Synchronising Neutron Instrument Control – A Challenge for Large-Scale Facilities.

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Outline

- Synchronisation at large facilities.
- MRF timing system.
- Application to ESS instruments.

What Do We Want From A ‘Timing System’?

- Enable synchronous operation of many components of the facility.
  - Digital events and pulse sequences.
  - Software events.
- Global timebase.
  - Attach timestamps to data.

Challenges on a Large Scale

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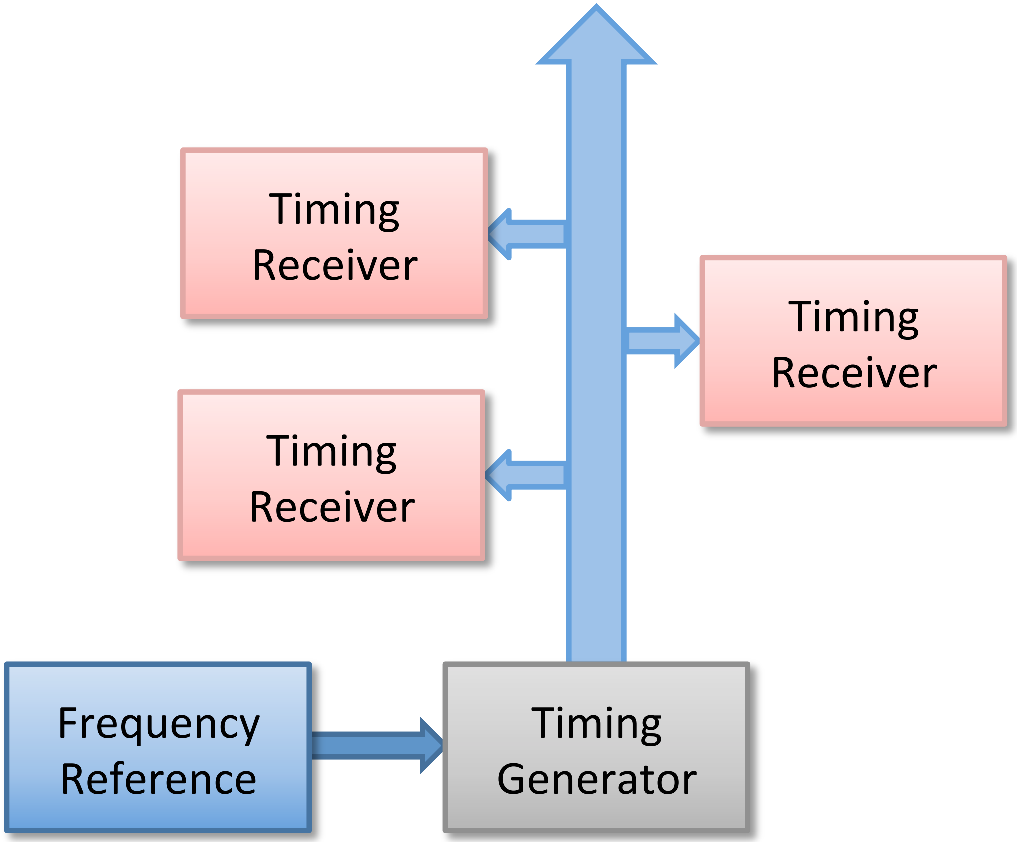
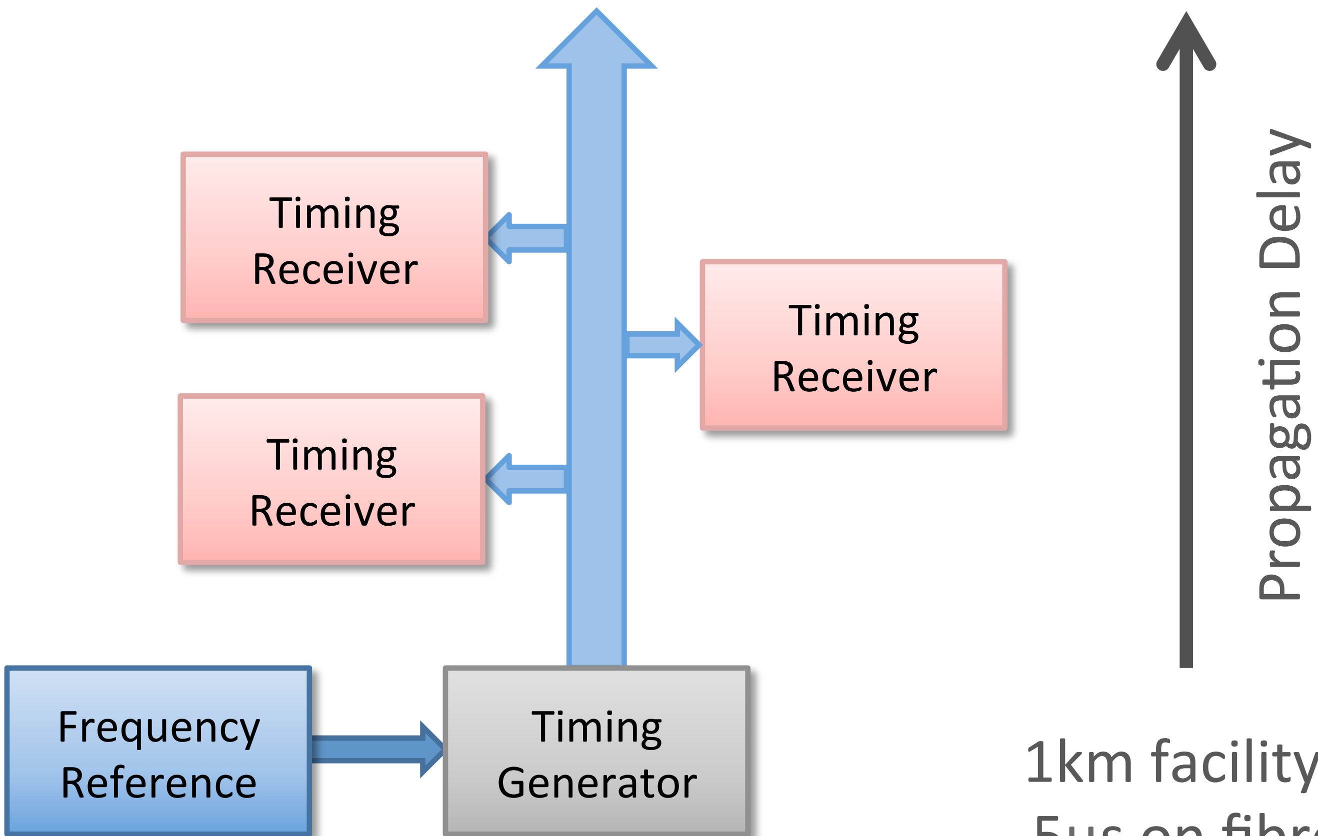
Central Timing System



