



Current State of Global Geodesy Supply Chain

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Expert Consultation on Strengthening the Global Geodesy Supply Chain

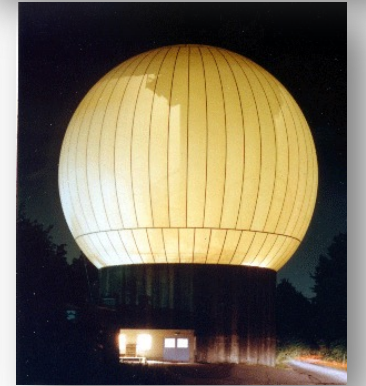
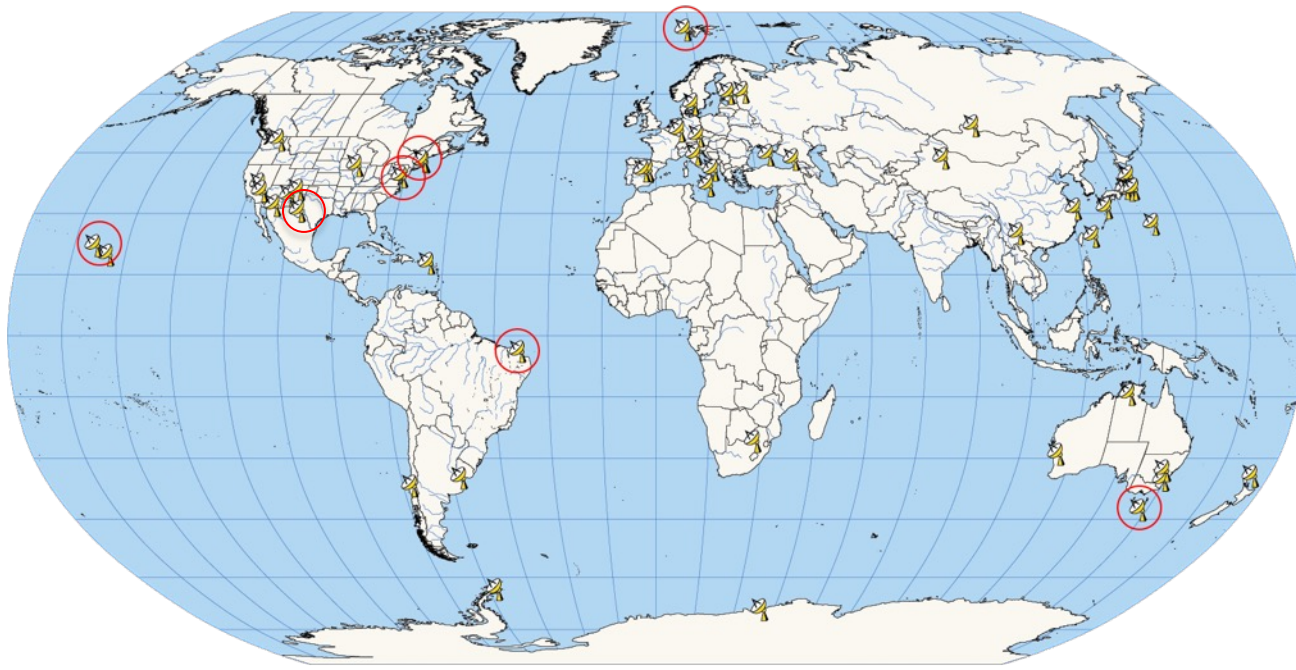
UN Campus, Bonn, Germany



VLBI Current Status



Very Long Baseline Interferometry (VLBI)

