CTA Candidate Sites in Namibia

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CTA Namibian & South-African task team

1 Introduction

Southern Africa has some of the world's best sites for air Cherenkov telescopes (ACT), satisfying all the requirements for the planned CTA (Cherenkov Telescope Array). In addition, the good infrastructure available and the low risks of Southern Africa have resulted in Southern Africa already hosting a number of world class telescopes. Namibia is successfully hosting the H.E.S.S. telescope and has hereby proved its capability to host an ACT. South Africa is hosting one of the largest optical telescopes, SALT (South-African Large Telescope) and has been selected to host the world's largest radio telescope array, the SKA (Square Kilometre Array).

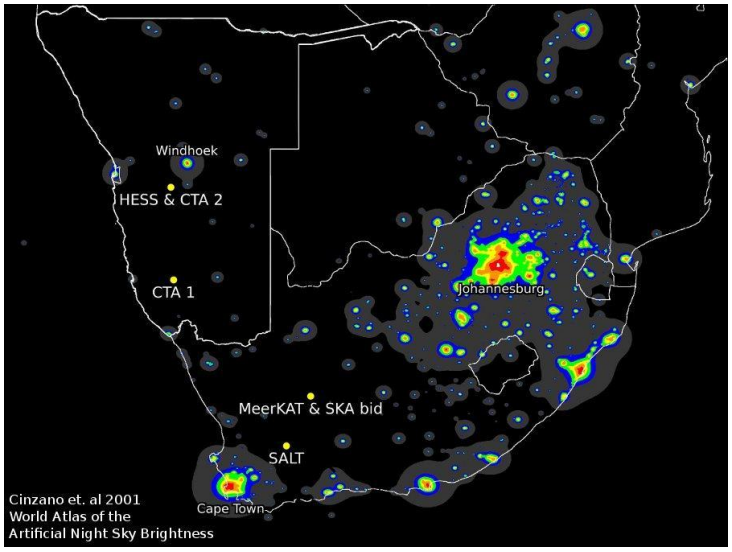

Figure 1: Artificial Night Sky Brightness of southern Africa (Cinzano *et. al* 2001) showing the positions of the two proposed CTA sites as well as other larger astronomy facilities.

First an overview is given of what led to the selection of the two sites. It is then shown that the two sites satisfy the CTA environmental requirements and that the necessary infrastructure can be provided. Lastly, it is shown that Southern Africa has the local scientific, technical and political support to make the CTA possible.

2 Contents

3 Site Location

The two main factors that drove the site selection process in Southern Africa were the weather conditions and available infrastructure. As ACTs can only operate during dark, moonless, cloudless nights, the number of cloudless hours directly influences the sensitivity of the telescope and has to be maximised. Secondly, the cost of building large infrastructure (such as roads, power lines etc.) has to be minimised.

Figure 2 shows that the western side of Southern Africa has very low cloud coverage, but that there are only a few places that are high enough (>1500m a.s.l.) and flat enough (over 10km^2) to host the CTA. Of these places, the best two were chosen:

The first site (Figure 2, site 2) is located on the farm Aar in the south of Namibia where the cloud coverage is the least. Although it is quite remote, it has good infrastructure as it is close Aus, a national road, a railway line, a power line and an optical fibre line. The second site is the well-known H.E.S.S. site, located on the farm Göllschau, which is much less remote as it is about one hour's drive from the capital Windhoek. Although Göllschau is a bit cloudier than Aar, more infrastructure is available which make it a cheaper site and it is a lower risk site because it is better known.