Central Timing System



1km facility = 5μs on fibre. Time variable.

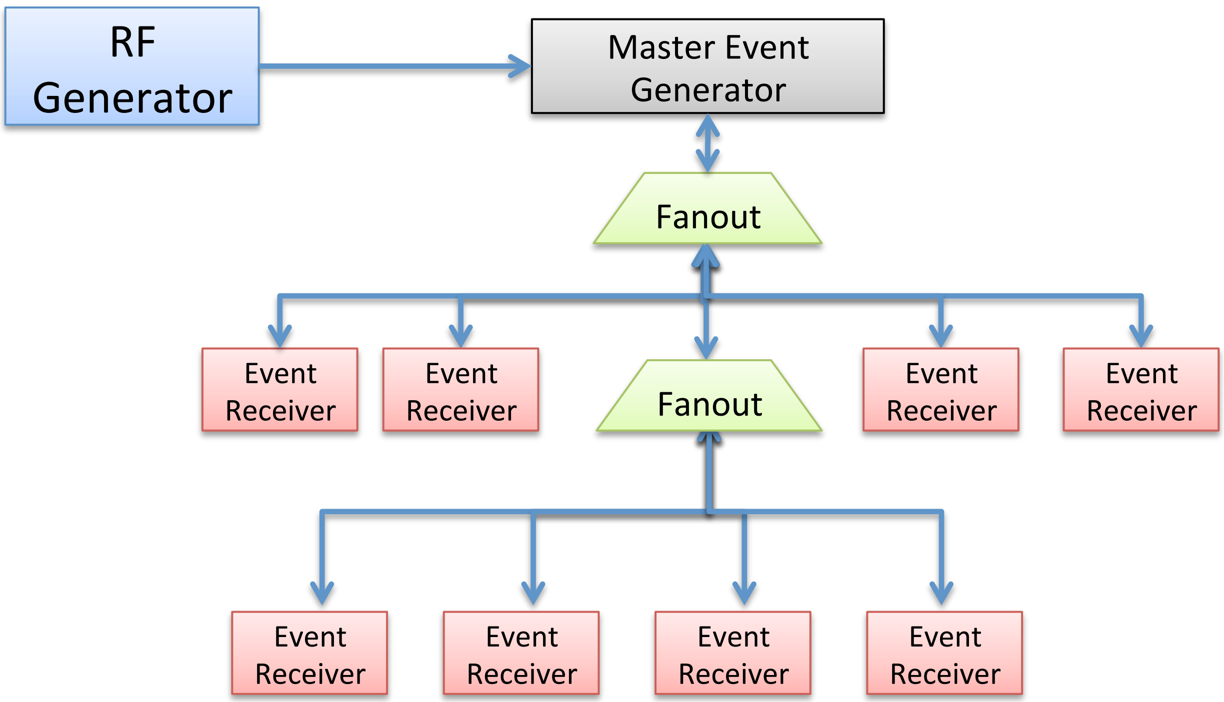
Delay Compensation

- Strategy 1: Calibration
  - Need to be able to measure delay artifacts to quantify and compensate.
  - Can vary with time (e.g. thermal effects or changing equipment on the timing distribution system).
- Strategy 2: Active Compensation
  - Measure delays and actively compensate.
  - Systems operate independently of spatial, thermal and other systematic delays.

The ESS Timing System

- ESS will use the Micro-Research Finland (MRF) timing system.
- Distribute up to 255 synchronous events to a large number of devices.
  - Event Receivers can be programmed to generate delayed electrical or optical triggers in response to an event.
    - Including sequences with multiple voltage transitions.
  - Triggers can also be software, triggering some action in the EPICS control software.
    - e.g. write values, perform a calculation, read a data value, latch a position, etc..

Structure of the ESS Timing System



- Fan-out system can (and will) have many levels. Synchronisation accuracy will not be affected by how many levels there.
- The (accelerator) synchronisation frequency (of 88 MHz) will be fed into the master event generator and used as the system clock.

Event Generator (cPCI)