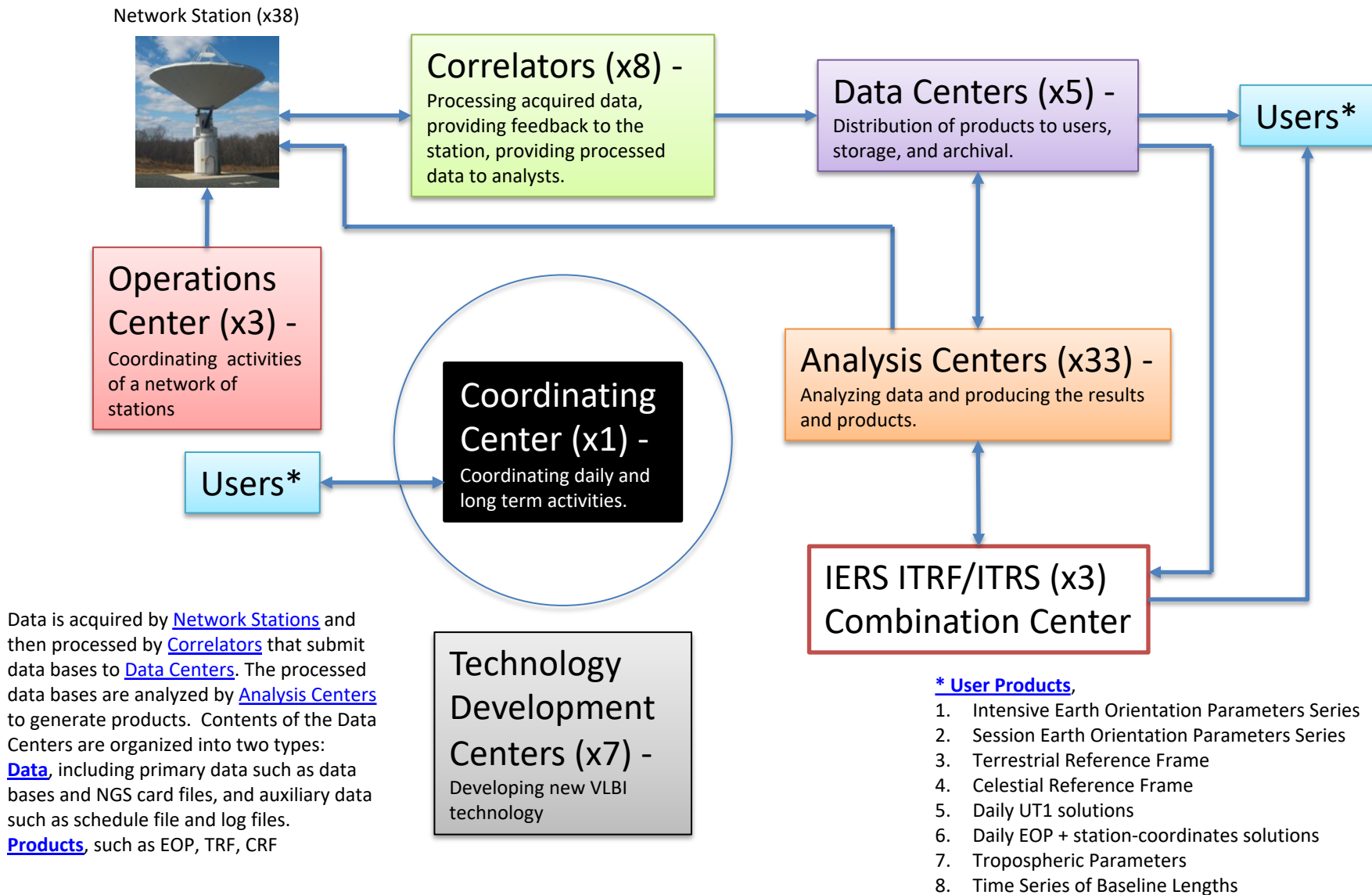


- ◆ Daily VLBI measurements are vital for determining and predicting the time-varying alignment of the Terrestrial Reference Frame with respect to the celestial reference frame (Earth Orientation Parameters).



International VLBI Service for Geodesy and Astrometry (IVS)