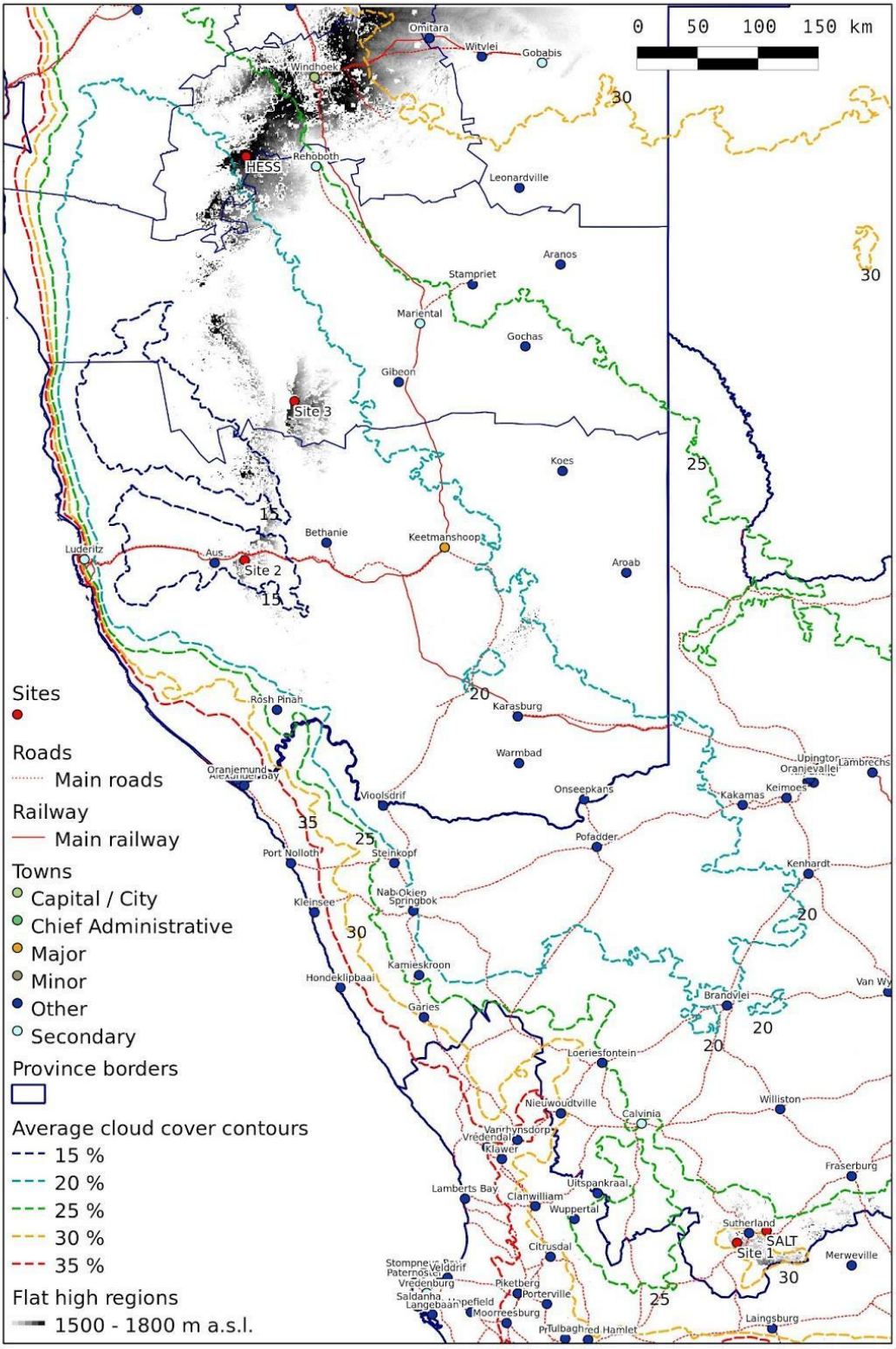

Figure 2: Average night-time cloud coverage contour map of Southern Africa using MODIS satellite data. The gray-scale overlay shows regions with an altitude higher than 1500 m and a gradient of less than 2 degrees.

3.1 Orography of the Sites

Both the Aar and Göllschau area is large and flat enough to easily implement the CTA configuration with ample of surrounding space for buildings. Figure 3 and Figure 5 show possible positions of the CTA array at Aar and Göllschau respectively. More detail is given in Appendix: Site Location. Figure 4 and Figure 6 show a photo of each site. More photos of the sites are available in Appendix: Photos.