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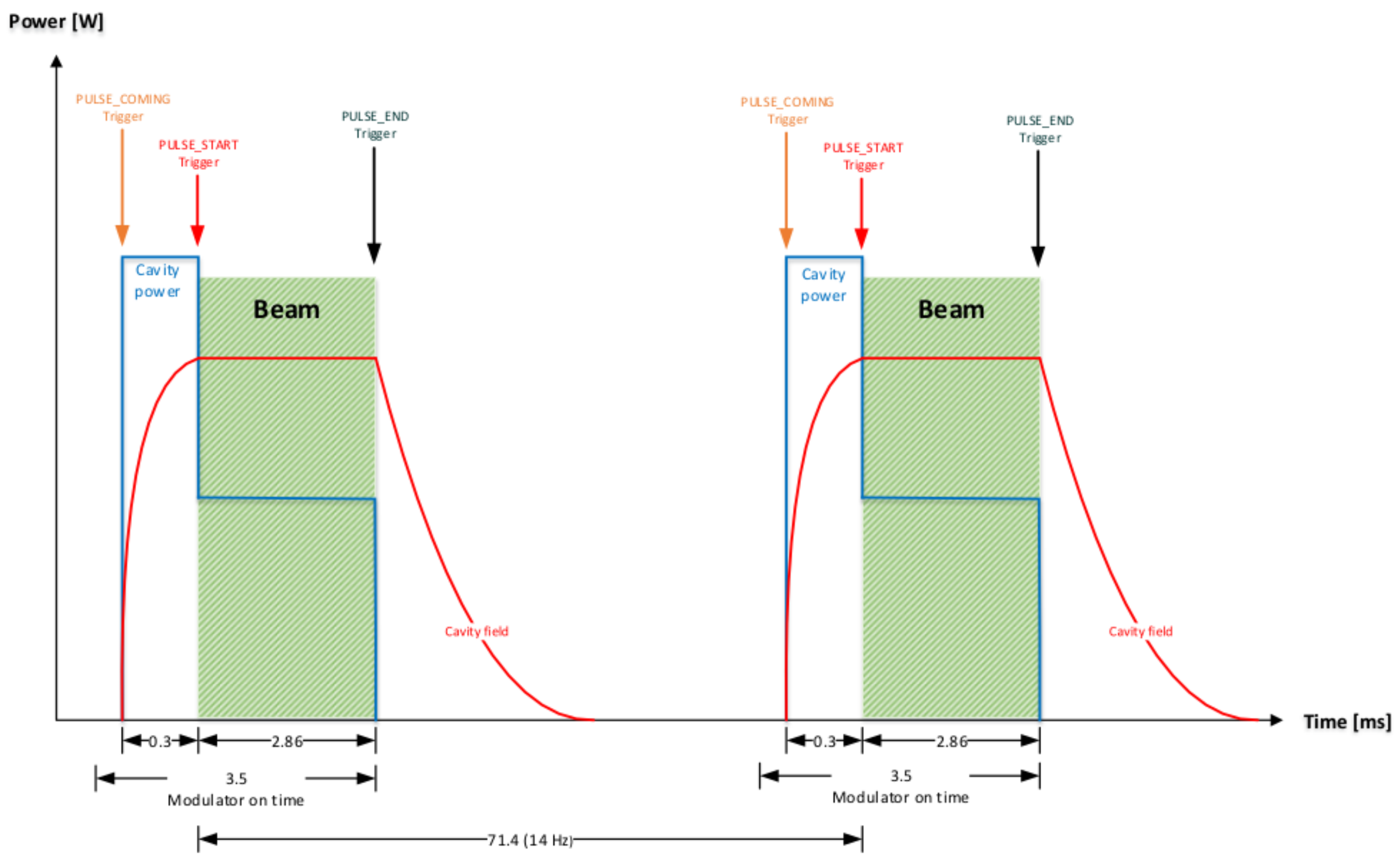
