Synchronization Protection & Redundancy in NG Networks

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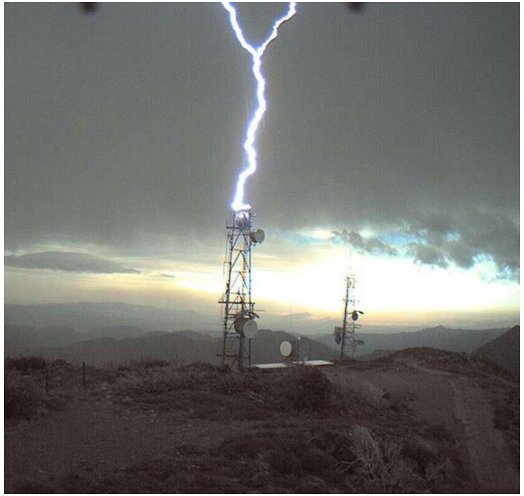
What can possibly go wrong … ?

- GNSS failure
  - Jamming
  - Antenna breakdown (lightning , cable cut)
- Equipment failure
  - HW failure
- Connectivity to GM is lost
  - Network outage or extreme overload



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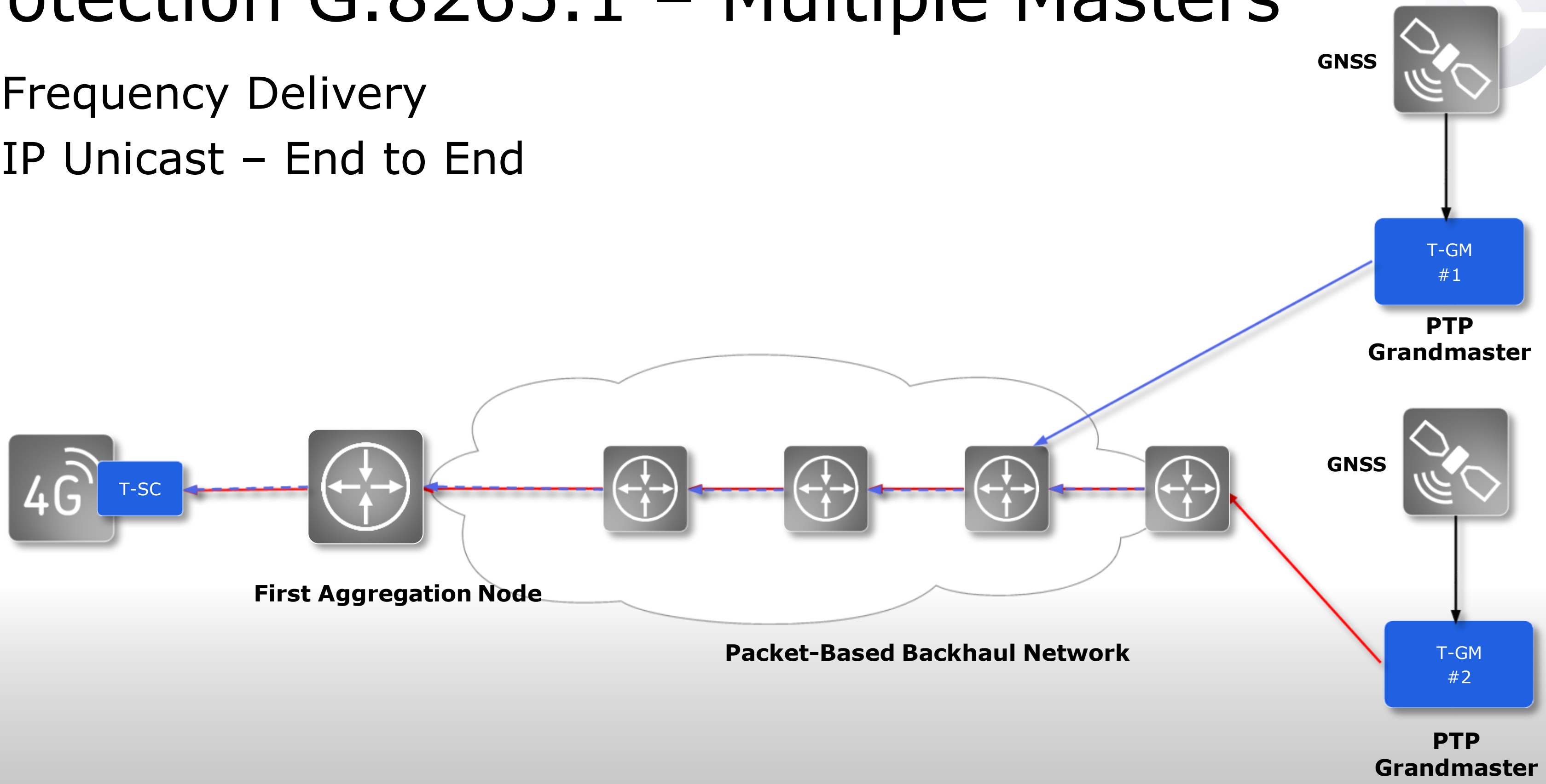
Protection and Redundancy Options:

- Protection at **Slave/BC side** – switching to a standby GM based on the relevant Best Master Clock Algorithm (BMCA)
  - May results network rearrangement
  - Switching between GM's may results phase transient
- Protection at **Master side** – GM switching to secondary source in case the primary source fails
  - Might prevent network rearrangement if secondary source if sufficiently good

