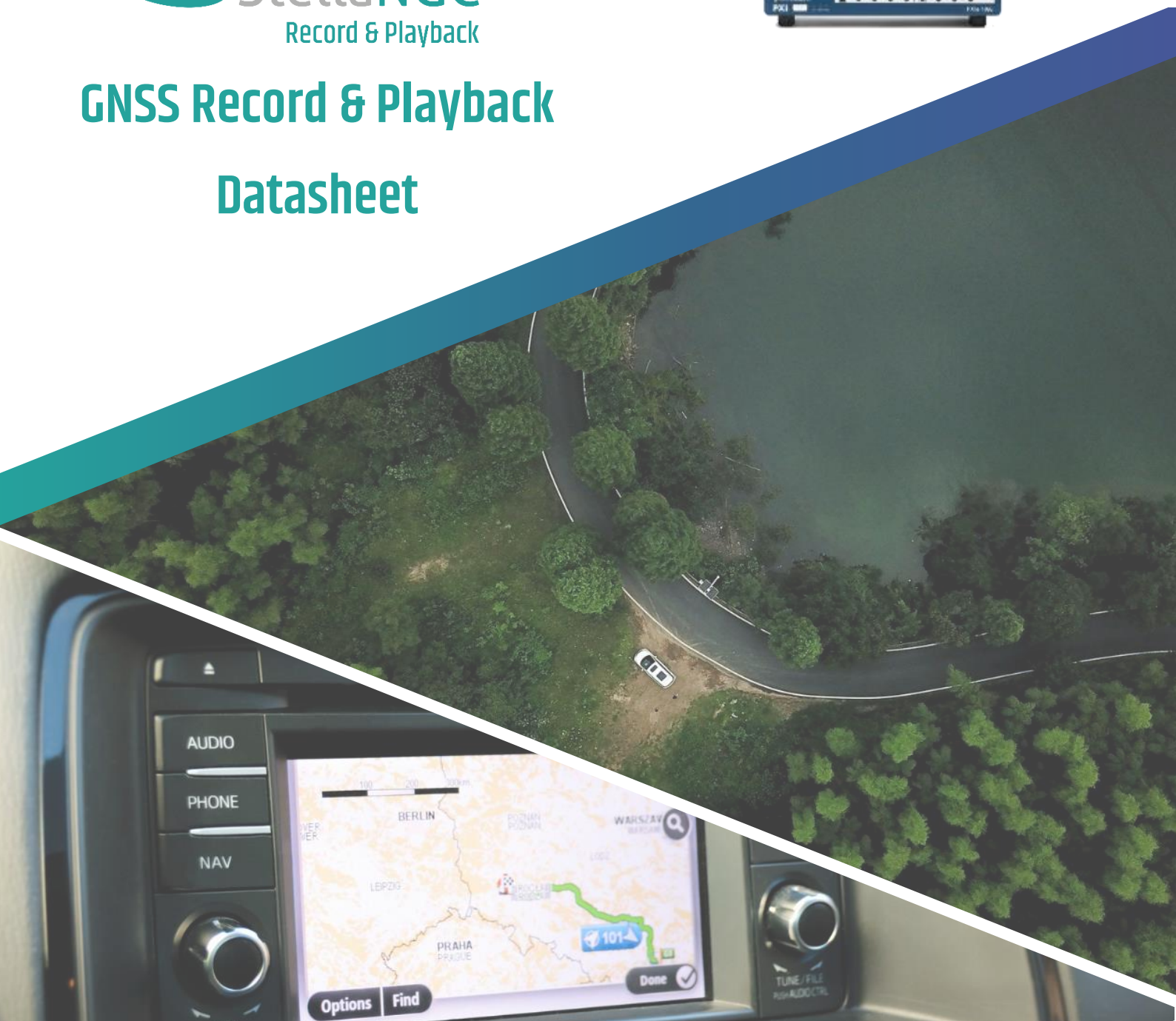
m3 systems

StellaNGC
Record & Playback

# GNSS Record & Playback

# Datasheet



# Table of Content

# Table of Figures

# I. Introduction

This document is StellaNGC Record & Playback product datasheet.