Components, Interfaces, Operations, and Products



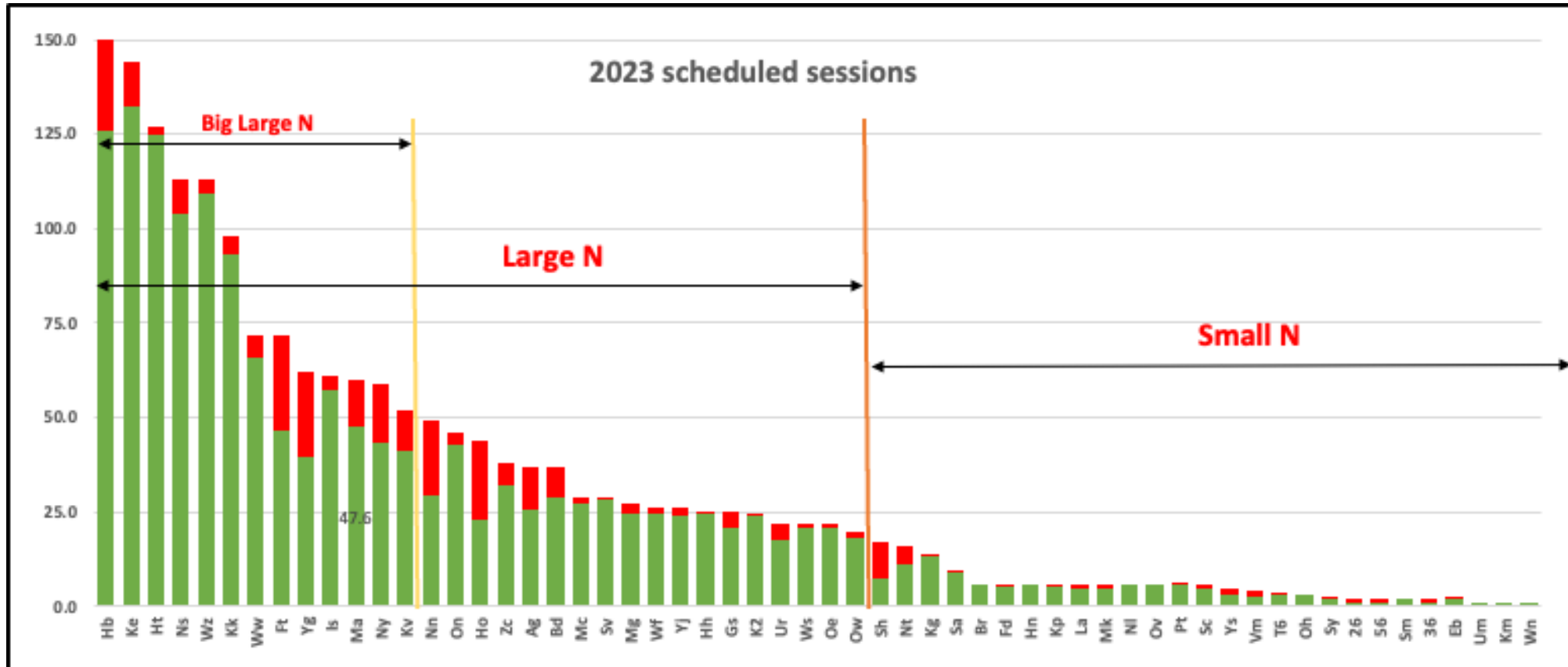


Station List from from IVS Website

Country	IVS Component Name	IVS code	8-letter name	Sponsoring Organization
Antarctica	ERS/VLBI Station O'Higgins	Oh	OHIGGINS	Bundesamt für Kartographie und Geodäsie (BKG), Germany
Antarctica	JARE Syowa Station	Sy	SYOWA	National Institute of Polar Research, Japan
Argentina	Observatorio Argentina-Alemán de Geodesia (AGGO)	Ag	AGGO	Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Bundesamt für Kartographie und Geodäsie (BKG, Germany)
Australia	Hobart 12m, Mt. Pleasant Radio Observatory	Hb	HOBART12	University of Tasmania
Australia	Hobart 26m, Mt. Pleasant Radio Observatory	Ho	HOBART26	University of Tasmania
Australia	Katherine	Ke	KATH12M	University of Tasmania
Australia	Yarragadee	Yg	YARRA12M	University of Tasmania
Australia	Parkes Observatory	Pa	PARKES	CSIRO
Brazil	Fortaleza, Radio Observatorio Espacial do Nordes (ROEN)	Ft	FORTLEZA	Centro de Radio Astronomia e Aplicacoes Espaciais
China	Nanshan VLBI Station	Ur	URUMQI	Chinese Academy of Sciences
China	Seshan	Sh	SESHAN25	Joint Laboratory for Radio Astronomy (JLRA), CAS and Shanghai Observatory, CAS
Finland	Metsähovi Radio Observatory	Mh	METSAHOV	Aalto University, Finnish Geodetic Institute
Germany	Effelsberg	Eb	EFLSBERG	Max-Planck-Gesellschaft zur Förderung der Wissenschaften
Germany	Geodetic Observatory Wettzell	Wz	WETTZELL	Bundesamt für Kartographie und Geodäsie (BKG) and Forschungseinrichtung Satellitengeodäsie der Technischen Universität München (FESG)
Italy	Medicina	Mc	MEDICINA	Istituto di Radioastronomia
Italy	Noto (Sicily)	Nt	NOTO	Istituto di Radioastronomia
Italy	Matera	Ma	MATERA	Agenzia Spaziale Italiana (ASI)
Japan	Kashima 34m	Kb	KASHIM34	National Institute of Information and Communications Technology (NICT)
Japan	Key Stone Project Kashima 11m	K1	KASHIM11	National Institute of Information and Communications Technology (NICT)
Japan	Key Stone Project Koganei	Kg	KOGANEI	National Institute of Information and Communications Technology (NICT)
Japan	Tsukuba VLBI Station	Ts	TSUKUB32	Geospatial Information Authority of Japan (GSI)
Japan	Ishioika VLBI Station	Is	ISHIOKA	Geospatial Information Authority of Japan (GSI)
Japan	Mizusawa 10m	Mn	MIZNAO10	National Astronomical Observatory of Japan (NAOJ)
New Zealand	Warkworth Observatory	Ww	WARK12M	Auckland University of Technology
Norway	Ny-Alesund Geodetic Observatory	Ny	NYALES20	Norwegian Mapping Authority
Russia	Radioastronomical Observatory Badary	Bd	BADARY	Institute of Applied Astronomy RAS
Russia	Svetloe Radio Astronomy Observatory	Sv	SVETLOE	Institute of Applied Astronomy RAS
Russia	Radioastronomical Observatory Zelenchukskaya	Zc	ZELENCHK	Institute of Applied Astronomy RAS
Spain	IGN Yebes Observatory	Yb	YEBES	Instituto Geografico Nacional
South Africa	Hartebeesthoek Radio Astronomy Observatory	Hh	HARTRAO	National Research Foundation
South Korea	Sejong Station	Kv	SEJONG	National Geographic Information Institute (NGII)
Sweden	Onsala Space Observatory	On	ONSALA60	Chalmers University of Technology
Ukraine	Simeiz	Sm	CRIMEA	Laboratory of Radioastronomy of Crimean Astrophysical Observatory
USA	Goddard Geophysical and Astronomical Observatory	Gs	GGAO12M	NASA Goddard Space Flight Center
USA	Goddard Geophysical and Astronomical Observatory	Gg	GGAO7108	NASA Goddard Space Flight Center
USA	McDonald Geodetic Observatory (NASA, UTexas)	Mg	MACGO12M	NASA Goddard Space Flight Center and The University of Texas Center for Space Research
USA	Westford Antenna, Haystack Observatory	Wf	WESTFORD	NASA Goddard Space Flight Center
USA	Kokee Park Geophysical Observatory	Kk	KOKEE	NEOS