Both options can be combined in
order to achieve best protection & redundancy

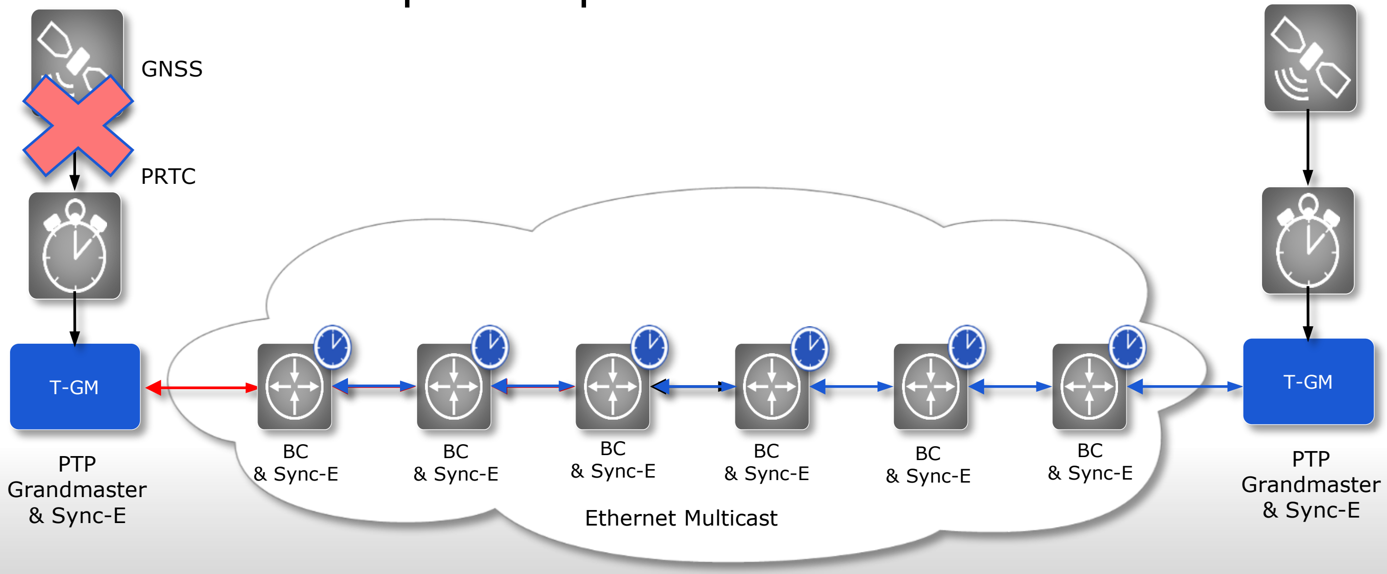
Protection G.8265.1 – Multiple Masters

- Frequency Delivery
- IP Unicast – End to End

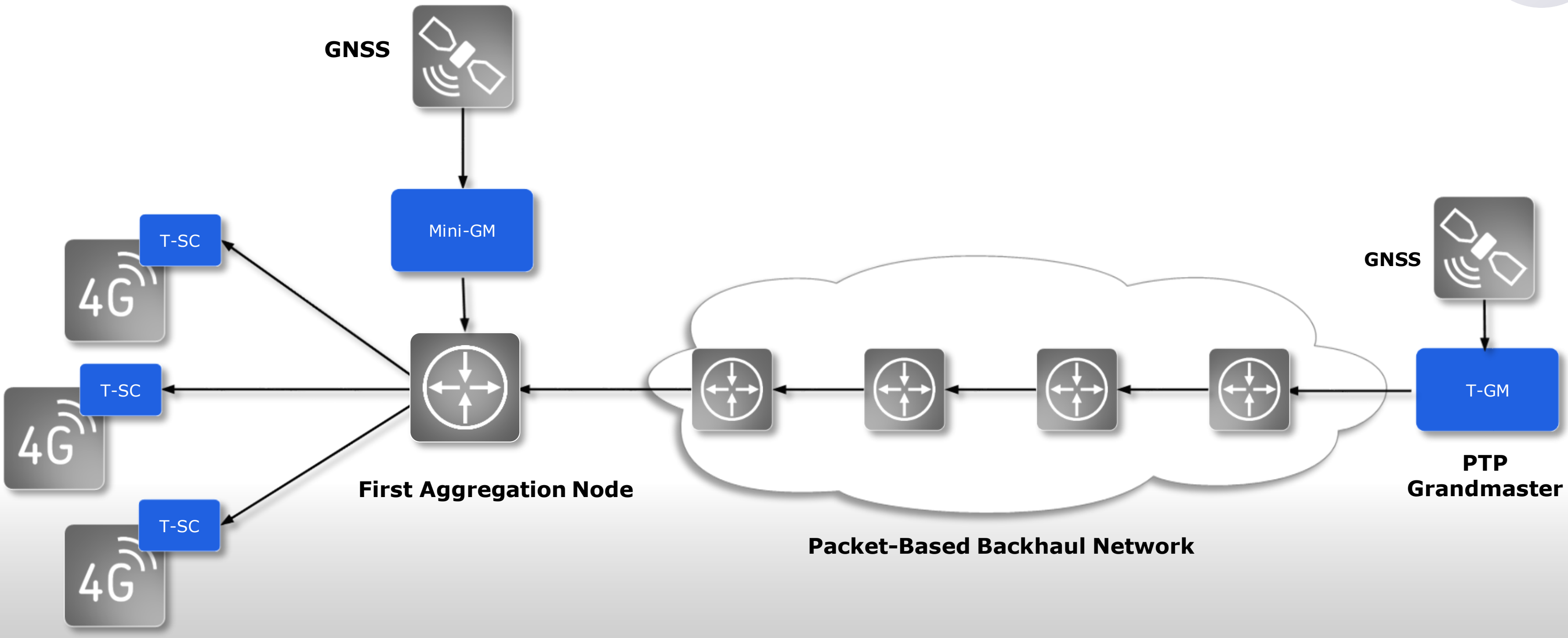


Protection G.8275.1 – Multiple Masters

- Phase & Frequency Delivery
- Eth' Multicast – Hop to Hop



Distributed Architecture Using Mini-GM



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Distributed GM Protection Options