### Applicable Documents

[AD. 1] StellaNGC® GNSS Simulator - Users Guide

[AD. 2] 2016 12 - M3 SYSTEMS - CGU Version GB

[AD. 3] StellaNGCv3_multipath_capabilities_RevA

[AD. 4] StellaNGCv3_RFInterferences_capabilities_RevB

[AD. 5] StellaNGCv3_spoofing_capabilities_RevA

### Reference Documents

[RD. 1] NI USRP-2950R Device Specification

[RD. 2] NI 5840 Device Specification 376626A-01 March 16, 2017

[RD. 3] NI 5841 Device Specification 378128B-01 April 6, 2020

[RD. 4] NI USRP-2954 Device Specification

## Abbreviations

| | |
|---|---|
| AGC | Automated Gain Control |
| API | Application Protocol Interface |
| DUT | Device under test |
| ECEF | Earth-Centered, Earth-Fixed |
| FPGA | field-programmable gate array |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning Systems |
| GUI | Graphical User Interface |
| Hw | Hardware |
| ICD | Interface communication document |
| IMU | Inertial Measurement Unit |
| LLA | Latitude, Longitude, Altitude |
| M3S | M3 Systems |
| N/A | Not Applicable |
| OEM | Original Equipment Manufacturer |
| PXIe | PCI eXtensions for Instrumentation |
| RAID | Redundant Array of Inexpensive Disks |
| RF | Radio Frequency |
| RP | Record & Playback |
| SDR | Software Defined Radio |
| Sw | Software |
| TBD | To Be Defined |
| TCP/IP | Transmission Control Protocol/Internet Protocol |
| TDMS | Technical Data Management Streaming: NI owner file format |
| OCXO | Over Controlled Cristal Oscillator |
| OS | Operating System |
| VST | Vector Signal Transceiver |

# II. System Overview

When new GNSS signals are defined, tests are required to ensure the end-user proper behavior. Alongside, GNSS system integrators require test facilities to validate their products with existing GNSS signals. This emphasizes the need of test facilities for GNSS receivers.

Two approaches are possible: test facilities which can simulate the GNSS signals or, recording & playing back real-life signals

StellaNGC RP aims to answer the needs recording & playing back real-life GNSS signals.

### Frequency Bands

- Signals
  - GPS: L1P, L2P, L2C, L5
  - GLONASS: G1, G2
  - GALILEO: E1BC, E5(A/B), E6
  - QZSS: L1C/A, L2C, L5
  - BEIDOU: B1i, B2i, B3i
- Programmable center frequency and bandwidth
- Single or multi-channel simultaneous records (up to 3 channels on a single chassis covering the full GNSS Bands)

### Graphical User Interface

- Spectrum display by channel for record and replay
- Self-test capability in real time
- Log files, pop-up windows, help for configuration (calculation of the transfer data rate and the required storage according to the configuration for a recording)
- ADC and FIFO occupancy for monitoring
- RF target status
- Reference power level and IQ gain

### Record Feature & Dynamic Range

- RF range
  - Max +0dBm
  - Min Average Noise level of -145dBm/Hz (Ref Level -10dBm) to -155dBm/Hz (Ref Level -50dBm)
- Signal Dynamic Range of 76dB (Linear)

### Replay Feature

- Automatic configuration of parameters

- Replayed signal amplification or attenuation
- Possibility to independently replay the channels in case of multi-channels recording

### Tunable RF Channel Parameters

- Adjustable quantization from 2 to 16bits/I and 2 to 16bits/Q
- Adjustable bandwidth

### Programmable Start Management

- Immediate, hardware triggered or delayed start for record
- Duration and periodicity configurable for record
- HW triggered start for record
- Possibility to replay from a certain start position in the record

### Storage Media Panel

- Storage equipment from 8TB to 24TB (Internal storage media inserted in the PXI chassis for a total integration in one single chassis)

StellaNGC RP is composed of an optimized hardware associated to an easy-to-use graphical user interface.

# III. Graphical User Interface

Thanks to the record tab, the user can define many useful parameters for record. For each channel two files are created; one file including I/Q data stored on TDMS format and a second file (Companion file) including all selected recording parameters.

