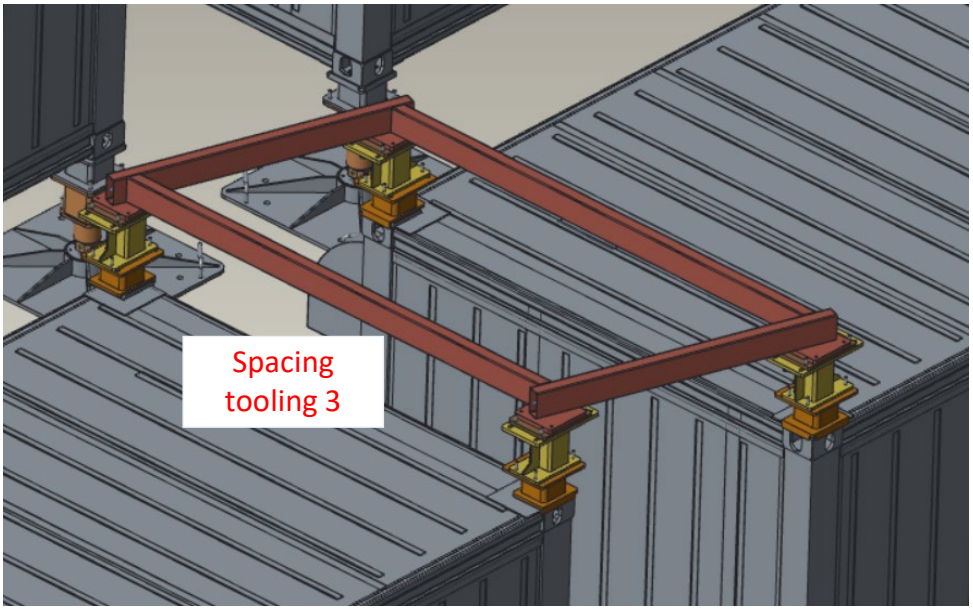


Figure 5-19 Positioning of Upper Adjustment Blocks on Adjacent Containers of the Same Column

4) For the adjacent containers of different columns, use spacing tooling 4 for positioning, as shown in Figure 5-20. Similarly, the positions determined in this

method needs to be reviewed and recorded in Table 5-3 to ensure that the difference with the theoretical values does not exceed ±2mm.

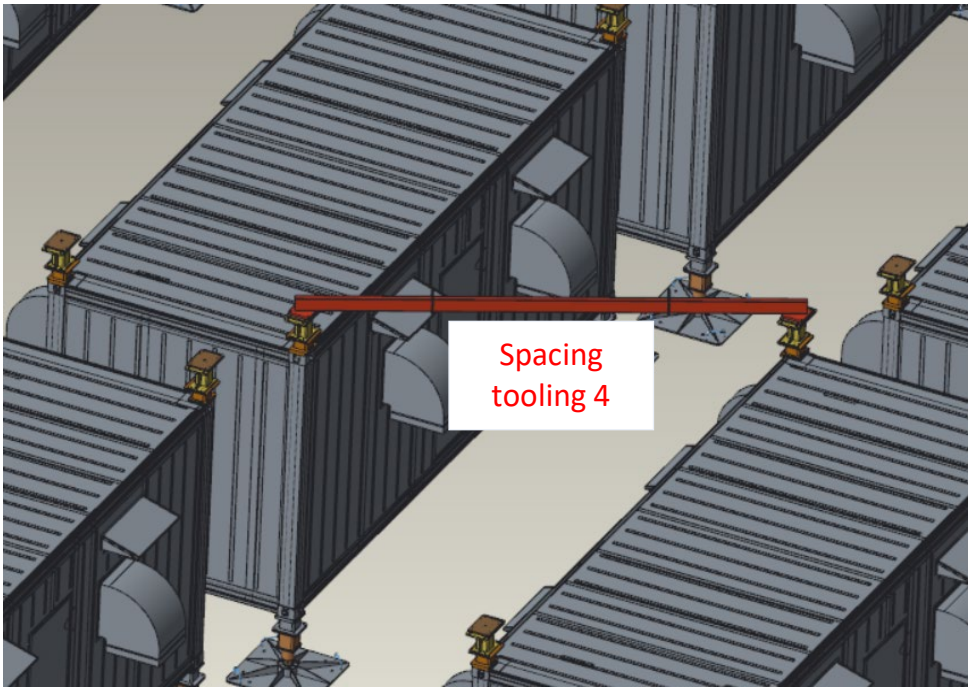


Figure 5-20 Positioning of Upper Adjustment Blocks on Adjacent Containers of Different Columns

5) If the X/Y direction adjustment amount is insufficient, only fine-tuning can be performed. Remove the upper adjustment blocks, and slightly move the container by hoisting, and then repeat the above steps to ensure that the upper adjustment block is adjusted to the correct position. The installation personnel might also use a crowbar to fine-tune the position of the container, and meanwhile use a rubber pad to protect the outer surface of the container.

6) Repeat the steps above to complete installation and adjustment of all upper adjustment blocks in Area A-1.

5.2.3.3.6. Install and Adjust Antenna Array

Place the antenna array after pre-installation onto the upper adjustment blocks, and adjust their seating positions.

1) Connect the 4 sling shackles with the 4 ring screws on the front of the antenna array, slowly lift the array. The installation persons on the ground control the sling

rope must not scratch the antenna unit, after the rope is straightened, the installation personnel standing on the array shall immediately evacuate.

Figure 5-6 Hoist and Place Antenna Array (Antenna Frame Mounted with Antenna Elements)

2) 4 installation personnel pull the lifting ropes till the antenna array arrive above the container. Slowly lower the antenna array till it almost touches the upper adjustment blocks. 2 installation personnel keep pulling the ropes.

3) The rest 2 personnel stand respectively on the two moving ladders (3.3m high) placed diagonally besides the two container corners, hold their hands on the antenna array, observe the relative position between the positioning hole on the antenna array mounting flange and the positioning pin on the upper adjustment blocks. When the positioning holes are aligned with the positioning pins, slowly lower the array till being perfectly fitted to the upper adjustment blocks.

Figure 5-22 Pull and Place the Antenna Array

4) After the antenna array lands, tighten the bolts between the antenna frame and the upper adjustment blocks. The 2 installation persons standing below the array to observe whether the seam between the sub-arrays are uniform and controlled with 20-40mm. If there is a significant deviation, measure the seating positions of the two neighboring antenna elements, to determine whether the deviation is within ± 15 mm. Measure the spacing of the two antenna elements on two neighboring sub-arrays using reference markers. If the deviation is excessive, loose the bolts between the X-direction adjustment seat and Y-direction adjustment plate, and hoist the antenna array slightly for fine-tuning.