- What if GNSS is locally in outage (e.g. Jamming)
  1. Physical layer input
     - Sync-E
     - BITS
     - Can be a good option – but not always available
  2. PTP input (APTS)
     - Recovering both frequency and phase
     - Recovering only frequency which is used for phase holdover
     - Will be reviewed in details in Dominik presentation
  3. **Holdover based on local oscillator**
     - Always available

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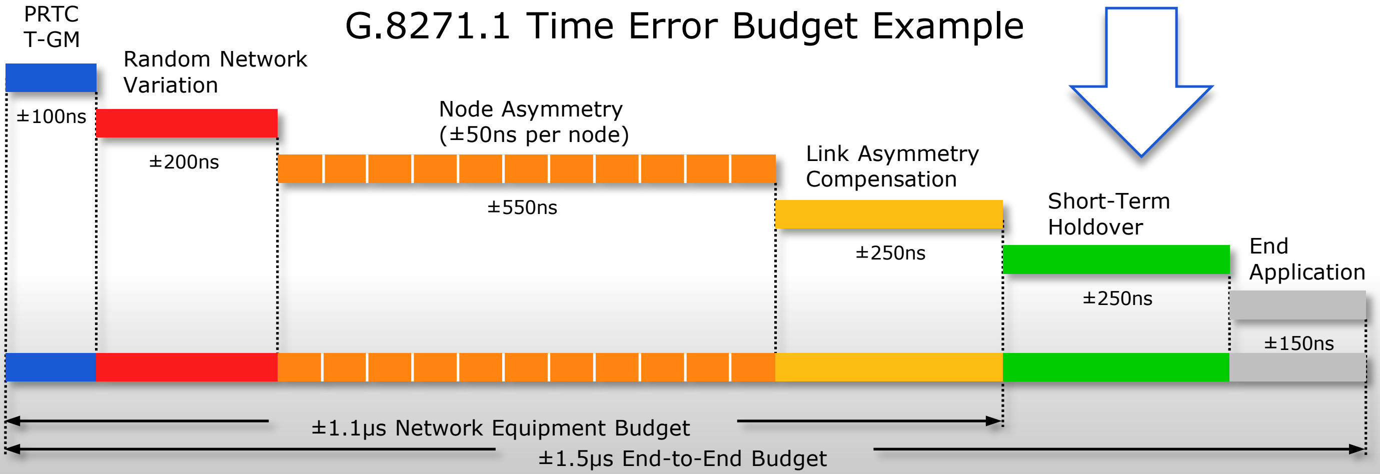
Short Term Holdover

- e.g. Temporary GNSS jamming or poor line of sight
- Duration : Few seconds – Few hours
- Holdover budget – few hundred of nsec



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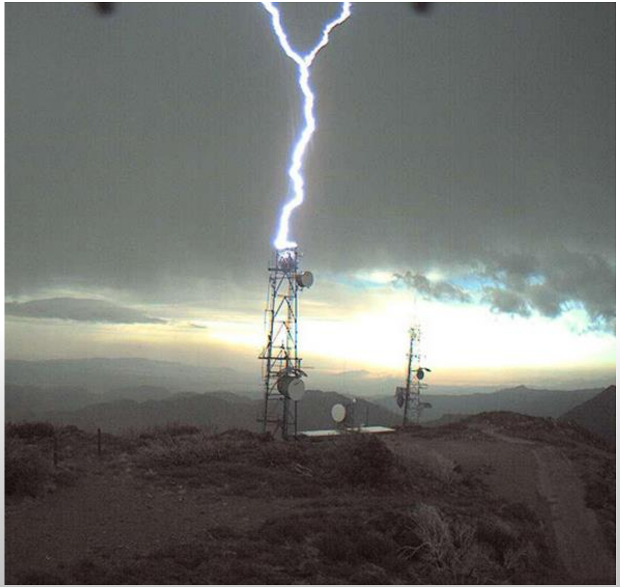
Long Term Holdover

- Antenna failure (e.g. lightening)
- Few hours – 3 days
- Depend on the available time error budget – but potentially can be more than 1500nsec