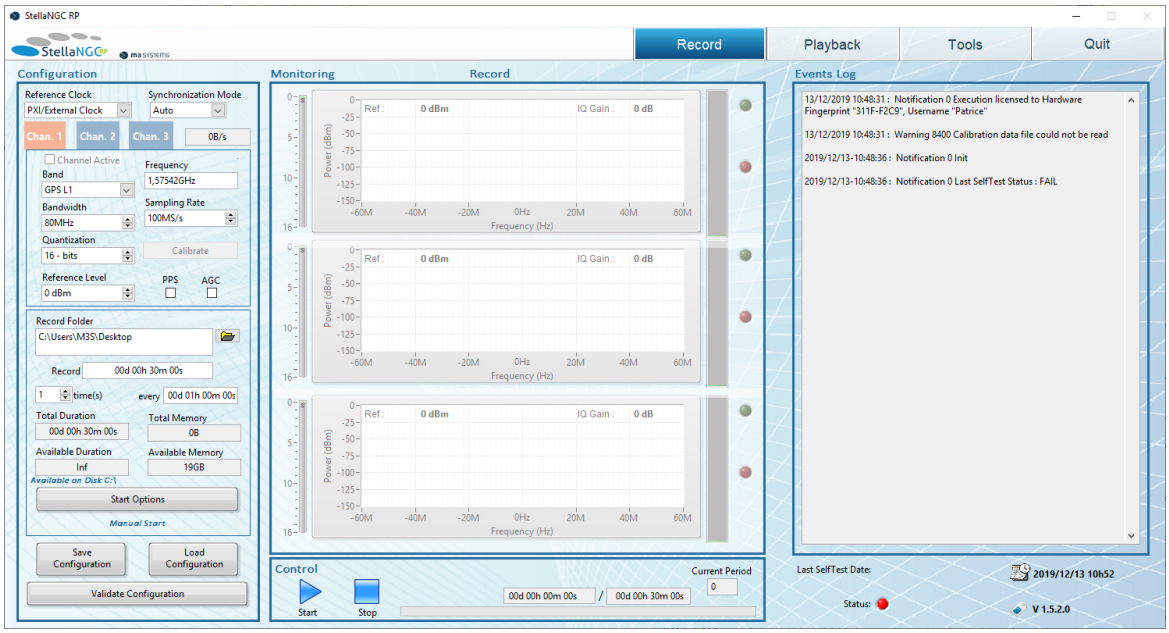



**Figure 1 GUI for Recording Parameters**

For each channel, the user sets many parameters:

- **Center Frequency:** Selection of the center frequency between 65MHz to 6GHz or predefined list of GNSS frequencies for each RF channels
- **Reference level:** this button displays a visual gauge to help the user to define the input gain according to the signal power level (ADC calibration tool)

Linear dynamic range with 16 bits of quantization is 76dB from Reference level.

- **Bandwidth:** up to 120MHz per RF front-end, the user specifies here the desire bandwidth to record
- **Sampling Rate:** this value defines the sampling rate in millions of samples per second. The ratio between sampling and bandwidth is 0.8. (Example: For a bandwidth of 80MHz the sampling rate is 100MS/s)
- **Quantization:** Number of bit selection for quantization
- **Estimated Size:** this field is computed and then it is automatically updated according to the sampling rate, the duration of the record and the resolution of the digitalization for each RF front-end

### Common record parameters

All below parameters are in common with all RF channels:

- **Recording directory:** path of the file for data storage. Each RF front-end will produce a TDMS file containing I/Q data associated with a setup file (recalling the record parameter, and used for the replay)
- **Duration:** Duration in second
- **Delayed start:** to schedule the start of the recording at a specific date and time
- **Periodicity:** to schedule a periodic recording at regular time interval (unity: second)
- **Trigger:** the recording will start on defined external trigger

## Playback tab

The Playback panel is used to control the replay of the recorded I/Q during operation (the 3 channels are replayed simultaneously with a perfect synchronization). Playback parameters are automatically pre-loaded thanks to the parameters file created during the recording (Companion file). Additional information is given on replay progression.