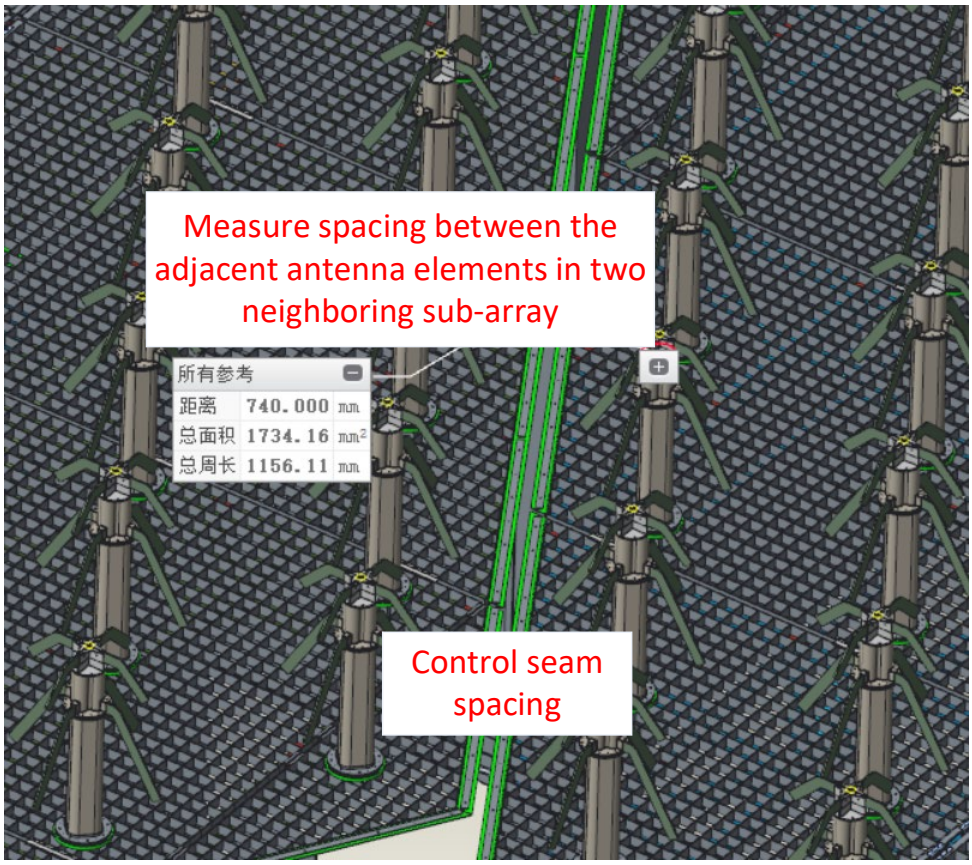


Figure 5-23 Measure Spacing between Antenna Elements in Adjacent Sub-arrays

5) After completion of all adjustment, fasten all the bolts.

5.2.3.4. Installation in Area A-X

Continue with installation in Area A-X following the installation steps in Area A-1 until all sub-array within Area A are installed. Reference container is no longer needed. Spacing tooling is used to determine the seating positions of upper adjustment blocks based on the seating positions of the reserved containers in Area A-(X-1). Adjust the positions in accordance with the corrected coordinates in Table 5-3. Record X/Y/Z direction coordinates of all upper adjustment blocks.

For instance, after installation of containers in Area A-1 in Skibotn site, reserve two containers as shown in Figure 5-24, which function as the reference for spacing and positioning in Area A-2.

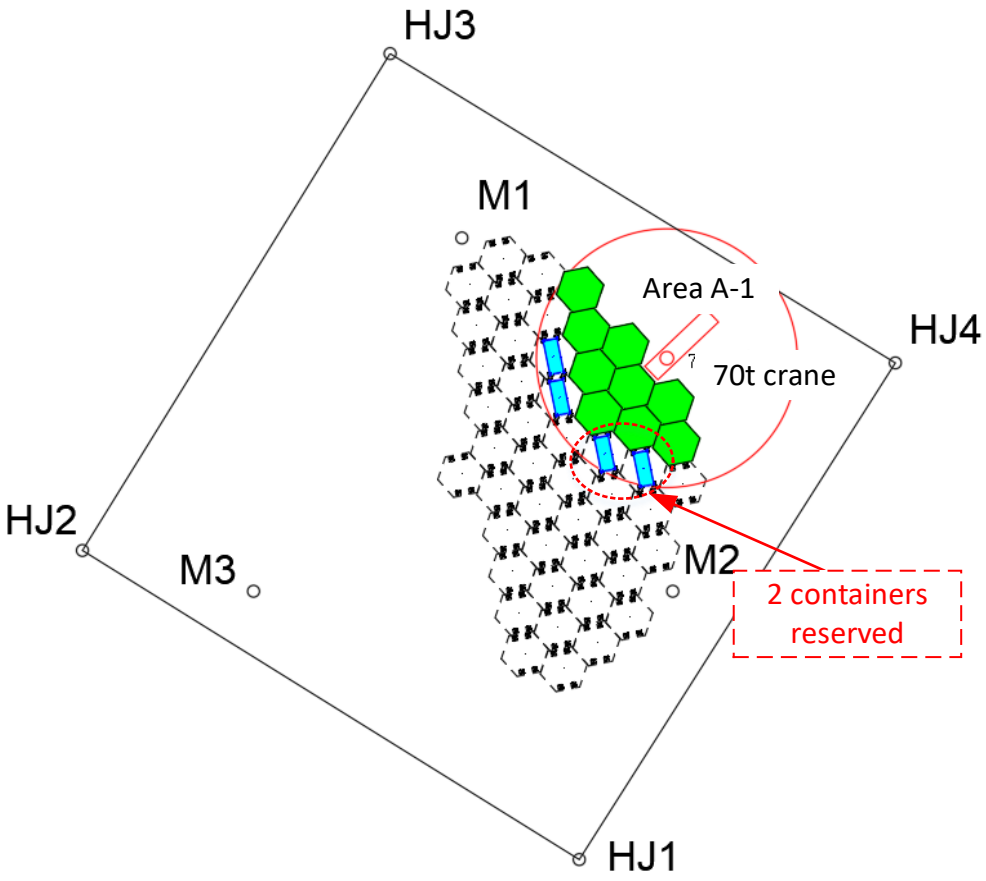


Figure 5-24 Reserved Containers in Area A-1

5.2.3.5. Installation in Area X

Continue with installation in Area B to Area X following the installation steps in Area A until all sub-arrays within the large core array are installed. Reference container is no longer needed. Spacing tooling is used to determine the seating positions of upper adjustment blocks based on the seating positions of the reserved containers in Area X-1. Adjust the positions in accordance with the corrected coordinates in Table 5-3. Record X/Y/Z direction coordinates of all upper adjustment blocks.

For instance, after installation of containers in Area A in Skibotn site, reserve container numbered N-055, which function as the reference for spacing and positioning in Area B.

5.2.4. Concluding Installation

Repeat the steps to complete installations of all containers and antenna array. Then install the external structural parts such as air ducts, connect all the RF cables and

handle the electrical connection between sub-arrays.

5.2.4.1. Install External Structural Parts

The external structural parts to be mounted include 4 pieces of air inlet/outlet, 4 pieces of rain cover and 1 piece of interconnection board protection box, as shown in Figure 5-25.

1) Take out the structural parts and auxiliary fasteners.
2) Cut off the Boeing soft sheets and plastic film applied on the container openings, and use a cloth dipped in alcohol to clean the surface and perimeter of the sealing strip.
3) Use a screwdriver to split the sealing strip, install corresponding air inlet/outlet and other structural parts on the sealing strip. Install all bolts with a passive drill.
4) Use a portable air compressor and attach an air-operated applicator to apply sealant around the air inlet/outlet flanges. Before application of sealant, apply paper tape surrounding the sealing position as protection. Wait for the sealant to dry, and then remove the paper tape.