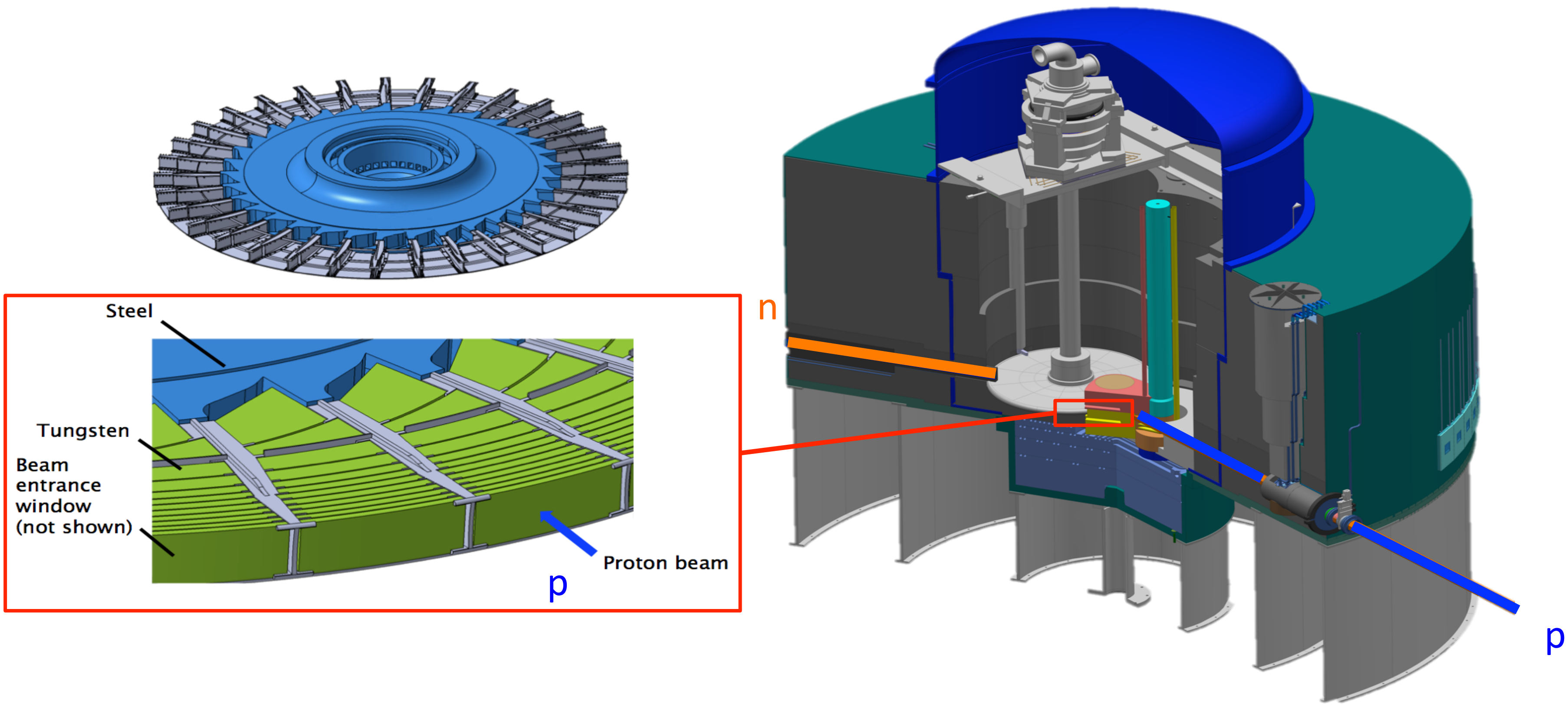
Event Receivers