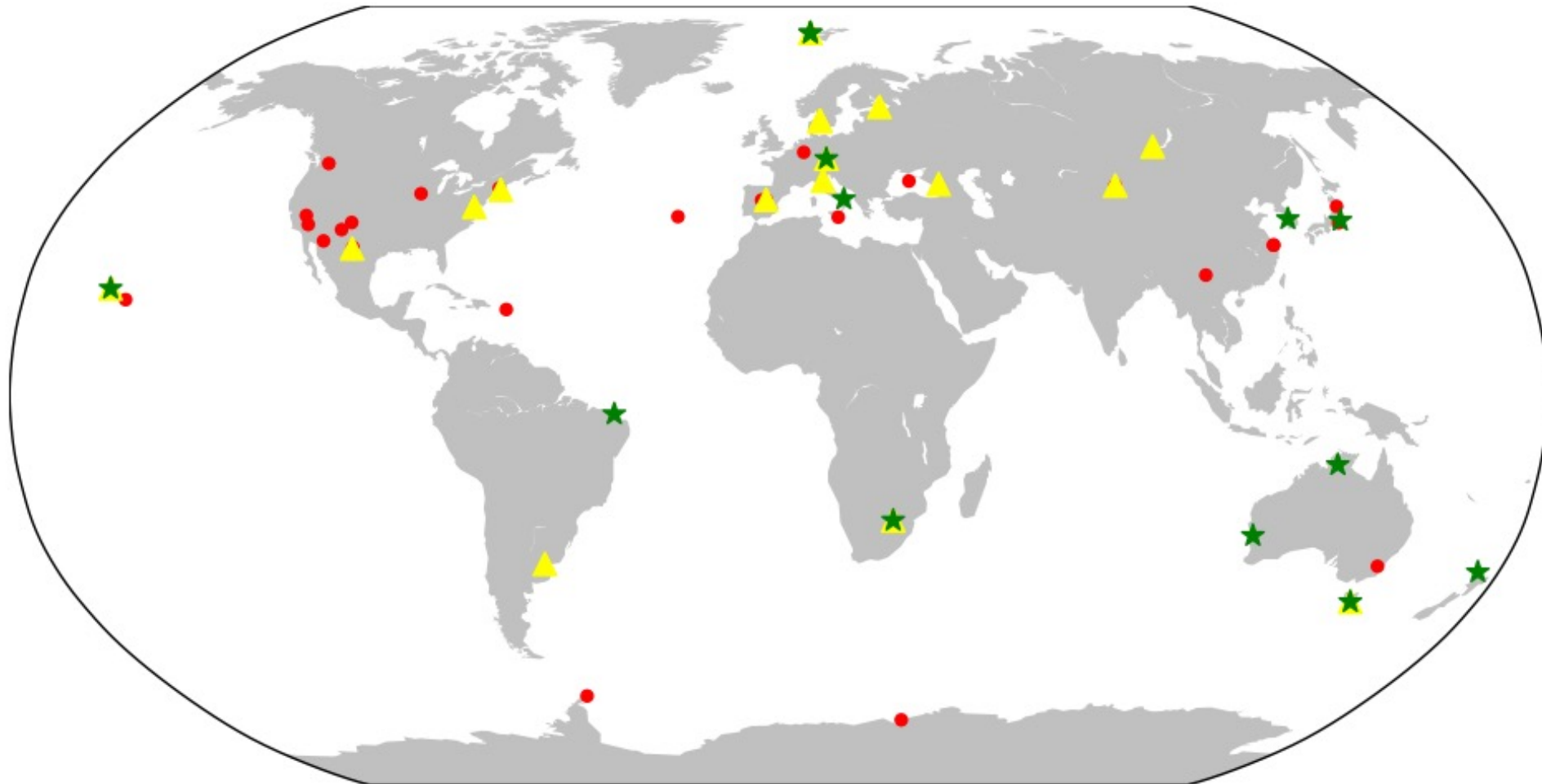
2023 VLBI Sessions



Category	Number stations	Station-days	Average	Median	>92%	>70%
Big Large N (>50)	13	1183	84.9%	91.7%	4	11
Large N (>20)	31	1731	85.5%	91.7%	13	26
Small N (<20)	26	146	84.3%	91.8%	14	20
Full Network	57	1877	85.0%	91.7%	26	46