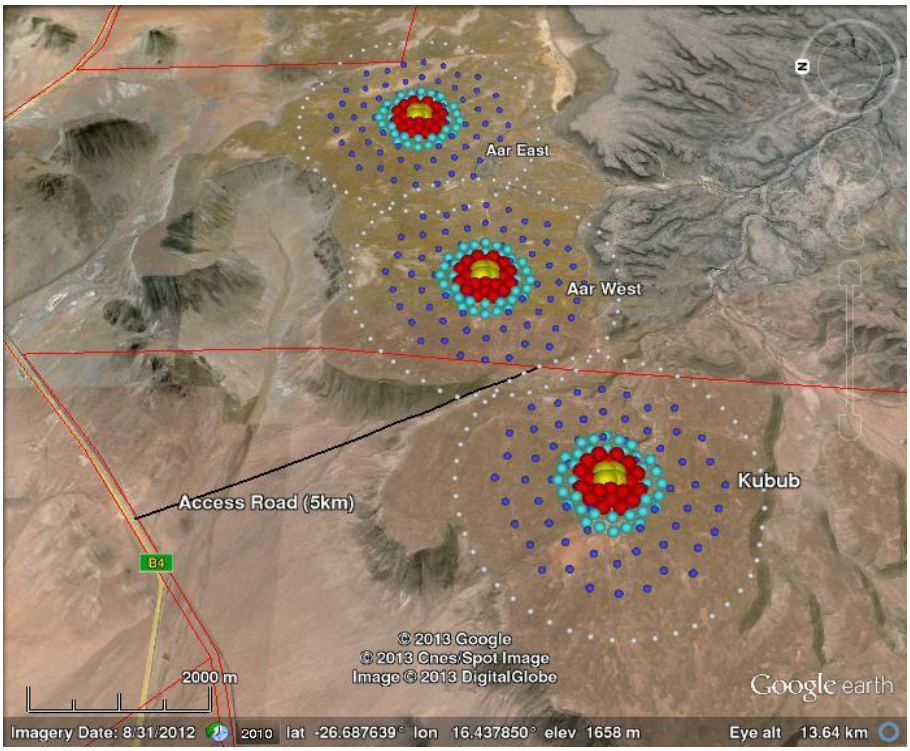

Figure 3: Three different possible CTA layouts at Aar, viewed from the east. White dotted circle shows a 10km^2 area. Other dots show telescope positions.