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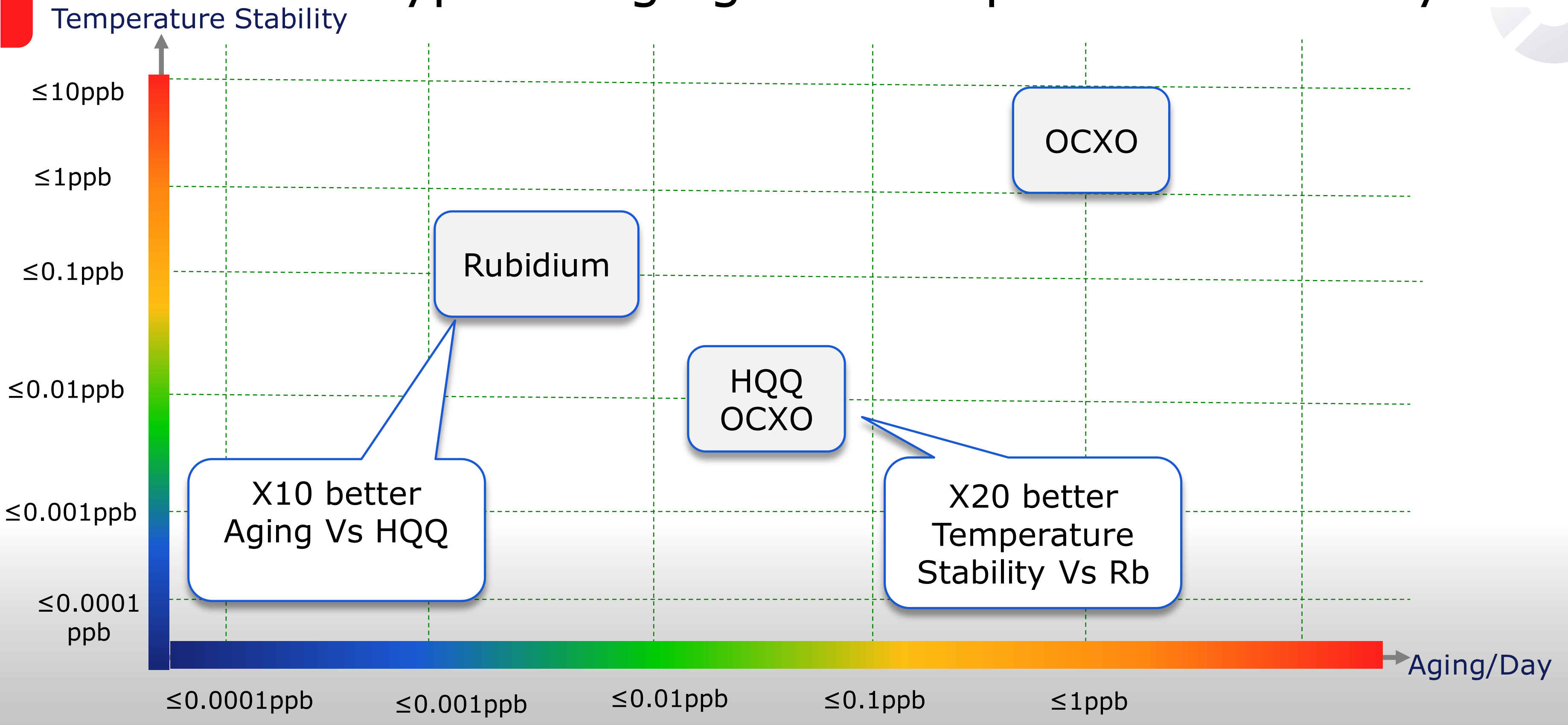
Oscillator Types – Aging and Temperature Stability



It can be very cold…

HUAWEI BS China 2008
winter storm

Telenor base station or snow creature?

Or very hot…

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And it can swing in between…

- The greatest temperature change in 24 hours occurred in Loma, MT. on January 15, 1972. The temperature rose 56 degrees, from -47C degrees to 9C.
- The greatest temperature change in 12 hours happened on December 14, 1924. The temperature at Fairfield, Montana, dropped from 17C to -29 at midnight

Environmental Condition

- Synchronization devices at the access network are subject to wider temperature variation!
- ETSI Environmental Classes:

	Class #	Class description	Temp. change rate	Temp. change range	Delta
Core	3.6	Control room locations	0.5°C / min	[+25, +30°C]	5°C
	3.1	Temp. controlled locations	0.5°C / min	[+25, +40°C]	15
	3.2	Partly temp. controlled locations	**0.5°C / min**	**[+25, +55°C]**	**30**
	3.3	Not temp. controlled locations	**0.5°C / min**	**[-5, +45°C]**	**50**
Access	4.1	Non-weatherprotected locations	**0.5°C / min**	**[-10, +40°C]**	**50**
	3.5	Sheltered locations	**1°C / min**	**[-40, +40°C]**	**80**

	Ethernet Access NE - typical operational temperature range		**[-40, +65°C]**	

Higher temperatures are expected in other continents

Oscillator Types

Clock Type #	Cost	Operational Temperature range of the clock	Typical Ambient Operational Temperature range of the Sync Element	Temp Stability	Aging/Day
OCXO	Low (10%)	-40 to 85 C	-40 to 65 C	1-10 ppb	1ppb
OCXO HQ	Medium (100%)	-40 to 85 C	-40 to 65 C	0.01 ppb	0.05 ppb
Rubidium	High (300%)	-10 to +75 C	-5 to +55 C	0.2 ppb	0.005 ppb

But Aging can be estimated with GNSS!