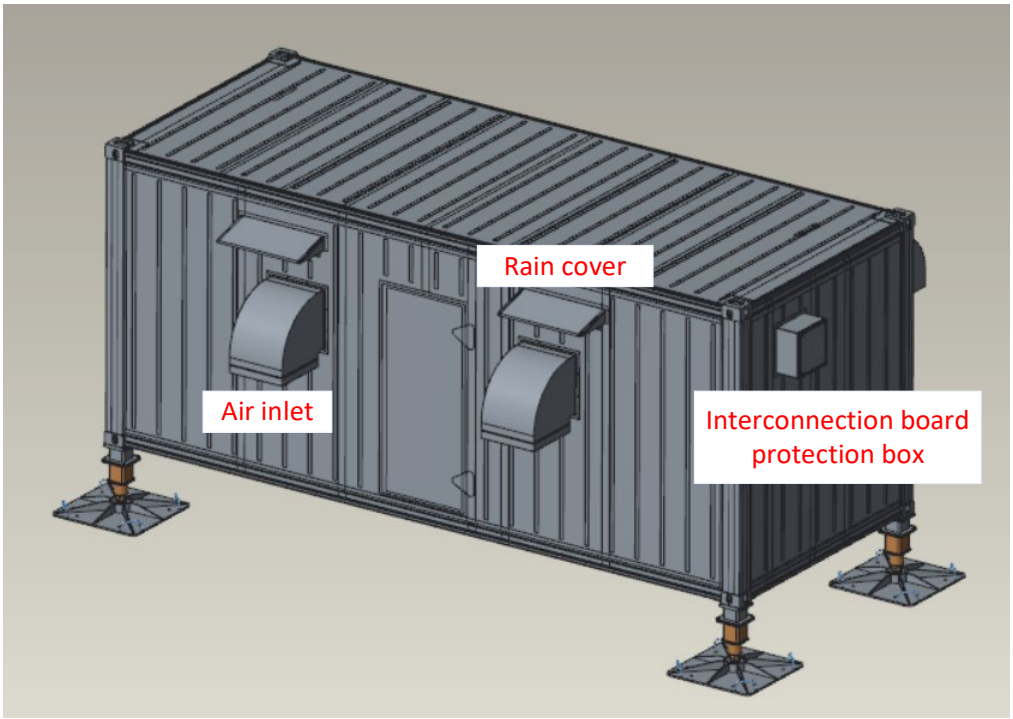


Figure 5-25 Installation of Structural Parts

5.2.4.2. Connect RF Cables

Connect the 182 RF cables between the interconnection board and antenna array. One end of the RF cables has been attached to their corresponding positions on the antenna array. Given the height of the interconnection board, the installation personnel need to stand at the 1.5 meter-high working platform to complete the connection.

1) Release the RF cables on the antenna frame, and remove the protective film and sleeve on the cable connectors. Check if there is water or water vapor inside upon removal of the protective film and sleeve. If so, use a dryer to get rid of the water.
2) Install the 8 sets of cabling rack mounting plate and cabling racks under the antenna frame.
3) Remove the protective cover of the connector on the interconnection board. Check if there is water vapor inside. If yes, use a dryer to get rid of the water.
4) Connect the RF cables to the interconnection board and fasten with the special-made wrench.
5) Arrange the RF cables and fix them to the cabling rack with metal cable tie to make them look neat and clean.

Figure 5-26 Connect RF Cables to the Interconnection Board

5.2.4.3. Electrical Connection between Neighboring Sub-Arrays

Electrical connection between sub-arrays is achieved by a combination of wire mesh and pressure plate. The pressure plate is riveted on the sides of the antenna frame. Portable air compressors and air riveting guns are required. When installing, first lay the triangular wire mesh between the sub-arrays, and then lay the rectangular wire mesh at the long seams between the sub-arrays. After each seam is laid, rivet the pressure plates in accordance with the drawing.

5.2.5. Inspection and Acceptance Test

For final acceptance of the AU installed, the following procedures need to be performed:

1) Functional check of the lighting and PDB inside containers.
2) Check the RF channels of antenna elements
3) Functional check of the temperature control devices
4) Appearance check of the AU and marking & labeling.

6. Supporting Resources Requirements

6.1. Construction Vehicles

Construction vehicles needed for installations at each site are listed in the tables below.

Table 6-1 Construction Vehicles Required for Skibotn Site

SN	Type	Qty	Use
1	Truck (low-holder, 7.6m long)	2	Transfer of antenna frame
2	Truck-mounted crane (25t)	2	Equipment unloading, assembly of antenna frame, transfer of antenna frame and containers, installation of tooling
3	Truck-mounted crane (70t)	1	Hoisting of containers & antenna frame for placement
4	Forklift (5t)	1	Transfer of mounting bases, upper adjustment blocks, etc.

Table 6-2 Construction Vehicles Required for Kaiseniemi/Karesuvanto Site

SN	Type	Qty	Use
1	Truck (low-holder, 7.6m long)	2	Transfer of antenna frame
2	Truck-mounted crane (25t)	2	Equipment unloading, assembly of antenna frame, transfer of antenna frame and containers, installation of tooling
3	Truck-mounted crane (50t)	1	Hoisting of containers & antenna frame for placement
4	Forklift (5t)	1	Transfer of mounting bases, upper adjustment blocks, etc.

6.2. Manpower

Table 6-3 Manpower Resources Required (Installation at one complete array)

SN	Type	Qty	Work Content
1	Project Manager	1	Coordinator and installation planning & management
2	Mechanical Engineer	2	Instruct on-site installation operations from technical perspective
3	Measurement Engineer	2	Measurement and surveying on site

4	Antenna Tester	2	Test antenna elements and check RF performance
5	Mechanical fitter	14	Hoisting and installation operations
6	Electrical fitter	4	Connect RF cables, cabling and fastening
7	Crane driver	3	Drive cranes
8	Truck driver	2	Drive trucks
9	Forklift driver	1	Drive forklifts

Manpower requirements for preparation phase, installation phase and concluding phase are described as follows.

1) Preparation phase

During the preparation phase, the work majorly includes: AU unloading and establishment of measurement system on site.

- For AU unloading, two teams work in parallel, each team equipped with 3 mechanical fitters and 1 truck-mounted crane (25t).
- After unloading the measurement tooling, start establishing measurement coordinate system, during which 3 mechanical fitters and a large-tonnage crane are required to install the measurement work platforms, and measurement engineer & mechanical engineer are required to conduct ground mapping and surveying.

2) Installation Phase

During installation, two groups of fitters are required for pre-installation and installation respectively.

- The pre-installation group is composed of 8 mechanical fitters and 4 electrical fitters that are divided into two smaller teams, each responsible for the entire process of pre-installation.
- The installation group is composed of 6 mechanical fitters, responsible for the

entire process of AU installation.

3) Concluding Phase

During the concluding phase, the work majorly includes RF cable connection, electrical connection handling and installation of external structural parts.

- For RF connections, 4 electrical fitters are required.
- For installation of external structural parts such as air ducts, 6 mechanical fitters are required.
- For handling of electrical connection spring plates between sub-arrays, 8 mechanical fitters are required.

6.3. Special Tools

Table 6-4 List of Special Tools

List of Special Tools						
SN	**Item**	**Norway Qty**	**Finland Qty**	**Sweden Qty**	**Total Qty**	**Description**
1	Measurement working stand(4-meter-high)	0	3	3	6	For installing and operating the measuring instruments
2	Measurement working stand (3.5-meter-high)	3	0	0	3	For installing and operating the measuring instruments
3	Mobile platform ladder (3.3-meter-high)	8	4	0	12	For staff to stand on to observe the antenna frame landing
4	Mobile platform ladder (4.2-meter-high)	2	2	2	6	For access to and from measurement operation platform and antenna array
5	Maintenance stand (1.5-meter-high)	8	4	0	12	For installing cables on the interconnection board and the air duct
6	Dowel and discs	450	250	0	700	For ground surveying and measurement
7	Transportation tooling	13	6	6	27	For transporting mounting bases' base plate and assembling antenna frame
8	Reference mark	4	3	3	10	For surveying and mapping of center positioning pin of adjustment block
9	Packaging box	119	54	55	228	For packaging of mounting bases and upper adjustment blocks
10	Lifting tool for antenna frame transport unit	4	4	4	12	2 lifting booms + 8 slings + shackles

11	Lifting tool for container	4	4	4	12	4 slings + 4 shackles
12	Lifting tool for antenna frame	4	4	4	12	4 slings + 4 shackles + 4 lift ring bolts
13	Spacing tooling 1	2	2	2	6	For spacing and surveying of the upper adjustment blocks
14	Spacing tooling 2					
15	Spacing tooling 3					
16	Spacing tooling 4					
17	Container position calibration & examination tooling					
18	Thread alignment pins	12	12	12	36	
19	1mm Compensating gasket	500	250	250	1000	For height compensation of the upper adjustment blocks