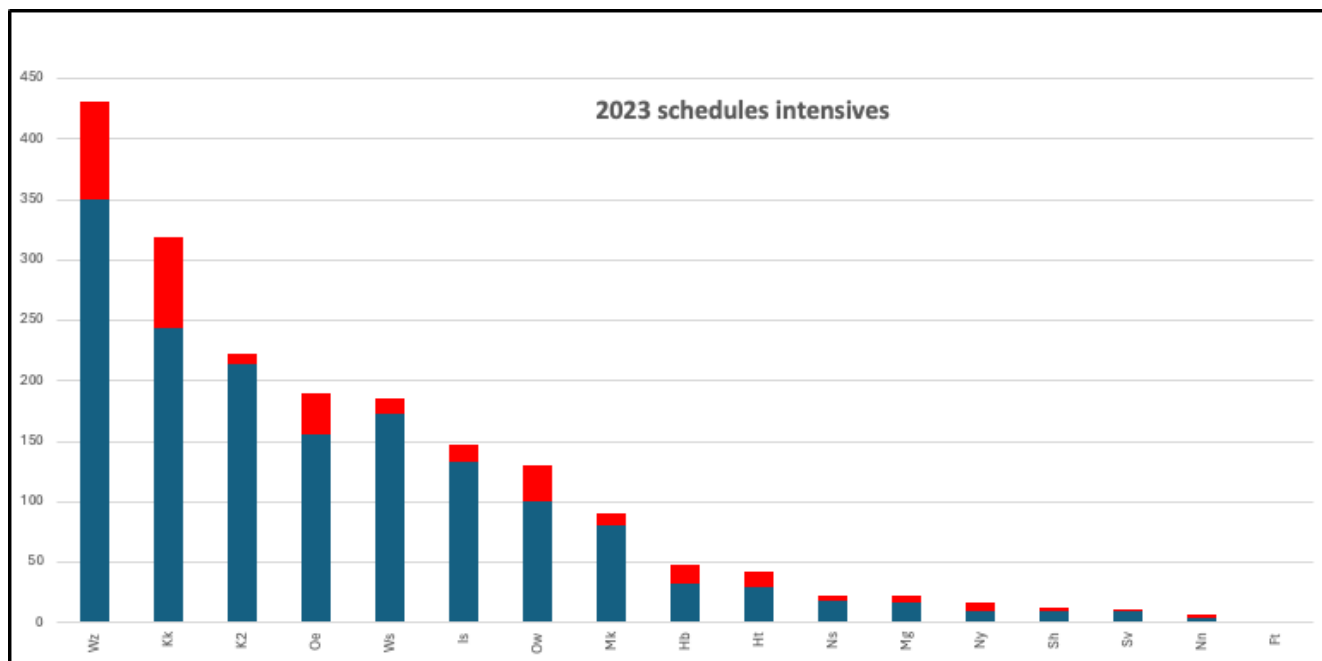
VLBI Network Performance



- ★ More than 50 sessions
- ▲ Between 20 and 50 sessions
- Less than 20 sessions



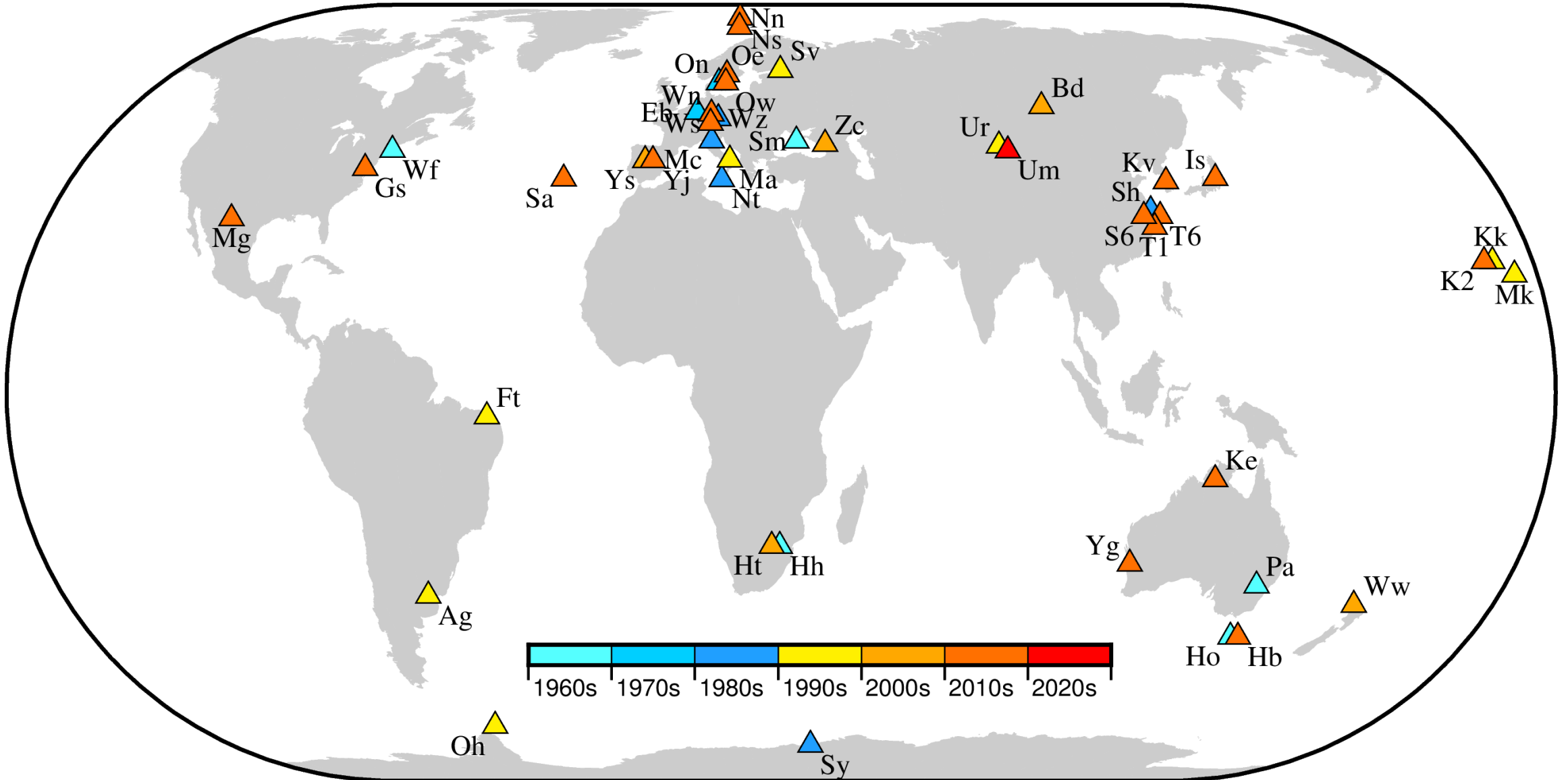
Daily UT1 Measurements (Intensives)



Station		Sessions	Observations		
Name	Code		Scheduled	Used	
WETTZELL	Wz	431	15185	12330.0	81.2%
KOKEE	Kk	319	9920	7560.0	76.2%
KOKEE12M	K2	223	14878	14281.0	96.0%
ONSA13NE	Oe	190	25544	20926.0	81.9%
WETTZ13S	Ws	185	13926	13055.0	93.7%
ISHIOKA	Is	147	23912	21655.0	90.6%
ONSA13SW	Ow	131	18862	14561.0	77.2%
MK-VLBA	Mk	91	3328	2935.0	88.2%
HOBART12	Hb	48	1436	992.0	69.1%
HART15M	Ht	42	1476	1025.0	69.4%
NYALE13S	Ns	23	1735	1427.0	82.2%
MACGO12M	Mg	22	1590	1227.0	77.2%
NYALES20	Ny	17	909	522.0	57.4%
SESHAN25	Sh	13	843	642.0	76.2%
SVETLOE	Sv	11	295	260.0	88.1%
NYALE13N	Nn	7	301	193.0	64.1%
FORTLEZA	Ft	1	40	25.0	62.5%

