# Status of the Washington Correlator

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**Abstract** The United States Naval Observatory (USNO) operates the Washington Correlator (WACO) out of Washington, DC. The Washington Correlator processes a variety of geodetic IVS sessions including both legacy (IVS-R4 Rapids, IVS-INT-1 Intensives) and VGOS (VGOS-OPS 24-hour sessions, VGOS-INT-A Intensives). WACO also correlates some non-geodetic sessions, including the IVS-CRF and IVS-RD series. The current Washington correlator is a second-generation DiFX software correlator based on off-the-shelf hardware, which is optimized to handle a mixture of legacy and current VGOS workloads. A third-generation software correlator is currently being built with the goal of supporting increased VGOS workloads into the future. This new correlator has a novel design optimized to process each scan on a single physical node rather than in groups of MPI (Message Passing Interface) clusters. This approach reduces performance for scans with very large networks but yields a substantial performance gain when correlating geodetic observations made with both VGOS and legacy networks, which have many scans with relatively few stations per scan. It also greatly increases the overall processing power, storage volume, and storage speed. There are also plans to expand ingest capabilities to include Mark 6 disk packs in 2024.

## 1 Introduction

The USNO Washington Correlator (WACO or WASH for short) has been in operation for close to 40 years and has served as an IVS correlation center since the founding of the IVS in 1999. In that time, the Washington Correlator has changed dramatically to keep up with the evolving needs of the geodetic VLBI community, most notably changing from a hardware correlation system to a DiFX software correlation system in 2012. The current Washington Correlator is the second iteration of DiFX software correlators at USNO, and a team from NRAO is building the third iteration at the time of writing.

## 2 Products

The Washington Correlator specializes in routine, low latency, operational products supporting frequent measurement of Earth Orientation Parameters (EOP). These include the legacy S/X IVS-R4 24-hour Rapid sessions, legacy S/X IVS-INT-1 one-hour Intensive and IVS-INT-00 one-hour "midnight" Intensive sessions, as well as the VGOS-INT-A one-hour Intensives and a subset of the VGOS-OPS 24-hour sessions. Besides operational Intensive and Rapid sessions, WACO correlates some of the Celestial Reference Frame in the Deep South (IVS-CRF-DS) 24-hour sessions. A small number of research and development (IVS-RD) sessions are also correlated at WACO.

Note that IVS-CRF-DS sessions include O'Higgins data from Antarctica which are transferred by disk pack shipments and are significantly delayed arriving at the correlator. This accounts for the five 2023 sched-

**Table 1** Sessions correlated at WACO.

| Session type | 2023 (schedul.) | 2023 (correl.) | 2024 (schedul.) |
|---|---|---|---|
| VGOS-INT-A | 227 | 218 | 227 |
| VGOS-OPS | 4 | 4 | 9 |
| IVS-INT-1 | 238 | 225 | 239 |
| IVS-INT-00 | 97 | 92 | 130 |
| IVS-R4 | 52 | 52 | 52 |
| IVS-CRF-DS | 6 | 1 | 6 |
| IVS-RD | 3 | 3 | 3 |

uled IVS-CRF-DS sessions which are not yet shown as correlated in Table 1. The 2024 scheduled sessions are also subject to change, as most of these have not been observed yet.

## 3 Current V2 Correlator

The current second generation DiFX software correlator makes use of off-the-shelf hardware in a set of MPI clusters. The correlator's software stack includes the familiar DiFX for correlation, HOPS for fringe finding, and NUSOLVE for diagnostics and packaging. WACO's Internet circuit currently provides 9 Gbps available for e-transfer, with an effective limit of approximately 1 Gbps for most single transfers. Some high-urgency Intensives are allowed to reach up to 2.5 Gbps per transfer, but this is done rarely and on a case-by-case basis. e-transfer comes into a 1.88 PB external storage volume backed by a 10 Gbps fabric. WACO has an additional 2.13 PB of storage on a 40 Gbps fabric for internal use.

Mark 5 disk packs are currently supported, but only on a limited basis. Mark 6 support is currently planned only for the upcoming V3 correlator.

## 4 Upcoming V3 Correlator

The third iteration of the software correlator has already been designed, and NRAO is currently building it for use at WACO in late 2024. The new Version 3 (V3) correlator is intended to enable WACO to ingest and correlate VGOS data with recording rates up to 16 Gbps from both weekly-cadence VGOS-OPS sessions and daily-cadence Intensive (VGOS-INT-A) sessions. To that end, it features a planned 40 Gbps In-

ternet circuit for e-transfer, over 14 PB of e-transfer storage on 100 Gbps fabric, and roughly four times the planned DiFX performance of the V2 correlator.

The V3 correlator has a novel design in which each compute node separately correlates a single scan, rather than spreading scans over multiple compute nodes as in traditional MPI setups. This is possible because each node has 128 CPU cores and makes use of the extreme memory bandwidth provided by state of the art AMD server chips. This approach greatly reduces network overhead and improves efficiency. Besides being environmentally beneficial, this increased efficiency directly translates into improved throughput on geodetic workloads with a dozen or fewer stations, which constitute most of even the most aggressively scheduled IVS S/X and VGOS sessions. The approach does suffer from diminishing returns above about a dozen stations per scan, so these more baseline-heavy scans are still correlated in the traditional way, with multiple nodes collaborating through MPI.

## 5 Other Updates

Correlation Centers double as data centers, handling immense quantities of raw data. The legacy tools for handling these raw data, such as TsunamiUDP and Mark 5 disk packs, are insufficient to meet the growing need for more robust operations and higher data rate recordings from VGOS. To that end, WACO has adopted the `etc/etd` e-transfer software as the preferred method of data shipment in most cases. There are also plans to bring several Mark 6 units online in late 2024 along with the upcoming V3 Correlator. Please note that the V3 Correlator will support only pull style e-transfer and Mark 6 disk packs. The V3 Correlator will not support either push style e-transfer or Mark 5 disk packs.

As of March 2024, WACO has partially automated the VGOS-INT-A Intensive sessions. The automation script only occasionally needs human intervention, though at present all sessions are checked by a human analyst before release.

Quite a few of WACO's correlator tools, including the report generator script for IVS correlator reports, are available at https://github.com/usno-vlbi/main.

A clock offsets configuration and script are available at https://github.com/usno-vlbi/config.

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