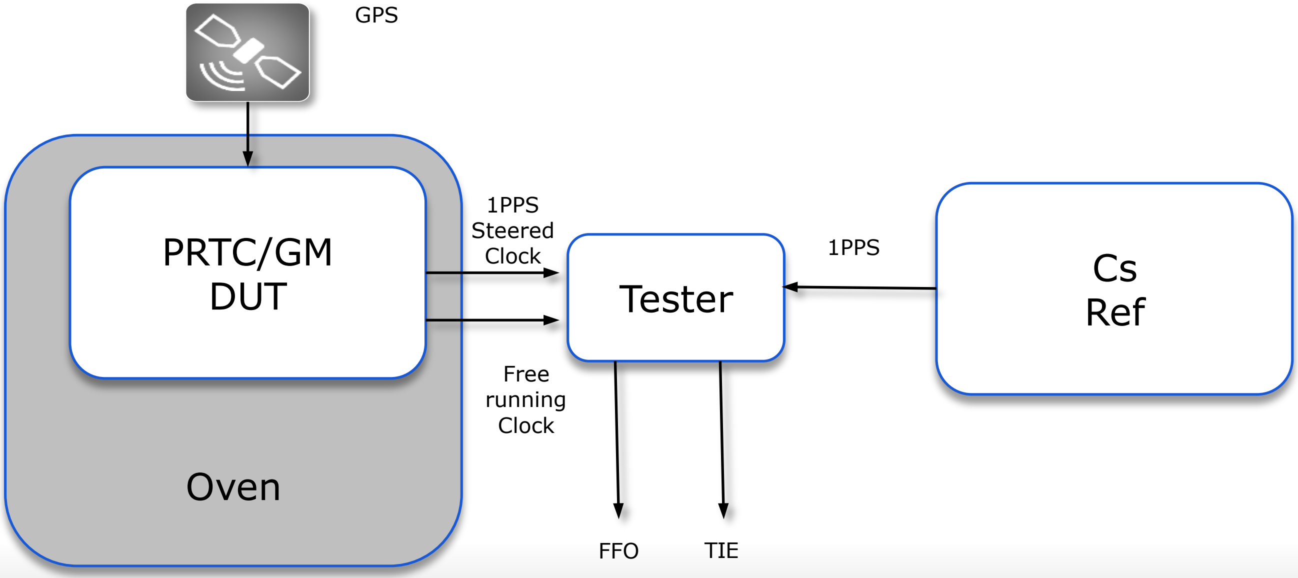
Rb High cost , limited operational temperature range and temperature instability make it less suitable for access devices

Aging seem to be the only advantage of Rb

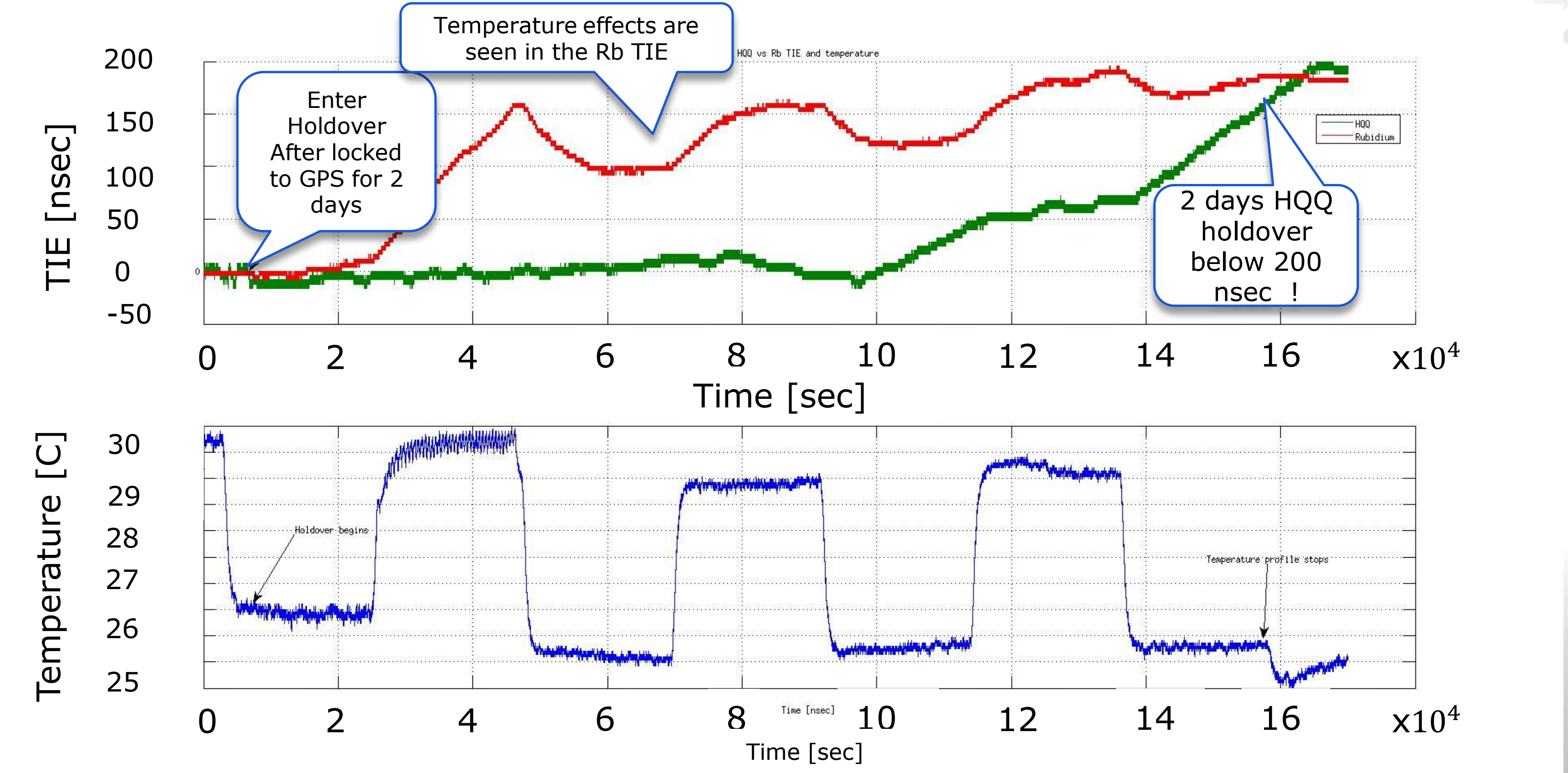
What Is The Optimal Solution?