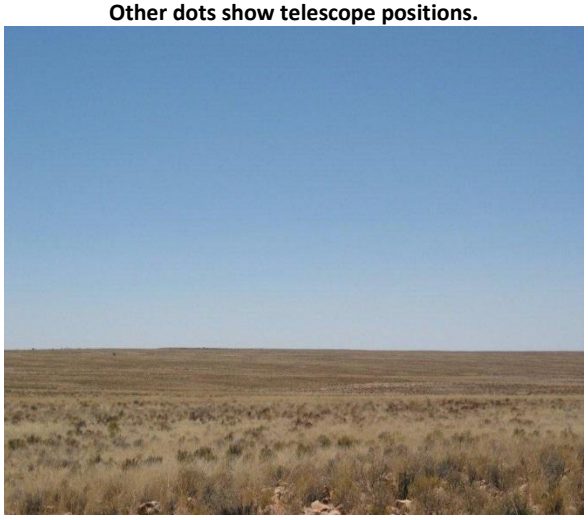

Figure 4: Photo of the Aar farm

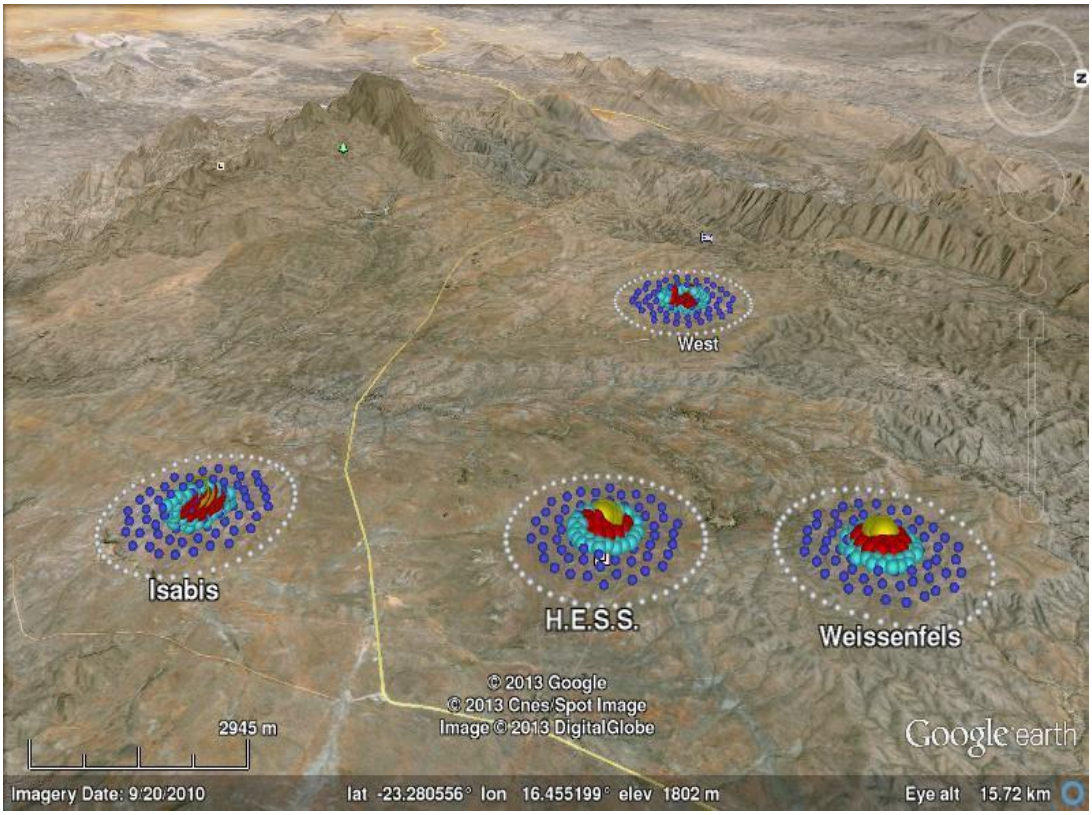

Figure 5: Four different possible CTA layouts at Göllschau viewed from the east towards Gamsberg. White dotted circles show a 10km^2 area. Other dots show telescope positions.

Figure 6: Photo of the Göllschau farm

3.2 Geotechnical Conditions

In a study conducted by UNAM (University of Namibia), it is shown that the Aar plateau (Figures 2.3 in Appendix: Geology & Hydrology) consists of quartzite sandstone, interlayered with shale, with a depth of around 20m. This makes it possible to use similar design and construction procedures as was employed for H.E.S.S. The construction can involve ringbeam-foundations placed on mass concrete that extends to an average depth of 1.03 m despite the different geological settings. The study also shows that the site has very good drainage.

4 CTA Environmental Requirements

In this section, it is shown that the proposed sites meet the CTA requirements as set forth in MAN-PO/120918, Version 1.6.

4.1 Geography and Topography of the Sites

For further detail, see Appendix: Site Location.

		Göllschau	Aar
A-ENV-0110	Latitude between -40° to -20°.	-23.3°	-26.7°
A-ENV-0130	Altitude between 1500 - 3800 m a.s.l.	1815 m	1640 m
A-ENV-0140	Available area >10 km².	Figure 5: white dots = >10 km²	Figure 3: white dots = >10 km²
A-ENV-0145	Available area linear extent in all directions of > 3 km.	Figure 5: white dots 3.6 km extent	Figure 3: white dots 3.6 km extent
A-ENV-0160	The local gradients in the area of the sites must be <8 %.	<3.5%, Figure 2	
A-ENV-0170	The local gradients in the area around the telescope and buildings, for 5 m beyond the structures must be <2 %.	Yes	Yes

4.2 Ambient Temperature

For further detail, see Appendix: Weather Analysis.

		Göllschau	Aar
A-ENV-0210	Ambient air temperature during observations will be -10 to +25 °C.	No time loss (SENES 0.009%)	Time loss small (SENES 0.07% KAV 0.7%)
A-ENV-0220	Extreme air temperature range -20 to +40 °C.	SENES: Always in the range of -5 to 35°C	

A-ENV-0230	Air temperature gradient at night time will be ± 5 °C/h.	% time larger: SENES: 0.01%	SENES: 0.01% KAV: 0.1%
A-ENV-0240	The natural temperature variations within 24 hours will be less than ±30 °C.	SENES: Always <22°C	SENES: Always <23°C

4.3 Relative Humidity

For further detail, see Appendix: Weather Analysis.

		Göllschau	Aar
A-ENV-0310	The relative humidity for observations is in the range 4-90 %.	Satisfied when dew point criteria (below) is satisfied	
A-ENV-0320	The relative humidity for survival in safe state is in the range 2-100 %	Always	Always
A-ENV-0330	Dew point too large for observation	2.2±1.3% time loss when not cloudy	2.2±0.8% time loss when not cloudy

4.4 Rain

For further detail, see Appendix: Weather Analysis.

		Göllschau	Aar
A-ENV-0410	The maximum rain precipitation in 24 hours is 200 mm.		<200 mm per month
A-ENV-0420	The maximum rain precipitation in one hour is 70 mm.	SENES: max 31 mm	SENES: max 16 mm
A-ENV-0430	The assumed wind speed for blowing rain is 90 km/h.	Max 10 min average wind speed < 50 km/h	
A-ENV-0450	No rain will be present during Observations	Included in cloud cover requirement	

4.5 Snow and Hail

For further detail, see Appendix: Weather Analysis.