6.4. General-Purpose Tools

Table 6-5 List of General-Purpose Tools

List of General-Purpose Tools						
SN	**Item**	**Norway Qty**	**Finland Qty**	**Sweden Qty**	**Total Qty**	**Description**
1	Open-end wrench (65mm)	8	0	0	8	For rotating the mounting base
2	Ratchet socket wrench set	8	0	0	8	For M8,M10,M12,M20 bolt fastening
3	Extended socket (30mm)	8	0	0	8	For M20 bolt fastening
4	Movable wrench (12-inch, SATA)	12	0	0	12	For M8,M10,M12 bolt fastening

5	M6/M8/M10/M12 Ratchet wrench	12	0	0	12	For bolt fastening (one open end, one socket)
6	Electric hand drill(Bosch)	10	0	0	10	For installing screws of antenna elements and air ducts
7	M5 & M6 hex screw head (SATA)	30	0	0	30	
8	M5 & M6 outer hex screw head (SATA)	10	0	0	10	
9	Straight and round mouth forceps set	4	0	0	4	4 pcs straight & 4 pcs round each set
10	Angle grinder	3	0	0	3	For grinding at positions where interference occurs
11	Metal cutting pieces	100	50	50	200	
12	Metal grinding discs	100	50	50	200	
13	Grinding head	8	4	4	16	
14	Silk cone plate teeth set (M6,M5,M3,M8)	5	5	5	15	For threaded hole installation (rework)
15	Drill bits 5.2, 5.1, 4.3, 3.3, 7 (set)	10	10	10	30	For drilling holes
16	Combination file set	4	0	0	4	For repairing holes and bolts
17	Portable air compressors	5	0	0	5	For powering pneumatic pull riveting gun and sealant gun
18	Pneumatic pull riveting gun (M5)	10	0	0	10	For electrical interconnection board pull riveting
19	Manual pull riveting gun (M5)	10	0	0	10	For electrical interconnection board pull riveting
20	Pneumatic sealant gun	8	4	4	16	For applying adhesive sealant on windows of container

21	Manual sealant gun		8	4	4	16	For applying adhesive sealant on windows of container
22	Relieving tool		10	10	10	30	For adhesive relieving
23	Jack 5-ton		4	0	0	4	For lifting container
24	Crowbar 1.5-meter		4	0	0	4	For prying mounting base and container
25	61 pcs tool set(09536)	Allen key	5	0	0	5	For electrical installation
		Wire pliers					
		Stripping pliers					
		Needle nose pliers					
		Oblique mouth pliers					
		Croissant hammer					
		Screwdriver set					
		Utility knife					
		4-14mm Hex bit socket					
		Soldering iron					
		Multimeter					
26	Carp tongs		5	0	0	5	For electrical installation
27	Hot air gun		10	0	0	10	For drying cable head
28	Metal cable tie gun		5	0	0	5	For tying metal cable
29	Utility knife (SATA)		10	5	5	20	For unpacking
30	Utility knife blades (15 pcs/set)		5	5	5	15	

31	Scissor	5	5	5	15	For unpacking
32	Tape (SATA 10m)	5	5	5	15	For measuring
33	100m cable reel + European adapter	8	0	0	8	For powering
34	European standard power strip	8	0	0	8	For powering
35	Pulling rope	400	400	400	1200	For pulling antenna frame and container during lifting
36	Trolley	5	0	0	5	For transiting equipment
37	Tool box	10	0	0	10	For placing tools

6.5. Auxiliary Materials and Consumables

Table 6-6 List of Auxiliary Materials & Consumables

List of Auxiliary Materials & Consumables						
SN	**Item**	**Norway Qty**	**Finland Qty**	**Sweden Qty**	**Total Qty**	**Description**
1	Cleaning cloth	10	5	5	20	Surface cleaning
2	Sandpaper 400/600 grit	1	1	1	3	For cleaning of the glued surface, 100pcs/set
3	Rubber mats	2	2	2	6	Protect from antenna frame lifting bumps, dimension 1.5mx10mx5mm
4	Tape(Black, white, brown, green, blue)	10	5	5	20	For electrical installation in PDB

5	Paper tape (width: 25mm)	120	60	60	240	For sealant protection
6	Paper tape (width: 50mm)	18	12	12	42	For labeling
7	Marker pen(Black, pen, red, each color 10 pcs)	5	5	5	15	For labeling
8	Lubricating grease	8	4	4	16	For lubrication protection of mounting bases
9	Plastic wire ties	6000	3000	3000	12000	Cable fixing
10	Metal wire ties	12000	6000	6000	24000	Cable fixing
11	Low temperature sealant	238	108	110	456	

7. Installation Planning

7.1. Skibotn Site (Norway)

7.1.1. Installation Planning

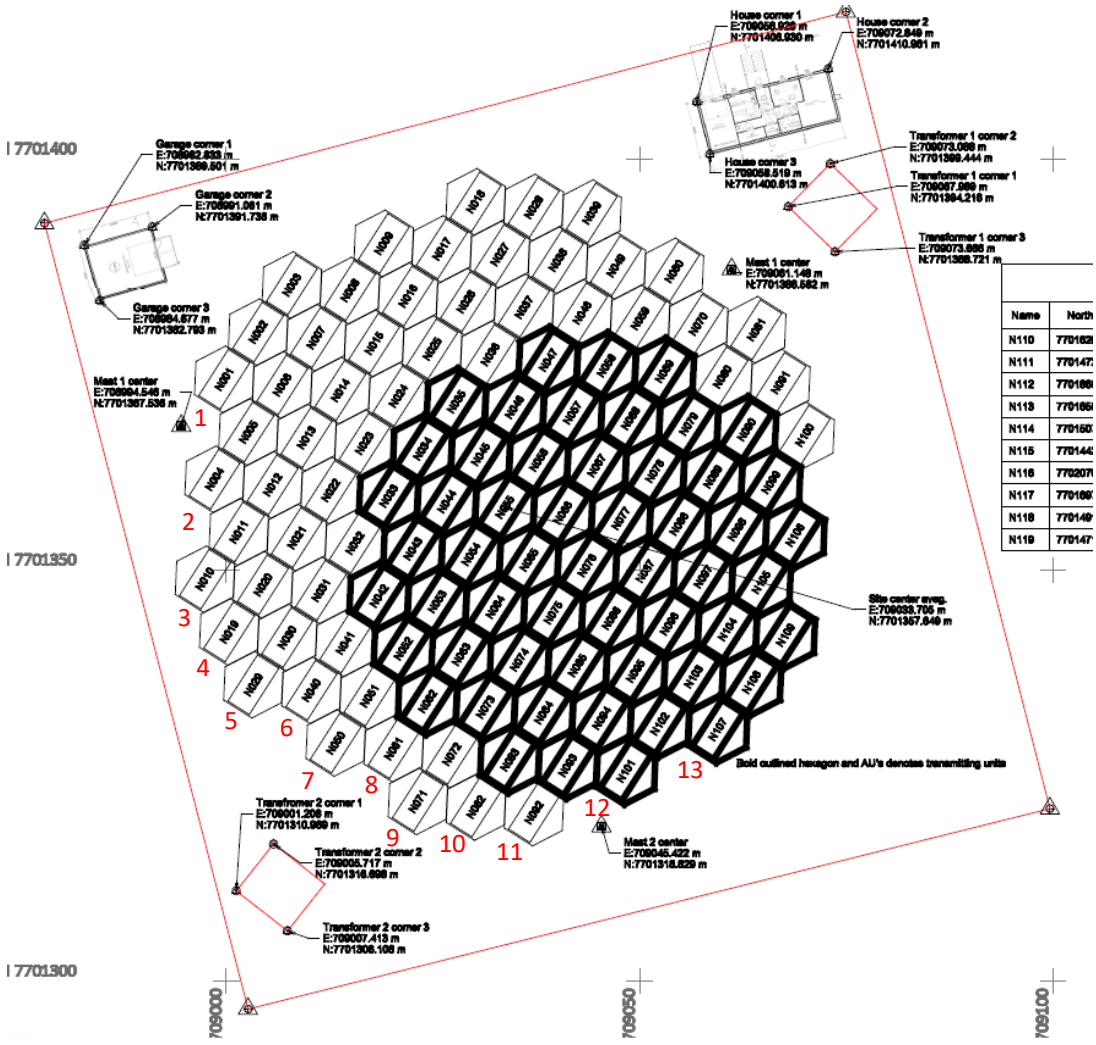


Figure 7-1 AU Layout in Skibotn Site

Illustrative layout of the Skibotn site is shown in Figure 7-1. Its entrance is located in the northwest corner near calibration mast M3. For easier AU entry, it is suggested that first install the half-core array near M2, which is sub-arrays in Column 8~13 in Area A. Use the 70t crane as the main crane.