- GNSS , while available (prior to holdover) can be used for learning local oscillator characteristics
- In order to be able to efficiently learn the oscillator aging the oscillator must have a very good temperature stability
- The GNSS long term accuracy is better than 1e-12 (G.8272 require PRTC to be with +/-100 nsec from UTC)
- **Combining the high temperature stability of the high end oscillator with the GNSS reference can generate optimized solution in both performance and cost**

Test Setup

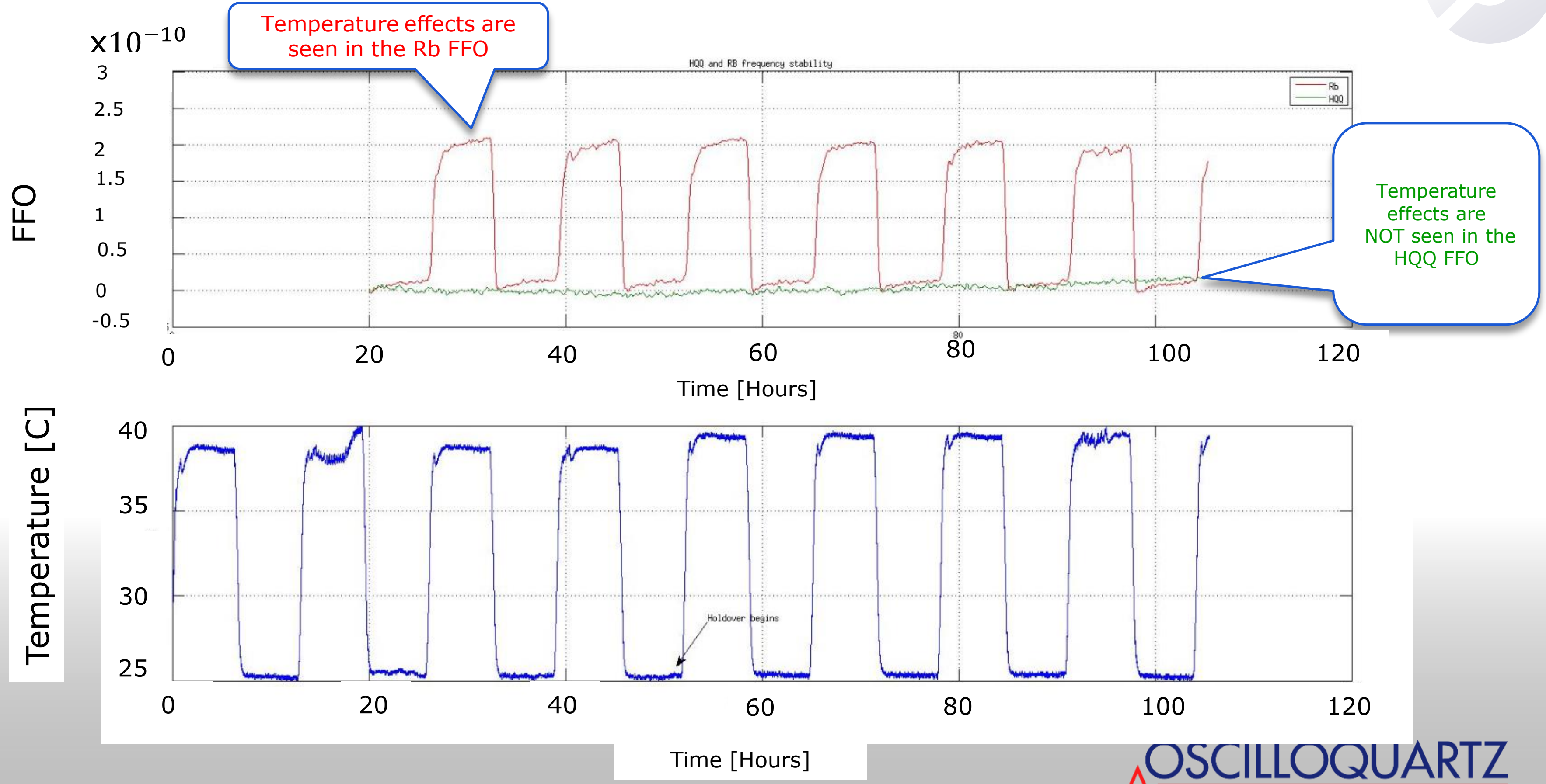

GPS
PRTC/GM
DUT
Oven
1PPS
Steered
Clock
Free
running
Clock
Tester
1PPS
Cs
Ref
FFO
TIE

HQQ Vs Rb – Controlled Room (25-30C)



- Tested in the Oven with controlled room profile
- Phase Holdover over 48 hours below 200nsec !

HQQ Vs Rb – Temp' Controlled Room (25-40C)