		Göllschau	Aar
A-ENV-0510	No snow will be present on the ground during Observations.	SENES: None	SENES: snow for 3 hours per year.
A-ENV-0520	Damage beyond the SL level must not be incurred during Safe State for a snow accumulation of the ground of <50 cm.	Never occurs	Never occurs
A-ENV-0540	The CTA sites must have a probability that hailstones with a diameter of > 20 mm should occur with a frequency <0.03 year−1.	SENES: None Nathan[1]: lowest risks	Plateau: none SENES: none Nathan: lowest risks

4.6 Ice

		Göllschau	Aar
A-ENV-0610	No ice will be present on any surfaces during Observations.	Morning frost possible	Morning frost possible
A-ENV-0620	Damage beyond the SL level must not be incurred during Safe state for an ice thickness (on all surfaces) of <20 mm.	Never thick ice	Never thick ice

[1] Nathan World Map of Natural Hazards, Munich RE

4.7 Wind

For further detail, see Appendix: Weather Analysis.

		Göllschau	Aar
A-ENV-0710	During observations the 10-minute average wind speed is <36 km/h.	Less than <0.5% observation time loss.	Time loss uncertain as Atmoscope give 0.2% and SENES 3%.
A-ENV-0720	During transitions, the 10-minute average wind speed is <50 km/h.	SENES: Never >50 km/h	SENES: 1h/10years: >50 km/h
A-ENV-0730	1-s gusts <200 km/hour or 10-minute average wind speeds <120 km/h.	10-minute average wind speeds never >60km/h	

4.8 Solar Radiation

		Göllschau	Aar
A-ENV-0810	The maximum solar radiation is 1400 W/m^2 (survival condition).	Always smaller than the perihelion solar irradiance of about 1400 W/m^2 at the top of the atmosphere.	

4.9 Dust and Sand

		Göllschau	Aar
A-ENV-0910	The natural cleanliness class of the site at 3 m above ground should be better than ISO-Class 8 (according to ISO14644-1) for 90% of the time (survival condition). This ISO-Class 8 corresponds to a limit of 29×10^3 particle of 5µm per m^3 of air.	SENES: Average 77h/year dust concentration >1µg/m^3 for particles >10µm	SENES: Average 75h/year dust concentration >1µg/m^3 for particles >10µm

4.10 Aggressive Atmosphere

		Göllschau	Aar
A-ENV-1010	The following aggressive atmosphere concentrations should not be exceeded: NO <3 ppb, NO2 <3 ppb, SO2 <3 ppb (Survival conditions).	No natural or human sources in vicinity (except lightning)	

4.11 Earthquakes

For further detail, see Appendix: Weather Analysis.

		Göllschau	Aar
A-ENV-1110	Peak horizontal ground acceleration < 0.25g and peak vertical ground acceleration < 0.3g with 10% probability of exceeding these figures within 10 years (reference return period 95 years).	<0.04g	<0.02g
A-ENV-1120	Peak horizontal ground acceleration < 0.5g and peak vertical ground acceleration < 0.6g with 10% probability of exceeding these figures within 50 years (reference return period 475 years).	<0.04g	<0.02g

4.12 Cloudiness

For further detail, see Appendix: Weather Analysis.

		Göllschau	Aar
A-ENV-1310	The site will have a fraction of moonless night hours completely cloud free above the site of >70 %.	7x7km above site Clear: 70±5%[2] CF<20%: 75±5%	7x7km above site Clear: 80±3% CF<20%: 85±3%

4.13 Background Light

Due to the sparse population of Namibia, the proposed sites have extremely little artificial light at night, as shown in Figure 1.

For further detail, see Appendix: Weather Analysis.

		Göllschau	Aar
A-ENV-1410	The median of NSB measurements over time must be:		
	>22.40 mag/arcsec² in B	23.5±0.2[3]	23.5±0.2
	>21.25 mag/arcsec² in V	22.5±0.2	22.5±0.2
A-ENV-1430	Illumination of telescope components and in particular of cameras by artificial light sources on or near the site must not exceed 10^6 photons ns^{-1} sr^{-1} cm^{-2}		No light sources near site. Site shielded from access road and Aus

[2] The error give the variation in cloud coverage between years

[3] Atmoscope NSB studies, Markus Gaug, 3th CTA Site Review, Heidelberg, March 2012

4.14 Number of Hours Available for Observation

The table below shows the estimated number of hours available at the two sites that meet all the CTA observation requirements. In order to use different dataset for the different environmental requirements, it was assumed that the phase of the moon and cloud coverage is uncorrelated and that the extreme wind, temperature and humidity are also uncorrelated. The last assumption has very little effect on the number of observation hours obtained.