1) Mount measurement work platforms on the three calibrations M1~M3.

2) Take M3 as the measurement point, conduct surveying and mapping to

determine seating positions of all mounting bases in Area A. Number the seating positions in accordance with the sub-array number, record the X/Y/Z coordinates in a table.

3) Place bottom pieces of all the mounting bases of sub-arrays in Area A (N055, N061~N109)

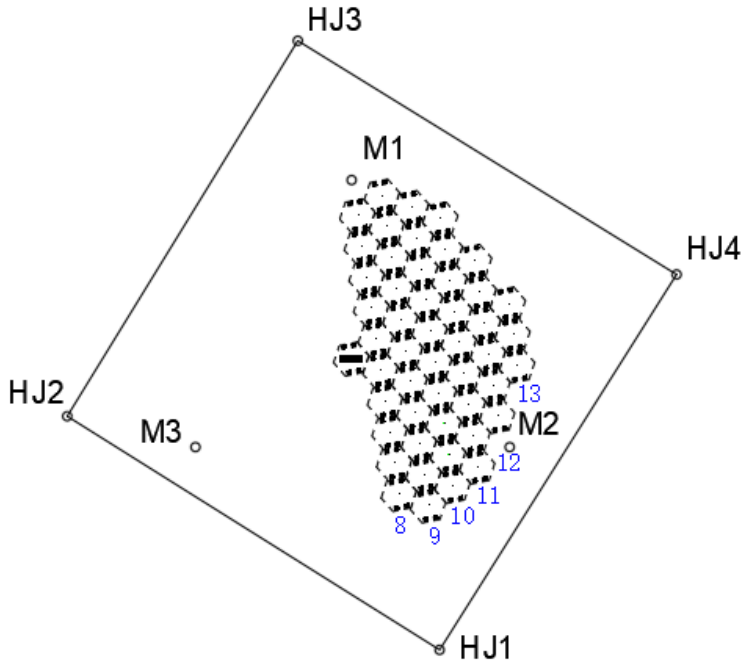


Figure 7-2 Place Bottom Pieces of Mounting Bases in Area A

4) Take container N088 as the reference container. Hoist and place all containers in A-1 and perform the installation operations starting from Area A-1 as described in section 5.2.3.3, as illustrated in Figure 7-3.

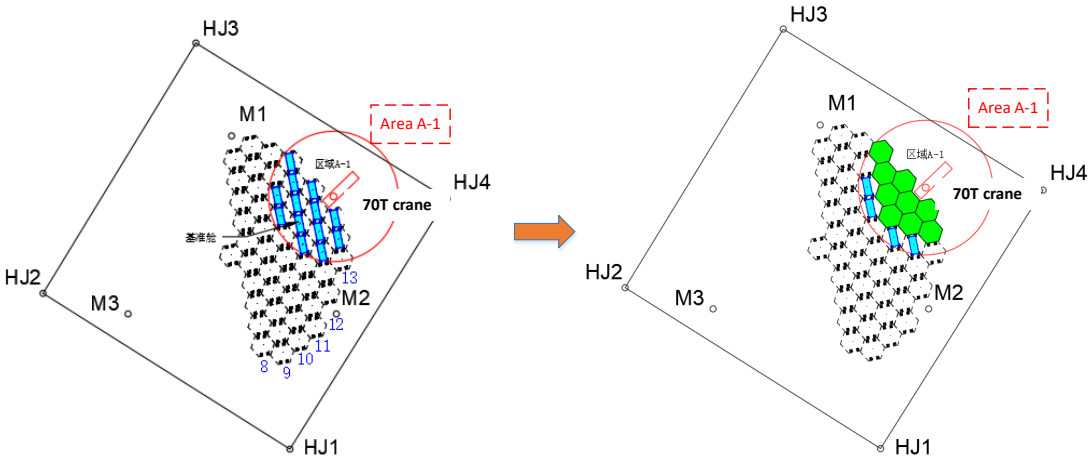


Figure 7-1 AU Installation in Area A-1

5) Continue to complete installation in Area A-2 to A-6, as illustrated in Figure 7-4.