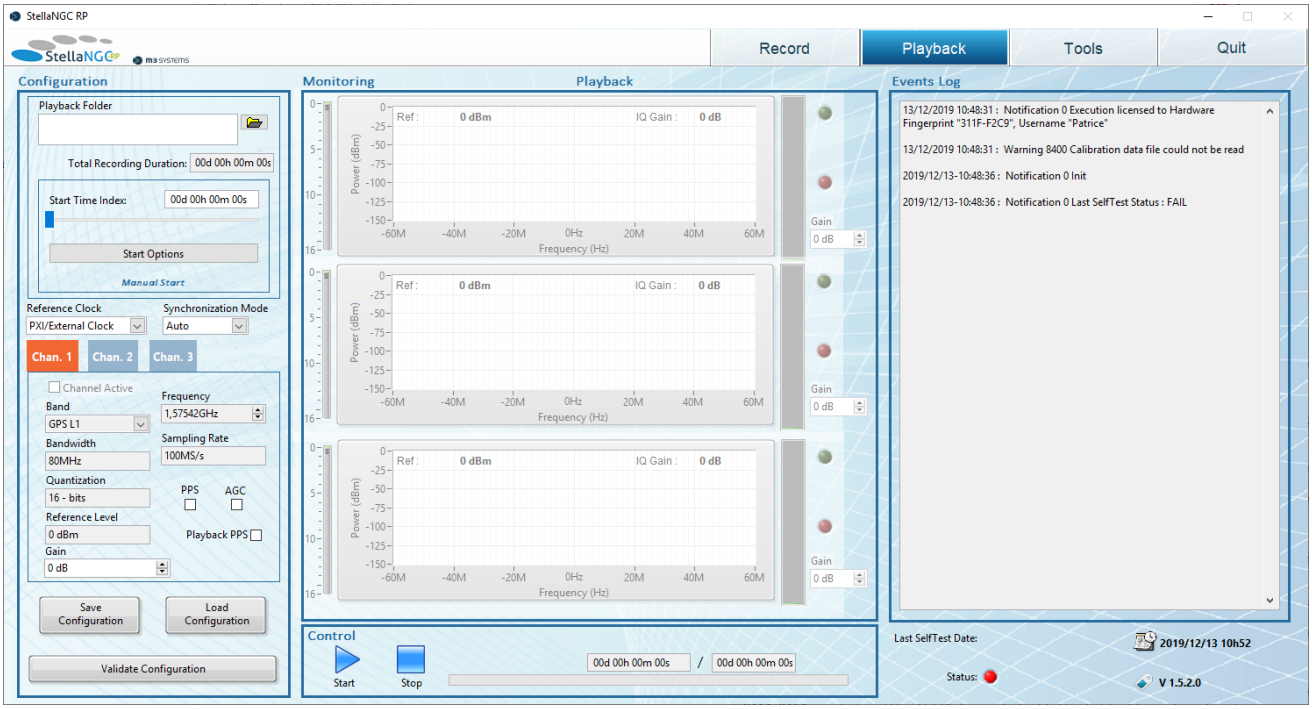



**Figure 2 Playback Screen**

# IV. StellaNGC Record & Playback Add-Ons

## IV.1 Automatic gain control (AGC)

It is also called automatic voltage gain is a closed loop regulating circuit, which purpose is to provide a controlled signal amplitude at its output, despite variation of the amplitude in the input signal. The average or peak output signal level is used to dynamically adjust the input-to-output gain to a suitable value, enabling the circuit to work satisfactorily with a greater range of input signal levels.

- Without AGC, a dynamic of 76dB is available below the reference level selected (maximum input power accepted for record). (Example: With a Reference level fixed at -30dBm, you can accept an input signal from -106dBm to -30dBm).
- With AGC, you have an automatic reference level adjustment regarding input signal power level in the aim to use during record the full dynamic of RF stage from +0dBm to -66dBm and so to record very low-level signal (closed to noise floor) and very high-level signal (close to maximum RF input level supported by VST +0dBm).

As mentioned previously the linear dynamic range with 16 bits of quantization is 76dB around the Reference power level. If the signal recording is done with less bits of quantization (for example, in order to reduce the data amount on storage equipment); with the aim to ensure a good signal recording even if in a disturbance appeared (high RF level peak during recording) M3S preconizes to use an AGC. The performance of integrated AGC on VST allows a response time of 80 µs typical and 100µs max on operational range.

## IV.2 API

The integrated API provides full access and control to Software functionalities through dedicated network messages for an integration into a test bench. The communication is based on the TCP/IP protocol and API strategy is based on a Pull method.

The complete ICD is provided along with the API for easy use in integration environment (Telnet session, Python scripts, C program…).

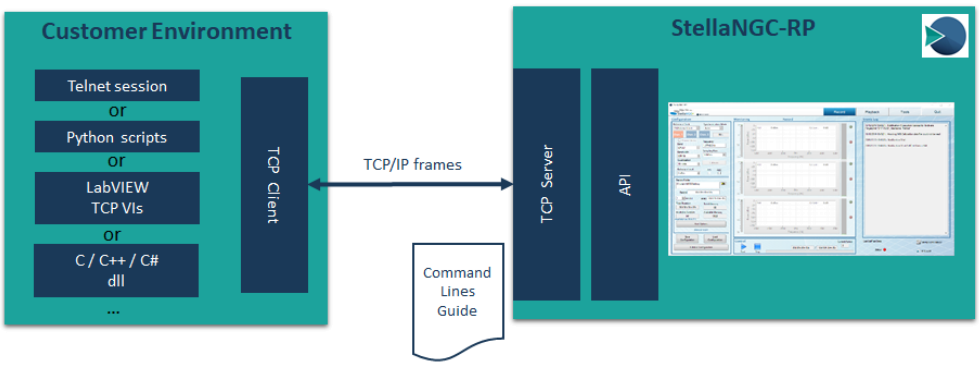



**Figure 3 API Version Architecture**

This feature includes:

- Full control of all software functionalities by specific commands
- Information and error feedback control for processing
- Operator support with specific sequences and modes

## IV.3 Splitting Tool

This add-on allows to optimize the quantity of recorded data stored on network. Thanks to this module you can extract a portion of recorded file for example to focus on a specific event. You have the possibility to record during a test campaign for example 10 hours and after to extract only 10 or 30 minutes and to generate a second file with only the interesting event. The interest is to reduce the size of recorded file.

## IV.4 PPS

The PPS signal can be recorded and played back with StellaNGC RP using an adapter.

- The 68 pins-connector is plugged on the DIO connector of the first VST of the equipment (VST closest to the controller: Slot 2 of the chassis)
- To record an input PPS signal, the Female connector of the adapter must be connected to the TTL signal source
- To playback the recorded PPS signal, the Male connector of the adapter must be connected to the TTL signal receiver

## IV.5 Selftest

The SelfTest functionality enables the user to perform an automatic test of StellaNGC®-RP to ensure the perfect functionality of StellaNGC®-RP before a test campaign.

The SelfTest functionality is composed of 4 main tests, one for each of the following sub-systems:

- Mass storage: tests the record rate of the mass storage device
- Baseband: tests the baseband Input and Output stages

- RF (Radio Frequency signal): tests the Input and Output RF stages
- DIO (Digital Input/Output signal): tests the Input and Output DIO stages

For a perfect traceability, the results of a selftest are logged in a report which also contains:

- The software name and version
- The Equipment Serial Number
- The Selftest Date
- A Global Selftest Status
- In more detail is provided: the number of tests failed, passed, not executed and cancelled
- The Selftest starting and ending dates and times

## IV.6 Smart I/Q Recording

One key feature of the system is the here-named smart recording capability. The overall principle is to reduce the records size without compromise on records fidelity. It is divided in two steps: event detection and selective compression.

**First step - Event detection:** in parallel of short-term memory, I/Q storage, the same I/Q samples are being analyzed by a custom signal processing IP (FlexRIO FPGA based). This function will analyze spectrally the signal amplitude to look for any over-the-range RF signals (defined through a user configurable pattern). Any detection will lead to an event detection trigger. This trigger can also be activated from outside the proposed system (e.g., by a receiver-based analysis or an arbitrary API command).

**Second Step - Selective compression:** once the incoming samples have analyzed for event detection (or enough time let for an external analysis to occur), a second custom IP (FlexRIO FPGA based) oversees compressing the I/Q samples trunk (by reducing the quantization and/or the bandwidth) in case of no event trigger. The compression parameter is user configurable. In case of event, no further compression shall occur.

# V. Hardware Compatibility

StellaNGC is compatible with the RF targets described in the below sections. In addition to RF targets, it is required to have a complete system with a Controller (such as NI PXIe-8160 or a standard PC) which hosts the software and the related environment. For PXIe environment, a PXIe chassis such as NI PXIe-1092 will be required.

### VST second generation

The NI-5840/5841 is the second generation of Vector Signal Transceiver from NI.

Direct outcome:

- 500MHz instantaneous bandwidth on L Band: One RF stage is needed for multi-frequency management.
- Calibrated target: the 5841 is factory-calibrated and can be yearly calibrated to ensure high end RF performance (e.g., IQ imbalance & frequency response)
- List of calibration item can be found here http://zone.ni.com/reference/en-XX/help/374564L-01/calexec/procedure_5840/

As an example, a possible standalone hardware configuration could be: NI PXIe-5841+ NI-PXIe-1092 + NI PXIe-8880 as shown hereunder. To address record and playback capability, an SSD PXIe Card is added (reference on demand)

### USRP-RIO

USRP-RIO is widely used as an entry RF-target for functional verification applications. We do support both NI-2950R 120MHz and NI-2954. This target generates multi-frequency GNSS on L Band (L1, L2 and L5). USRP-RIO can be used along with a PXIe chassis or a standard PC (PCIe link is used in this case).



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