	Göllschau		Aar	
Observation when cloud coverage is	**<20%**	**0%**	**<20%**	**0%**
Annual moonless hours[4]	1602	1602	1584	1584
Cloudless time fraction	75±5%	70±5%	85±5%	80±5%
Moonless, cloudless hours	1202±80	1121±80	1346±48	1267±48
Humidity too high	2.4±1.3%	2.2±1.3%	2.9±1.0%	2.2±0.8%
Wind too strong	0%	0%	2±2%	2±2%
Temperature too high	0%	0%	0.5±0.5%	0.5±0.5%
Available observation hours	**1173±80**	**1097±80**	**1275±54**	**1208±53**
% better than Göllschau			9%	10%

4.15 Aerosols

Aerosols in the atmosphere directly influence the sensitivity of an ACT, as it changes the optical depth of the atmosphere[5]. At both sites the aerosol optical depth is around 0.1, expect at Göllschau during springtime when it sometimes significantly increases due to biomass burning in the north. The average September aerosol optical depth increases to 0.3 at Göllschau and 0.2 at Aus as shown in Appendix: Weather Analysis.

[4] T. Bulik: Estimate of the annual usable time at sites and its errors, 3th CTA site review meeting

[5] R. de los Reyes, J. Hahn, K. Bernlöhr , P. Krüger, C. Deil, H. Gast, K. Kosack , V. Marandon, Impact of biomass burning aerosols and adverse atmospheric conditions on the data quality for spectral analysis of Cherenkov telescopes. To be submitted to Astroparticle Physics.

5 Infrastructure Requirements

In this section, the relevant infrastructure requirements, as given in MAN-PO/121128, Version 1.3 are considered.

5.1 Access

The nearest international airport is just outside Windhoek, which is the nearest airport to Göllschau (1.5h drive). From there, there are a few flights to Luderitz, which is the closest airport to Aar (1.5h drive). The closes harbours that can handle containers are located at Walvisbaai and Luderitz. Aus have a railway station that can handle containers. Göllschau is about 80 km from Windhoek by gravel road, whereas Aar is 5 km from the national B4 road. Driving distance and times from Aar to various towns are given in Table 1.

Table 1: Driving distance and time to Aar

	Distance [km]	Drive time
Aus (Accommodation, etc.)	22	30 min
Luderitz (Harbour, Airport)	140	1.5 h
Keetmanshoop (Hospital)	200	2.0 h
Windhoek (Int. Airport)	680	7 h
Cape Town	1200	13 h

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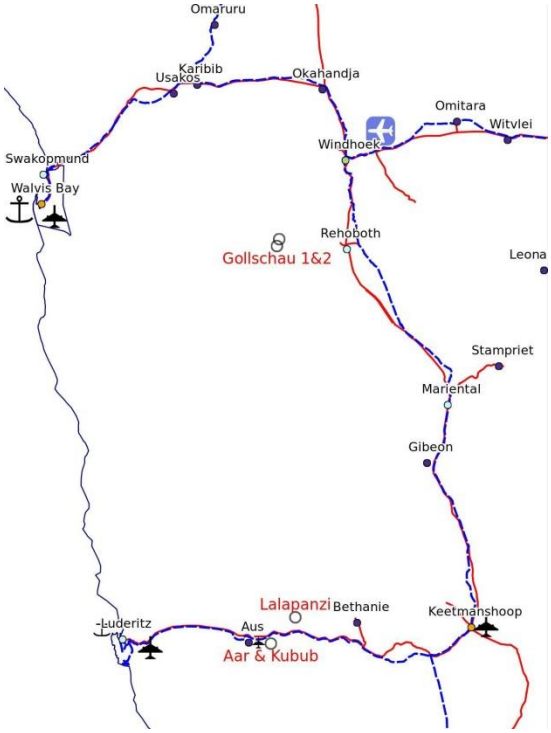

Figure 7: Major roads (red), railway (blue), airports, harbours, towns and cities around proposed sites

		Göllschau	Aar
B-INFRA-0100	Access Road	Existing 80 km gravel road to Windhoek	5 km road from B5, up the escarpment, needed
B-INFRA-0120	Parking & storage space	Enough space around site	Enough space around site
B-INFRA-0130	Access control	Fence needed	Escarpment provides natural access barrier on one side

5.2 Power

(B-INFRA-0300...-0320,-0370)

Namibia is part of the Southern African Power Pool[6], having interconnection stations at Keetmanshoop and Windhoek. From Keetmanshoop, there are two 132kV lines passing the farm Aar. The closes substation is just north of Aus, connecting Aus to the grid with a 33 kV line. A new power line, from Aus to farm Aar would have to be built. Such a 20 km line will cost about 3.6 million N$ (about 360 thousand €)[7]. Detailed quotations from NamPower have been requested.