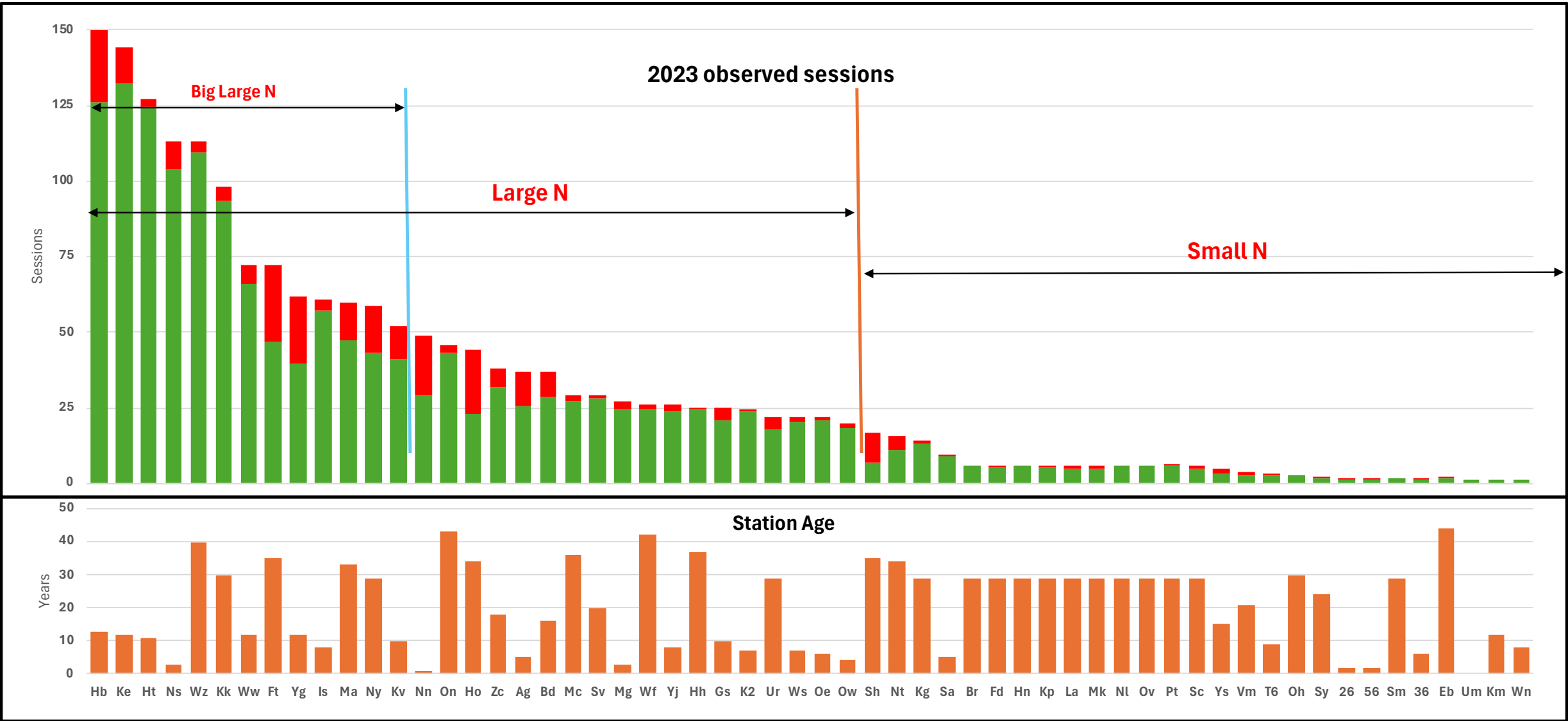


VLBI Network Age



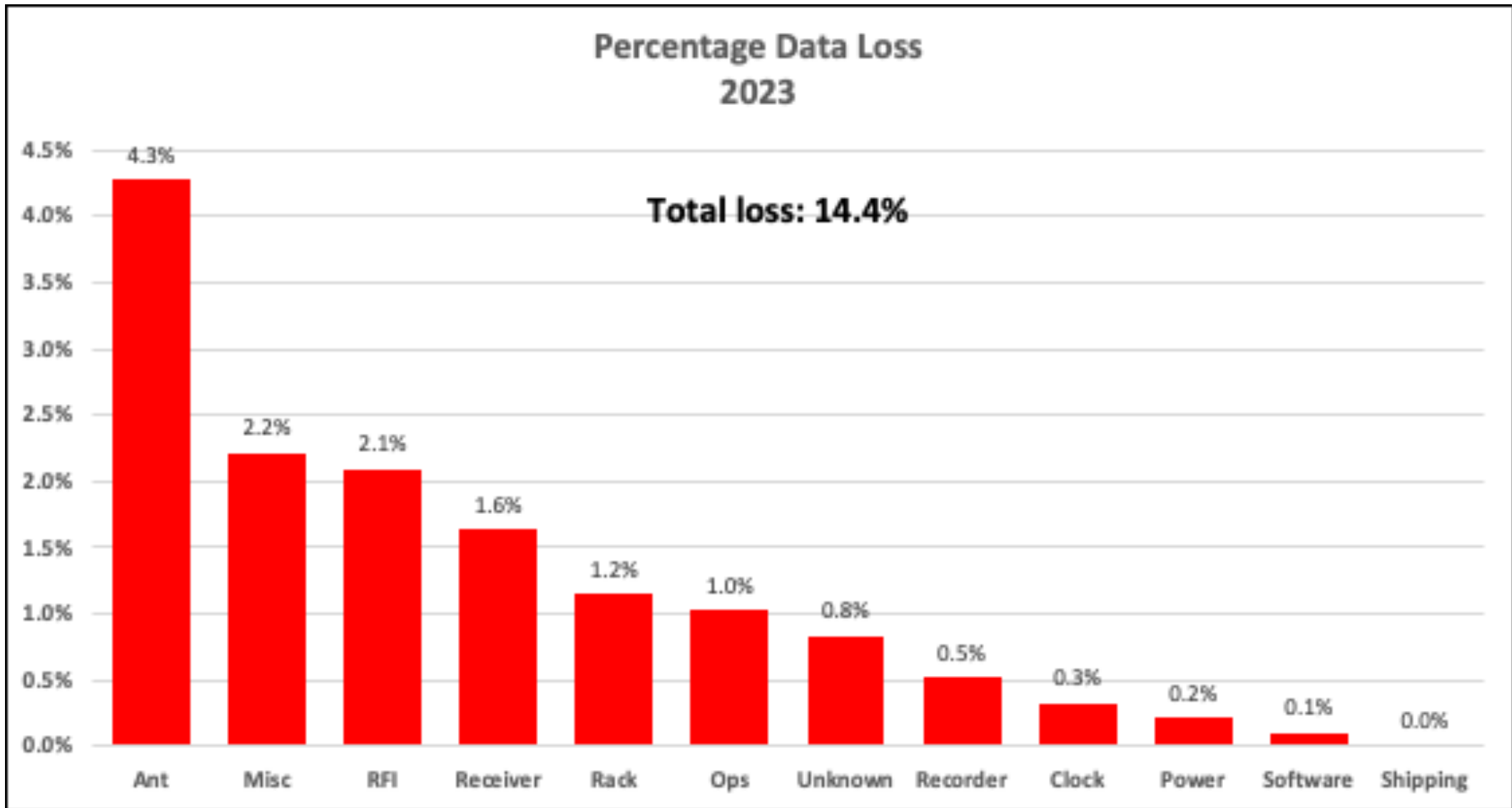


Station Age





Documented Station Issues





VLBI Global Observing System (VGOS)



Hawaii



Maryland



Texas

- ◆ Less costly systems with as good or better performance than legacy VLBI.
- ◆ 1 mm measurement accuracy on global baselines
- ◆ Small (12m), fast, rigid, efficient antennas
- ◆ Broadband (2-14 GHz) with 4 tunable 512 or 1024 MHz bands,
- ◆ Fast data recording rates (16 Gbps).

- ◆ NASA completed deployment of 3 domestic stations, developed the correlation and analysis capabilities, is deploying a new station to Brazil, and is planning for a station in Tahiti.