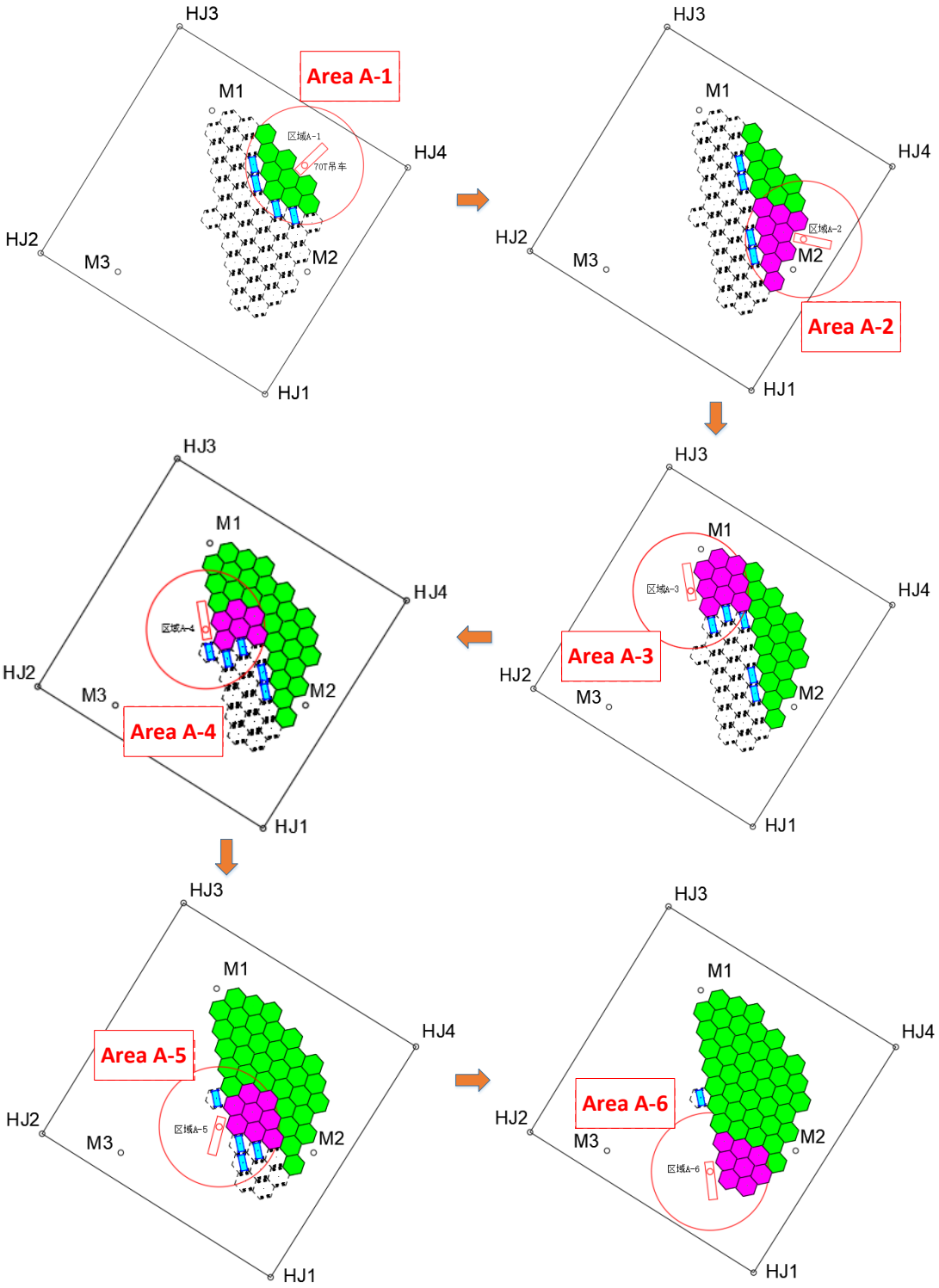


Figure 7-2 Installation in Area A

6) Meanwhile, conduct pre-installation of antenna array on the ground in two areas in parallel. Then transfer the antenna array (antenna frame mounted with antenna elements) to the installation position via truck.

7) Repeat the steps in Area A to proceed with installation in Area B (Column 6

and 7), as illustrated in Figure 7-5.

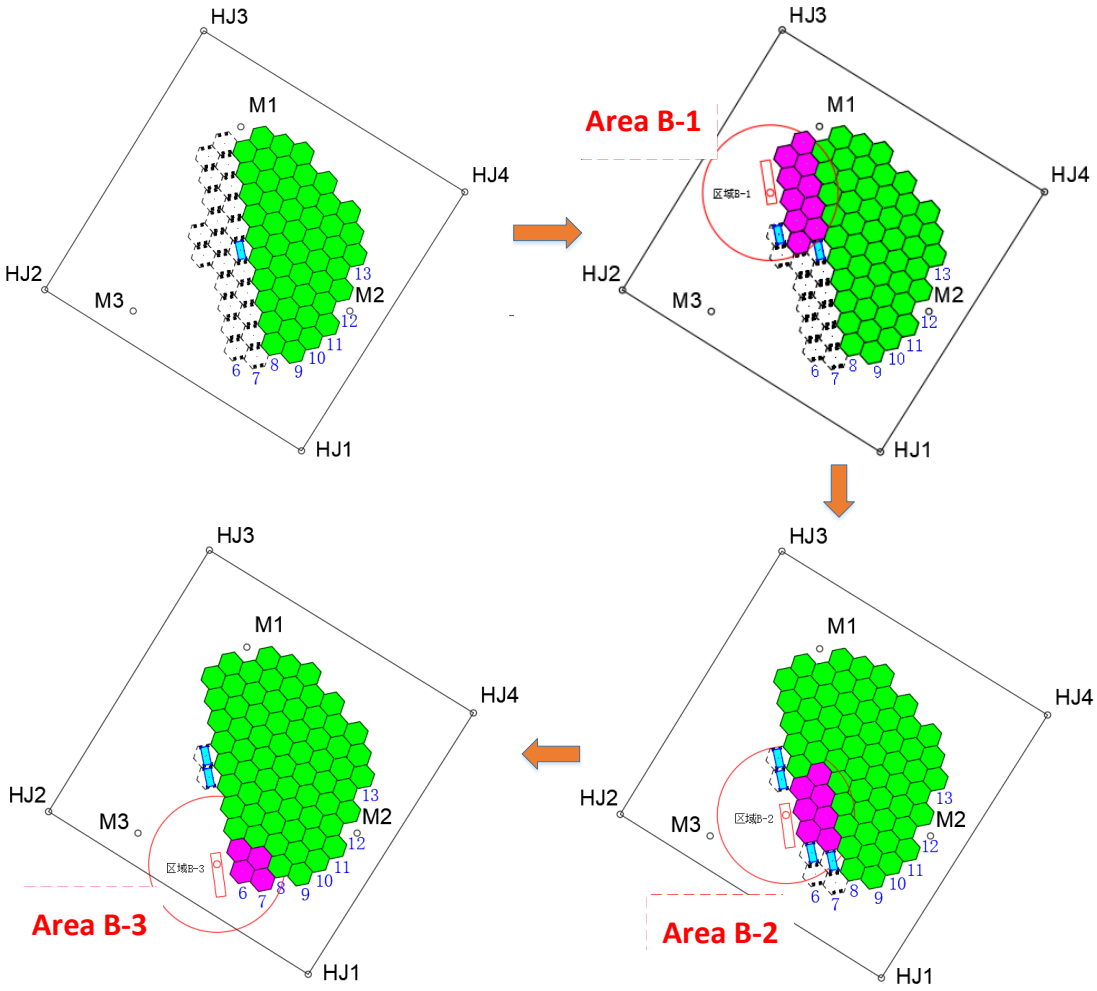


Figure 7-3 Installation in Area B

8) Continue to complete installation in Area C (Column 4 and 5), as illustrated in Figure 7-6.