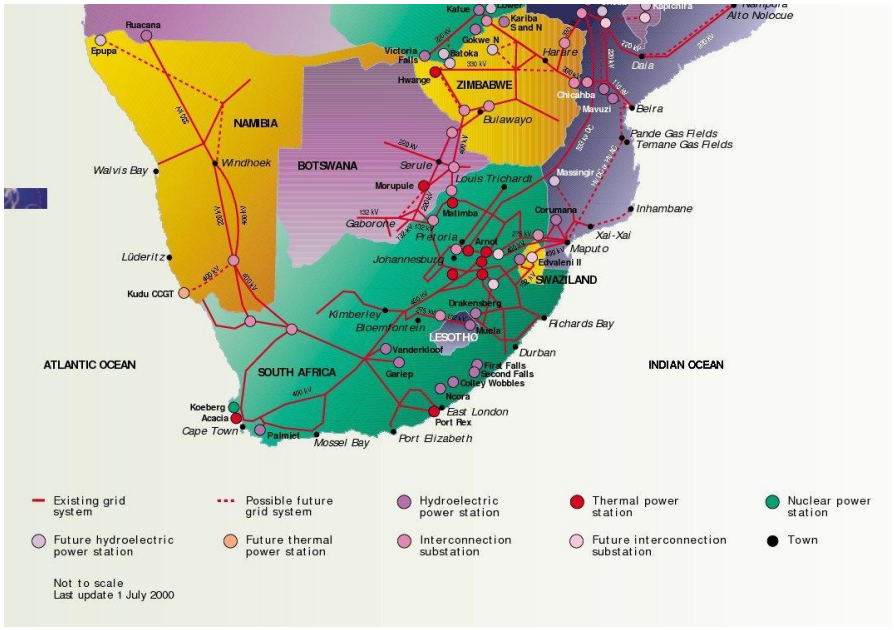

Figure 8: Southern Africa Power Network

[6] http://www.sapp.co.zw/

[7] SKA-SA estimate for a 33 kV line is N$ 161/m and a N$ 345 000 connection fee. However, in private communication with Mr. D. Kleingünther of NamPower, an estimated price of N$ 70/m was mentioned.

Figure 9: Infrastructure around Aar site

Power is readily available on the Göllschau farm (H.E.S.S.) from a 33 kV line coming from Rehoboth.

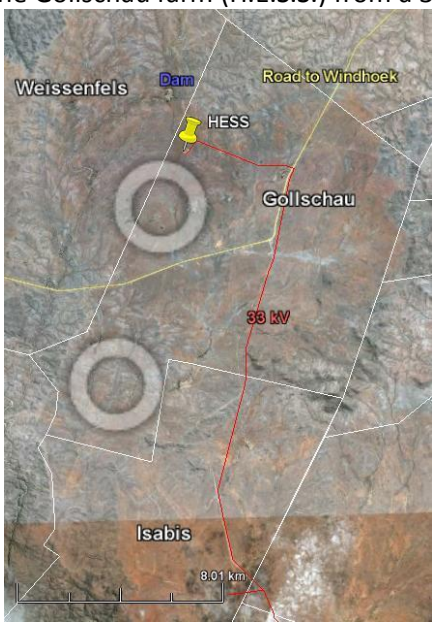

Figure 10: Infrastructure around Göllschau site

5.3 Water

(B-INFRA-0500)

Water can be supplied at the Aar farm from the boreholes on the neighbouring farm Kubub. This water supply has been used for the road construction and is estimated to be available at a rate of 35m³/hour. Some of the water is already pumped to a water point just below the escarpment and only has to be pumped or transported up to the site.

The Göllschau farm has boreholes that can deliver more than 5m³/day for general use and the neighbouring farm Weissenfels has a large dam that can supply water for construction.

5.4 Communications

B-INFRA-0400: 1 Gbps link

The data network in Namibia is operated by Telecom Namibia. See Appendix: Telecom Namibia for quotations for a 1 Gbps link and a highly redundant, fully protected IP service solution from the sites to Europe. Telecom Namibia is able to provide alternative designs with a lower Uptime guarantee as well as a lower price tag.

90 km of new fibre route to Rehoboth from Göllschau would be required or 30 km of new fibre route to Aus from Aar. Telecom Namibia will build and provide these network extensions at no additional costs to ensure reliable transport from the remote site back to the Telecom Namibia Backbone.