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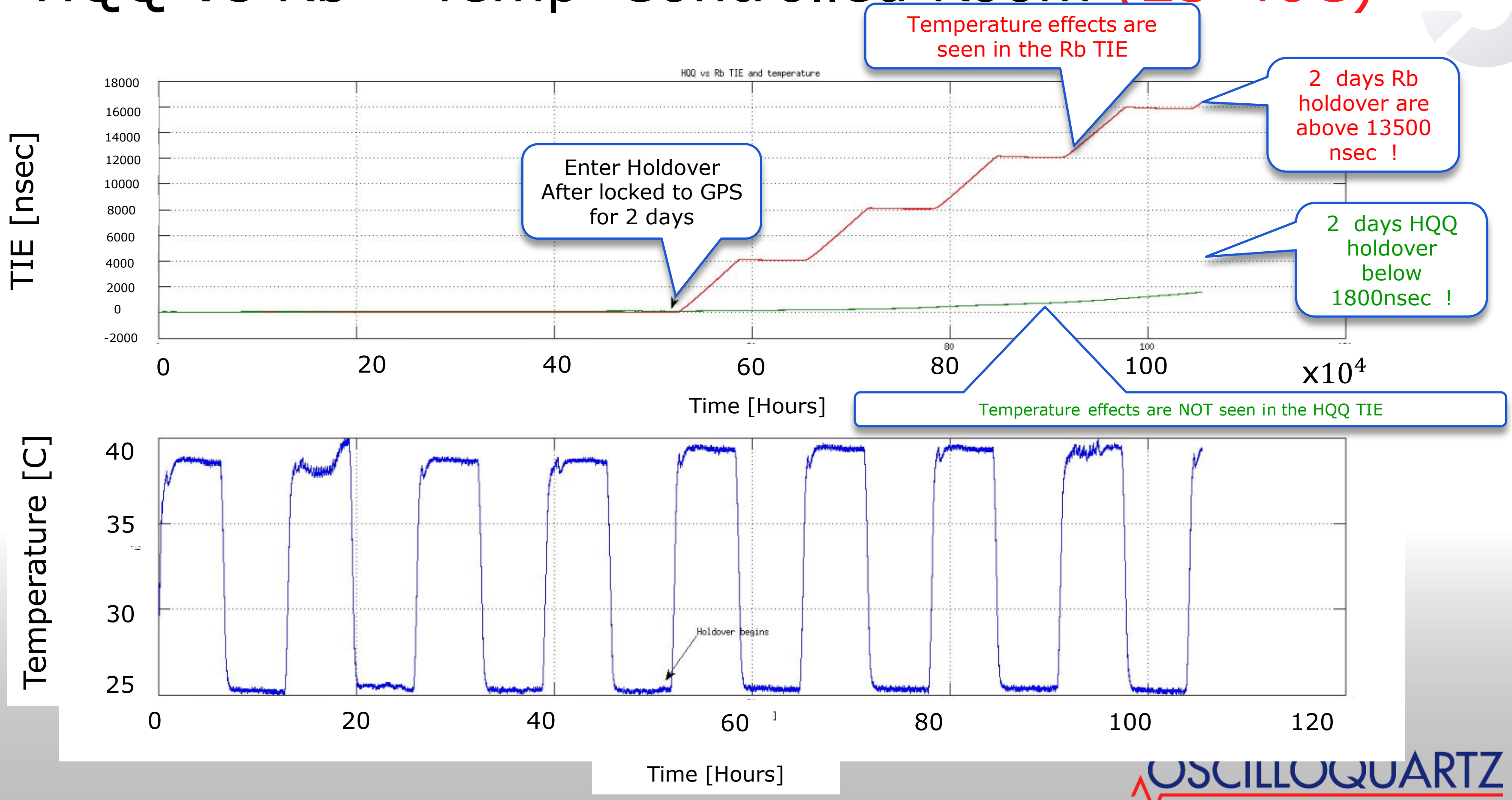
HQQ Vs Rb – Temp' Controlled Room (25-40C)