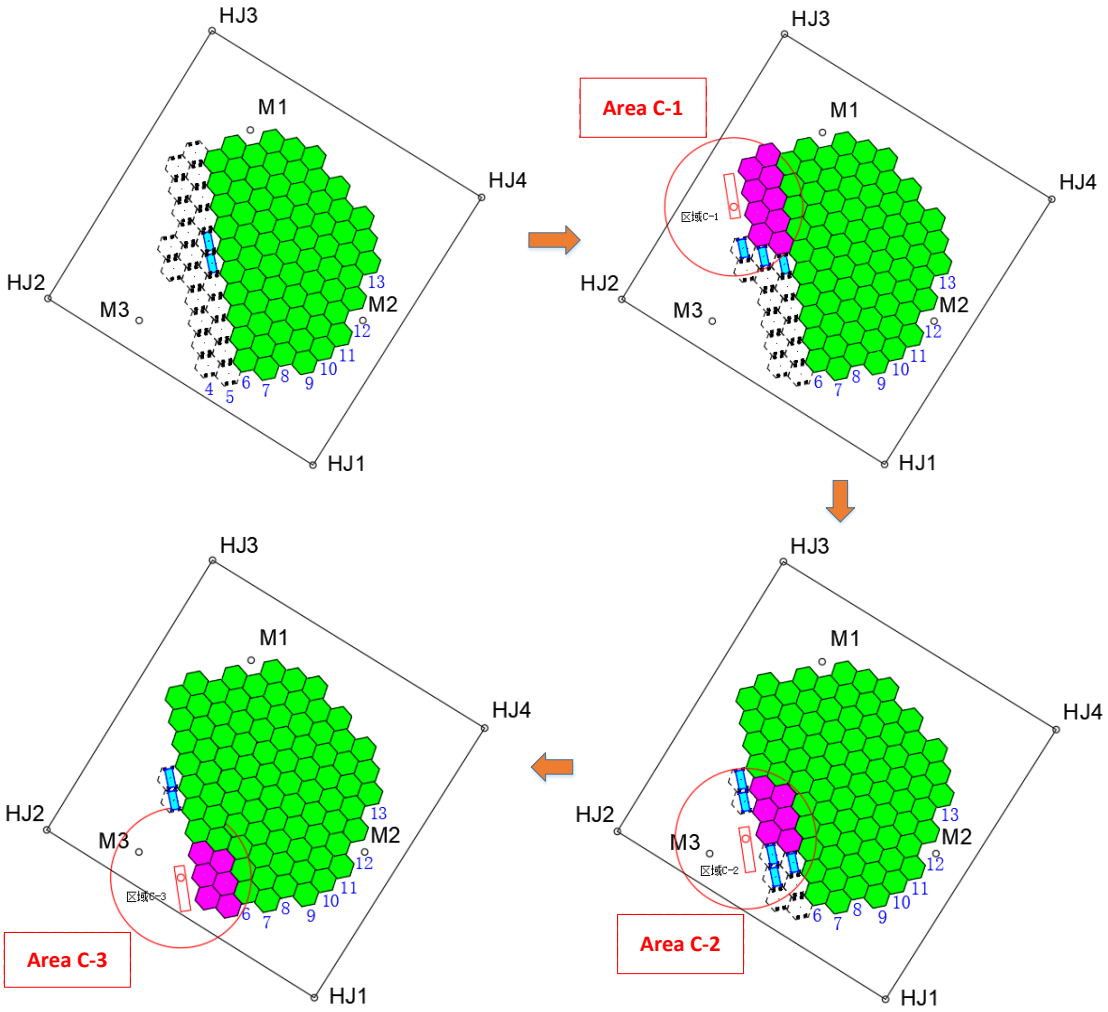


Figure 7-4 Installation in Area C

9) Continue to proceed with installation in Area D (Column 1, 2 & 3), as illustrated in Figure 7-7.

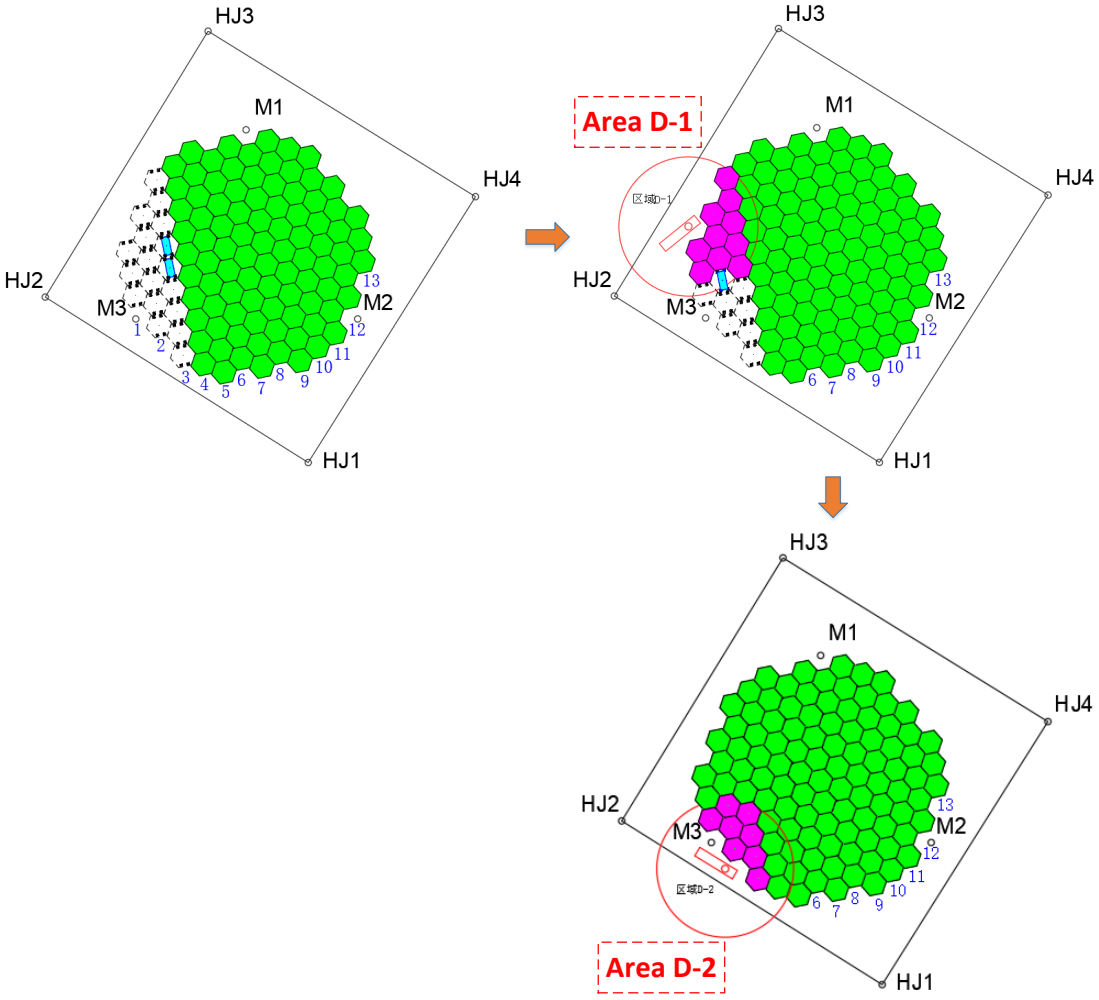


Figure 7-7 Installation in Area D

10) Start concluding installation work, which include RF cable connection, installation of structural parts such as air duct and electrical connection handling between sub-arrays.

11) Meanwhile, complete installation of the independent array of 10 sub-arrays.

7.1.2. Site Arrangement

To minimize equipment transfer and maximize installation efficiency, it is suggested that:

1) Place the 3 containers filled with tools and tooling near the entrance of the site, which makes it easier for the installation personnel to take out tools and spare parts.

2) Place 3 sets of mounting base TU I at each of the 4 corners of the site. The rest 1 set of mounting base TU I plus 6 bottom pieces at the entrance of the site.

3) Place the containers N082~N109 at the blue areas illustrated in Figure 7-8, ready for installation.

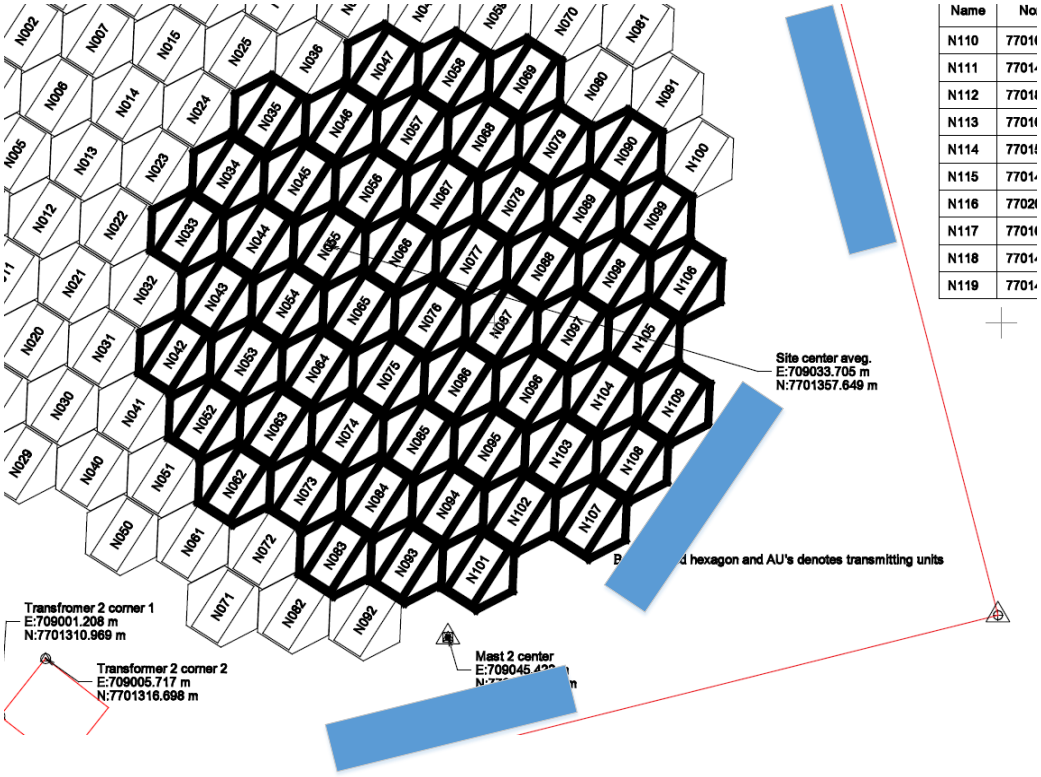


Figure 7-8 Placement Areas of Containers N082~N109

4) Containers N001~N049will be placed along the edge of the site, as illustrated in the blue areas in Figure 7-9. The rest containers can be placed in the operating radius of the main crane.