- ◆ Better geographical distribution and additional stations will provide better EOP measurements and enhanced redundancy and robustness.



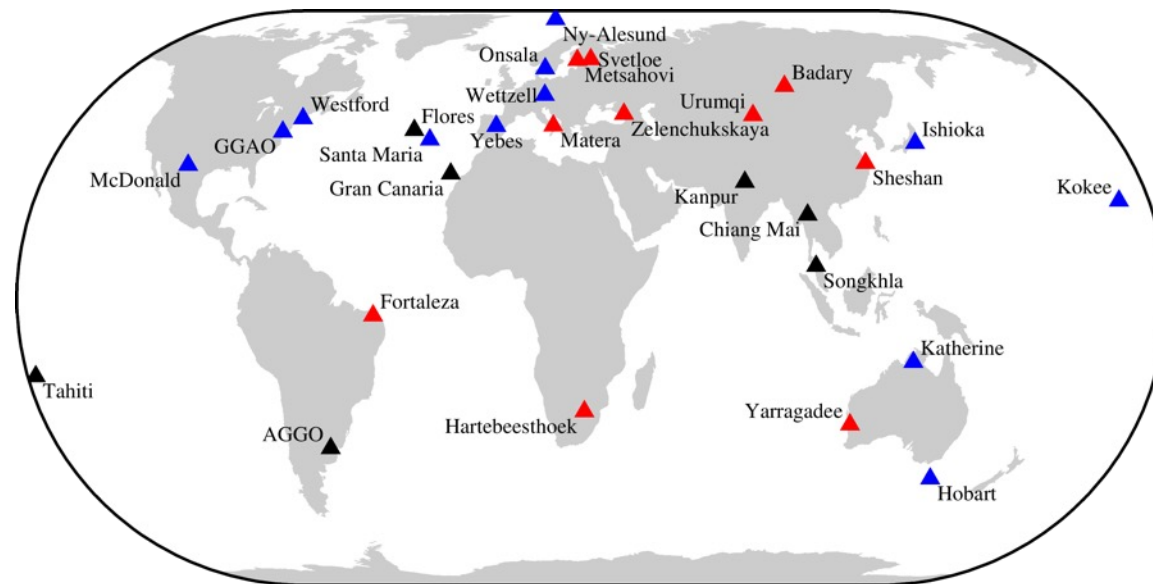
VGOS Continues to Grow

VGOS Network expanded to 12 stations with more planned.

Hawaii-Germany 1-hour VGOS sessions producing rapid UT1-UTC predictions.

Correlators cut turnaround time for 24-hour sessions by more than half to ~30 days while cadence increase from 2 to 3 per month.

Evaluations of alternative intensive baselines such as Texas-Germany drive towards a more robust network.