Inside the Telecom Namibia International Platform, the traffic is transported via four Sub Marine Cables in a highly redundant way, The Sub Marine Cables are WACS, SAT3 (Both at the West Coast) and SEACOM and EASSy (East Coast) (See Figure)

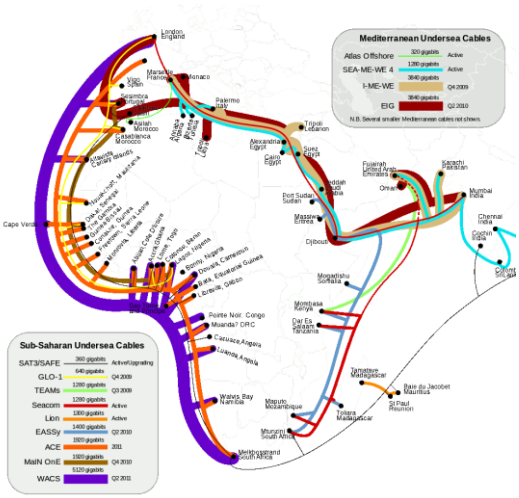

Figure 11: Sub-Sahara Undersea Cables

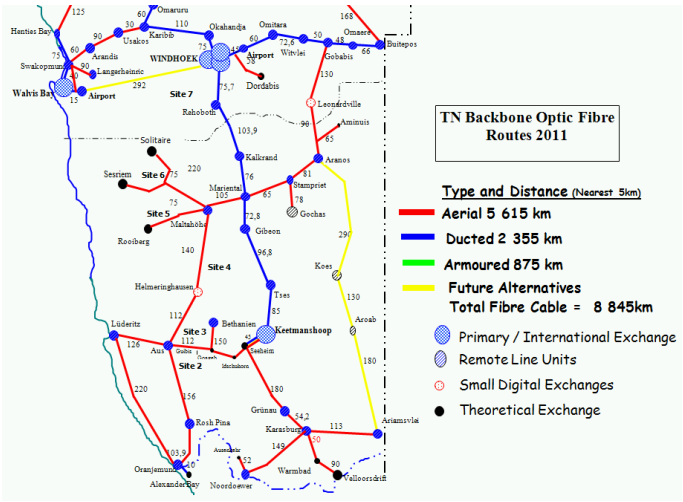

Figure 12: Telecom Namibia Backbone Optical Fibre Routes

B-INFRA-0410: Telephone communications

Both sites have good cellular phone coverage, making communication easy. See for example the MTC network coverage map as shown in Appendix: Site Location. The Atmoscope on Aar shows the reliability of the network, as it is used for daily internet access.

6 Living Conditions

The Göllschau site has the advantage that it is about one hour's drive to the capital Windhoek, where everything for daily living is available. It is possible to live in Windhoek and drive to the site on a daily basis, although it would be better to have on-site accommodation. There are various guest houses in the vicinity of the site for short term accommodation.

As the Aar site is less than 30 minutes from Aus, very little on-site accommodation would be necessary. Aus has a population of about 300 people with a gasoline station, food and general supplies, a police station and a medical clinic. The two largest accommodation providers are the Bahnhof hotel (44 beds and small conference centre) and Desert Horse Inn (24 rooms). Several self-catering units are also available. However, the nearest schools and hospitals are located in Luderitz and Keetmanshoop.

The official language of Namibia is English, with many people understanding some German as well, making it easy for foreigners to get along in Namibia.

7 Risks

7.1 Natural

The farms are located in one of the most seismically stable regions on earth, there is not enough bio-material to pose a fire risk and there is no danger of volcanic activity.

Farm Aar has good drainage and is at the watershed, so that is no flood risk. Similarly, farm Göllschau has very little flood risk. Hail is not known on the farms.

7.2 Economic and Political

Namibia is stable, with a B Euler Hermes risk grade.

7.3 Crime

Although the crime statistics of Namibia is quite high, most violent crimes takes place in specific areas in the larger cities. When keeping away from these places, Namibia is very safe. Remote places, such as the proposed sites, are safe with regard to violent crimes. However, it is still necessary to make provision against burglary.

8 Construction and Operational Costs

Various cost estimates regarding construction and operation are given in Appendix: SCE SDEV answers. It should be noted that building in Namibia is quite cheap compared to other countries, due to the availability of cheap labour.

9 Site Ownership

To obtain permission for using a farm for CTA, only a contract with the farm owners has to be negotiated, as was done with H.E.S.S. For the Göllschau site, CTA could be located entirely on the farm Göllschau, although a better layout would be to put a part on the neighbouring farm Weissenfels. For the Aar site, the entire CTA could be built either on the farm Aar or the farm Kubub, with the access road on the farm Kubub.

No construction permits are needed, although it is advisable to do an environmental impact study.

10 Political Support of Host Country

Both the national and local government have expressed their support for the CTA in Namibia. See, for example, Appendix: Speech by regional councillor. The Namibian government has signed the CTA letter of intent and has made money available for further investigation of the sites.