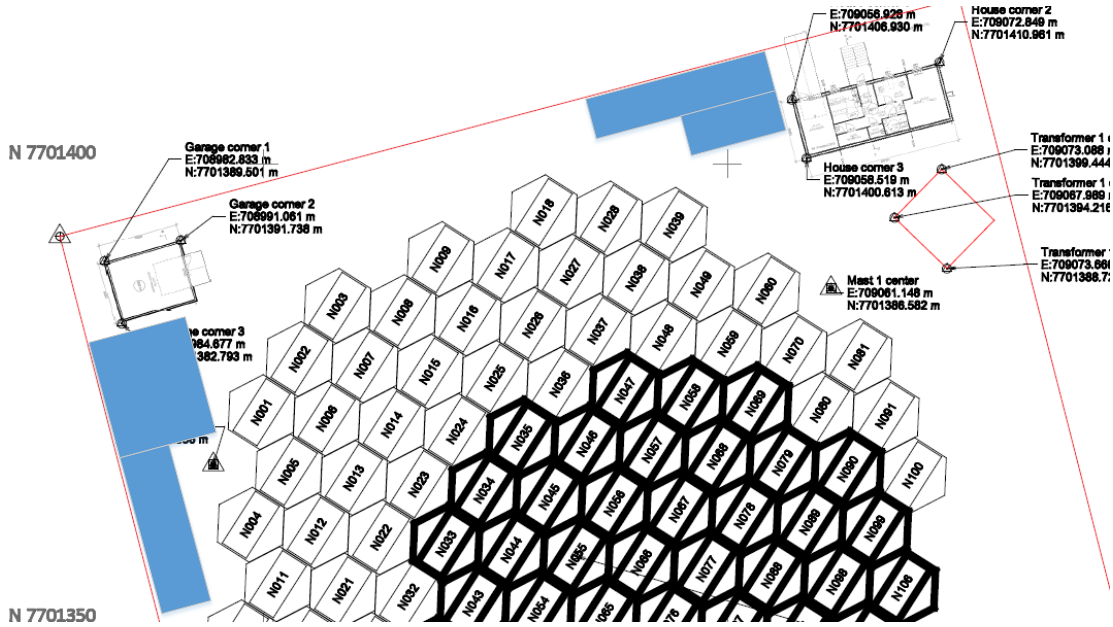


Figure 7-9 Placement Areas of Containers N001~N049

5) The antenna frame TU can be stacked in the two blue areas as illustrated in Figure 7-10.

Figure 7-10 Placement Areas of Antenna Frame TU

6) The measurement work platforms can be trucked directly to the three calibration masts. The rest tooling will be placed near the containers filled with tools.

7.1.3. Schedule Planning

7.1.3.1. Preparation Phase

During land transport, each truck is loaded with 2 container TU or 2 antenna frame TU. Use 2 crane for the unloading. Suppose unloading of 12 trucks can be done in one working day, then unloading of all AU for Skibotn site takes 9 working days.

Meanwhile, the measurement personnel start establishment of measurement system and ground surveying.

7.1.3.2. Installation Phase

For Skibton site, pre-installation of a single antenna array takes appx 4 hrs. therefore, pre-installation of 119 antenna arrays could take 30 working days.

Installation of antenna arrays include:

1) Placing mounting base bottom pieces

For the core array (109 antenna arrays) in Skibotn site, installation of altogether 436 mounting base bottom pieces is needed. If installation of 1 mounting base bottom piece takes 15 mins (5mins for surveying and mapping, 10mins for placement), then the total required are listed as follows:

Table 7-1 Time Required for Installing Mounting Base Bottom Pieces

Area	Qty of Bottom Pieces of Mounting Base	Time for Surveying (min)	Time for Placing Bottom Pieces (min)	Total Time (h)	Working Day (8h of work)
A	200	1000	2000	50	6.25
B	88	440	880	22	2.75 (appx 3)
C	84	420	840	21	2.625 (appx 3)
D	64	320	640	16	2
Total					**14 working days**

2) Placing the Container

To place a container could take appx 40mins:

- Adjust 4 screws of the mounting bases: 5mins

- Install 4 mounting bases: 20mins
- Hoist and place container: 15mins

3) Installing and Adjusting Upper Adjustment Blocks

Installation and adjustment of the upper adjustment blocks for each container could take appx 40mins:

- Install upper adjustment blocks: 20mins
- Adjust adjustment blocks in Z direction: 10mins
- Adjust adjustment blocks in X/Y direction:10 mins

Table 7-2 Time Required for Installing Containers

Area	Qty of Containers	Time for Placing Container (min)	Time for Installing Upper Adjustment Blocks (min)	Total Time (min)
A-1	13	520	520	1040
A-2	9	360	360	720
A-3	10	400	400	800
A-4	6	240	240	480
A-5	7	280	280	560
A-6	5	200	200	400
B-1	11	440	440	880
B-2	9	360	360	720
B-3	2	80	80	160
C-1	10	400	400	800
C-2	8	320	320	640
C-3	3	120	120	240
D-1	9	360	360	720
D-2	7	280	280	560
Total				**8720 (19 working days)**

4) Installing Antenna Array

Installation of 1 set of antenna array takes appx 50mins, the total time required is appx 12 working days (8hrs of work each working day).

Table 7-3 Time Required for Installing Antenna Arrays

Area	Qty of Antenna Arrays	Time (min)
A-1	9	450
A-2	9	450
A-3	9	450
A-4	6	300
A-5	8	400
A-6	8	400
B-1	10	500
B-2	7	350
B-3	4	200
C-1	9	450
C-2	6	300
C-3	6	300
D-1	10	500
D-2	8	400
Total		**5450 (12 working days)**

7.1.3.3. Concluding Phase

1) Installing structural parts

- Installation of each structural part and apply sealant: 10mins/2persons

  *4 persons in 2 teams work in parallel, each container is with 9 structural parts

- Altogether the process will take 11 working days.

2) Handling electrical connection between sub-arrays

- Handling of electrical connection for each sub-array: 180mins/2persons

  *6 persons in 3 teams work in parallel

- Altogether the process will take 13 working days.

3) Connecting RF cables

- RF cable connections of 1 sub-array (with 182 RF cables): 180mins/1person

  *3 persons work in parallel

- Altogether the process will take 13 working days.

The three operations are conducted in parallel. Therefore the whole concluding phase will take 13 working days.

7.1.3.4. Installation of Independent Array (10 sub-arrays)

4 mechanical fitters and 1 electrical fitter are required for installation. Installation of the 10 sub-arrays will take 12 working days.

7.1.3.5. Installation Time in Total

Table 7-4 Total Time Required for AU Installation in Skibotn Site

SN	Phase	Time (working day)
1	Preparation phase	9
2	Installation Phase-Installing Mounting Base Bottom Pieces	14
3	Installation Phase-Installing Containers	19
4	Installation Phase-Installing Antenna Arrays	12
5	Concluding Phase	13
5	Independent Array Installation Phase	12 (in parallel with concluding phase)
Total		**67**

7.2. Karensuvanto Site (Finland)

Refer to the installation planning for Skibotn site. The time required will be half of the time required by Skibotn site.

7.3. Kaiseniemi Site (Sweden)

Refer to the installation planning for Skibotn site. The time required will be half of the time required by Skibotn site.