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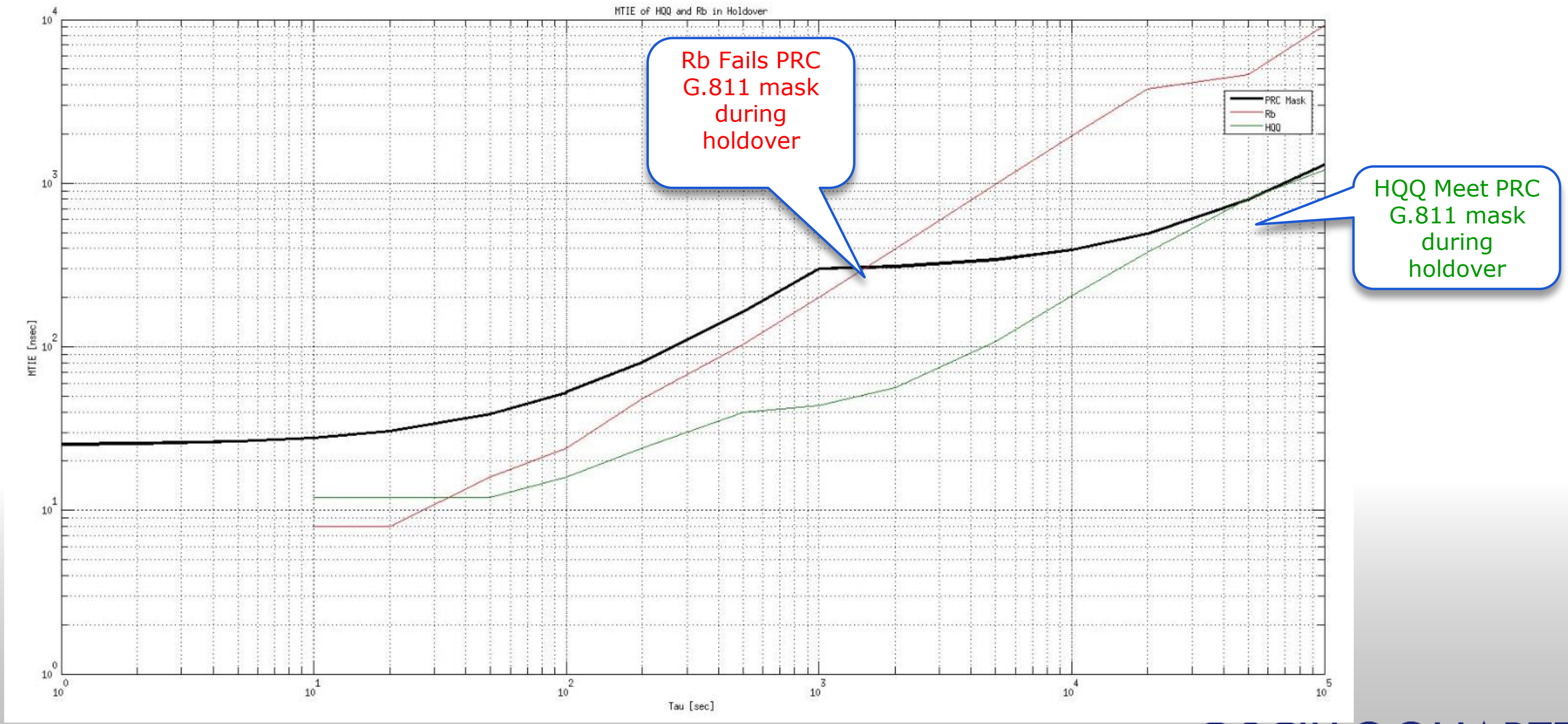
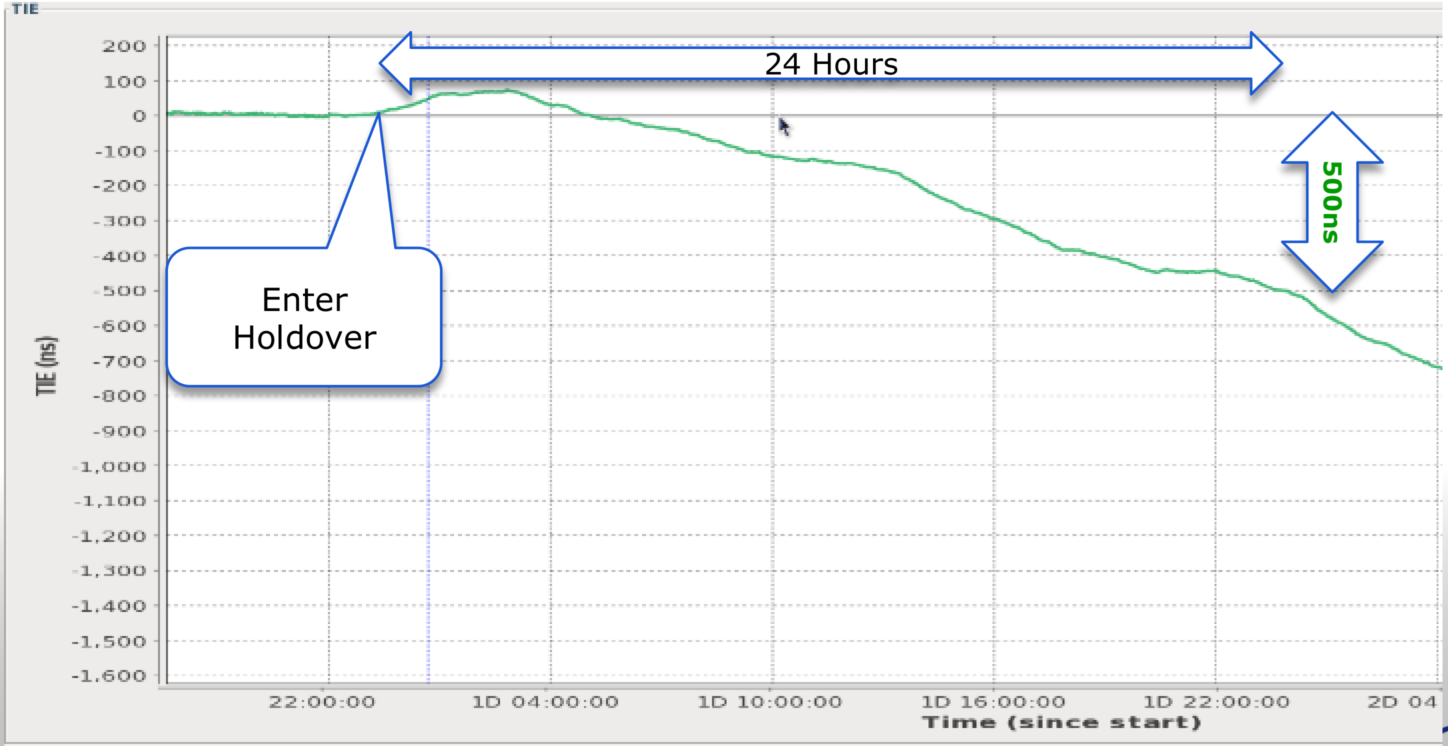
HQQ Vs Rb – Temp' Controlled Room (25-40C)



HQQ Holdover at +/- 20C (0-40C)

- Tested in the Oven with temperature profile +/- 20C
- Phase Holdover over 24 hours below 500nsec !



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Advantages of the High Quartz Oscillator Over Rubidium

- **Better operational temperature range and stability** – guarantee better performance in the field
- **Cost Effective Solution** – ~one third of the cost
- **Superior holdover performance** with the aging learning algorithm enabled for High quality oscillator

	400nsec	1.1usec	1.5usec	5usec	10usec
HQ Oscillator	15 hours	~1.3 days	2 days	4 days	6 days
Rubidium benchmark	NA	NA	1 day	3 days	5 days

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Thank You