▲ operational ▲ online in 1-2 years ▲ longer term plan



Hawaii



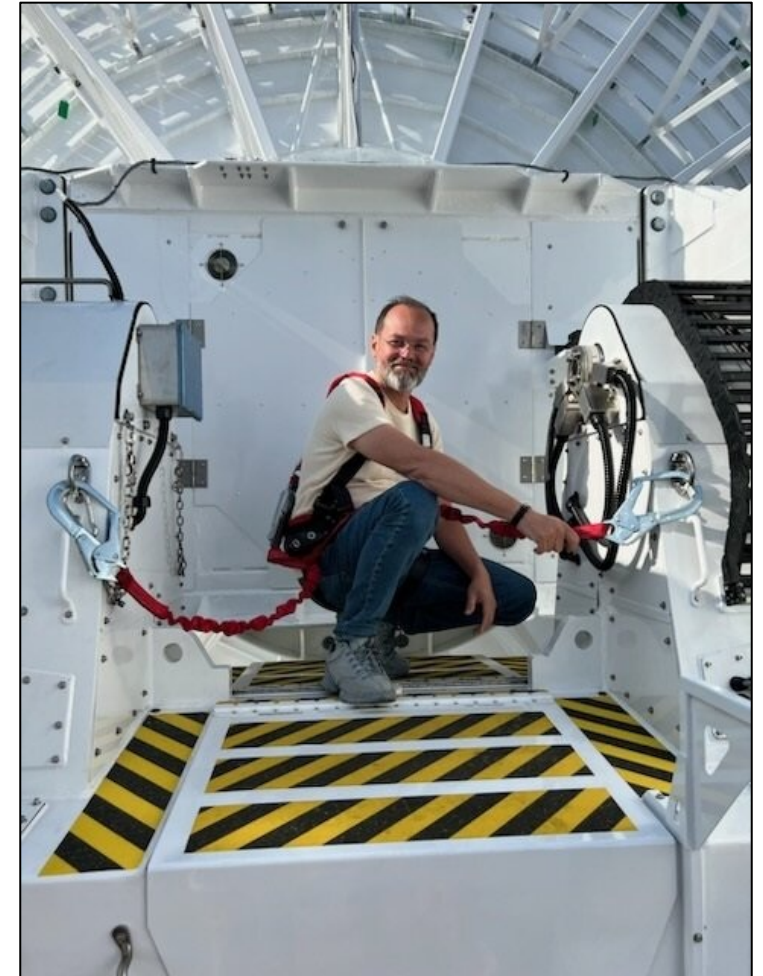
Goddard



Texas



Brazil NASA VGOS Deployment

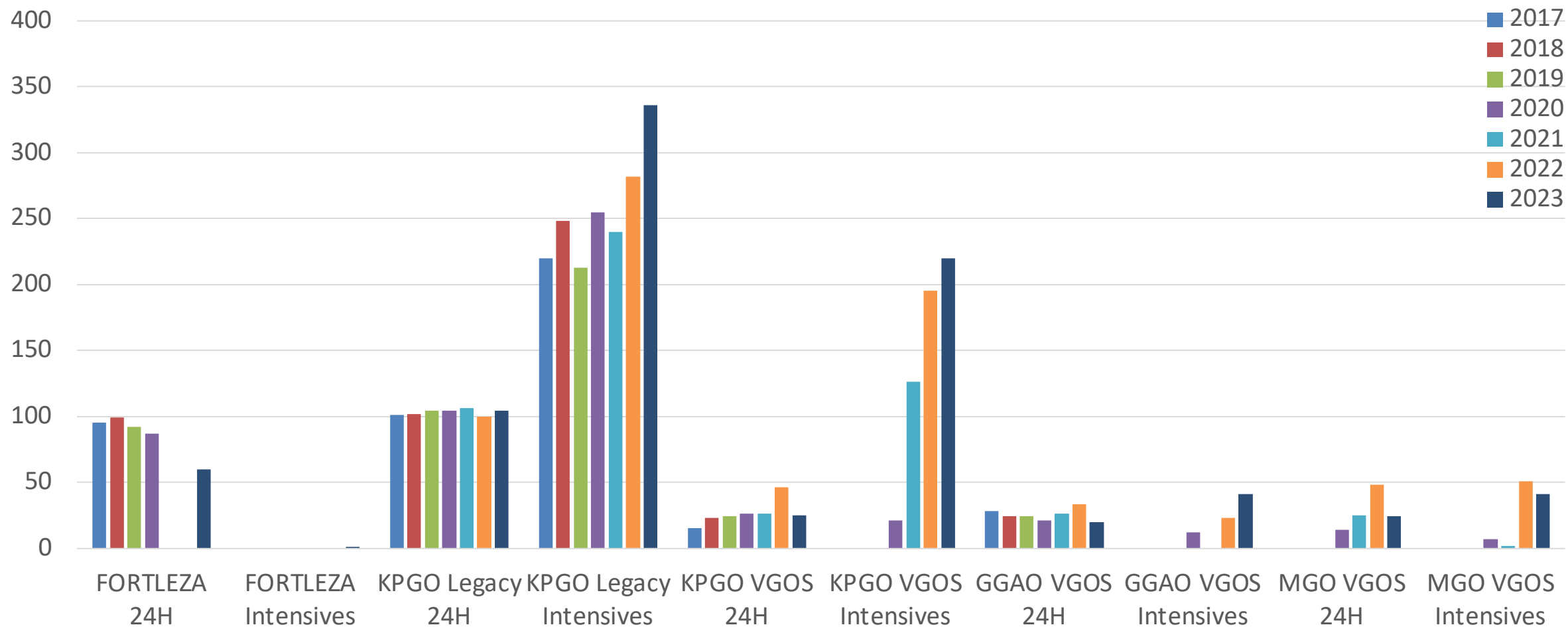


- ◆ Station leverages design and technology from NASA's first 3 station deployments
- ◆ Infrastructure improvement work underway at site
- ◆ Signal chain build underway
- ◆ Scheduled for operations in 2025

Antenna build complete and ready to deploy when site is ready



NASA VLBI Stations Sessions



VGOS session frequency continues to be limited by correlator capacity



Network Bandwidth

- ◆ Correlator capacity and network bandwidth continue to limit VGOS session expansion.
- ◆ Remote station network bandwidth also contributes to latency in VGOS analysis.

CORRELATOR	Rate	Tested
Bonn	10 Gbps	1 Gbps
GSI	10 Gbps	not tested
Haystack	10 Gbps	10 Gbps
Onsala	10 Gbps	5-10 Gbps
Shanghai	4 Gbps	2 Gbps
UTAS	4 Gbps	1 Gbps
		2.9 Gbps single stream; 8.6 Gbps multi streams
Vienna	10 Gbps	
Washington	10 Gbps	10 Gbps
Wetzell		
Yebe		



Legacy Station Sustainment Challenges

NASA Brazil antenna resumed operations April 2023 after main bearing replacement.





VGOS Station Sustainment



Paint →



First-generation VGOS stations are starting to need significant maintenance