Timing Example - Accelerator

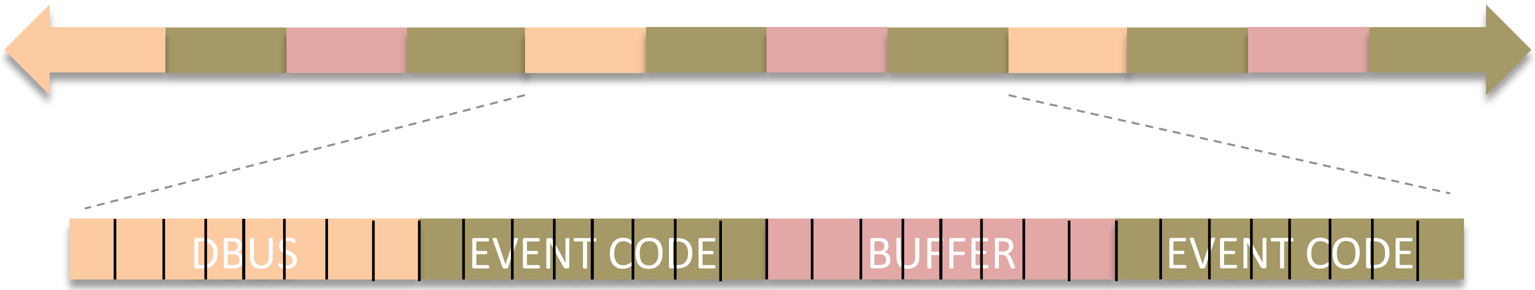


Timing Example - Target



- Target motion control system must be precisely synchronised with the 14Hz operation of the accelerator to ensure proton pulses can be ‘painted’ in the middle of the face of each tungsten sector.

On-The-Wire Protocol



- Alternating sequence of event code and distributed bus/synchronous data buffer bytes.
  - Distributed bus (DBus) can broadcast eight binary signals across the timing network, which could then be output from the front panel of each Event Receiver.
  - Data buffers (up to 2kB) can distribute arbitrary data.
    - e.g. broadcast a unique ‘Pulse ID’ every 14Hz.
- 8b10b encoded - Adds two extra bits per byte to achieve DC balance and guarantee no more than five ones or zeroes in a row, to allow clock recovery.

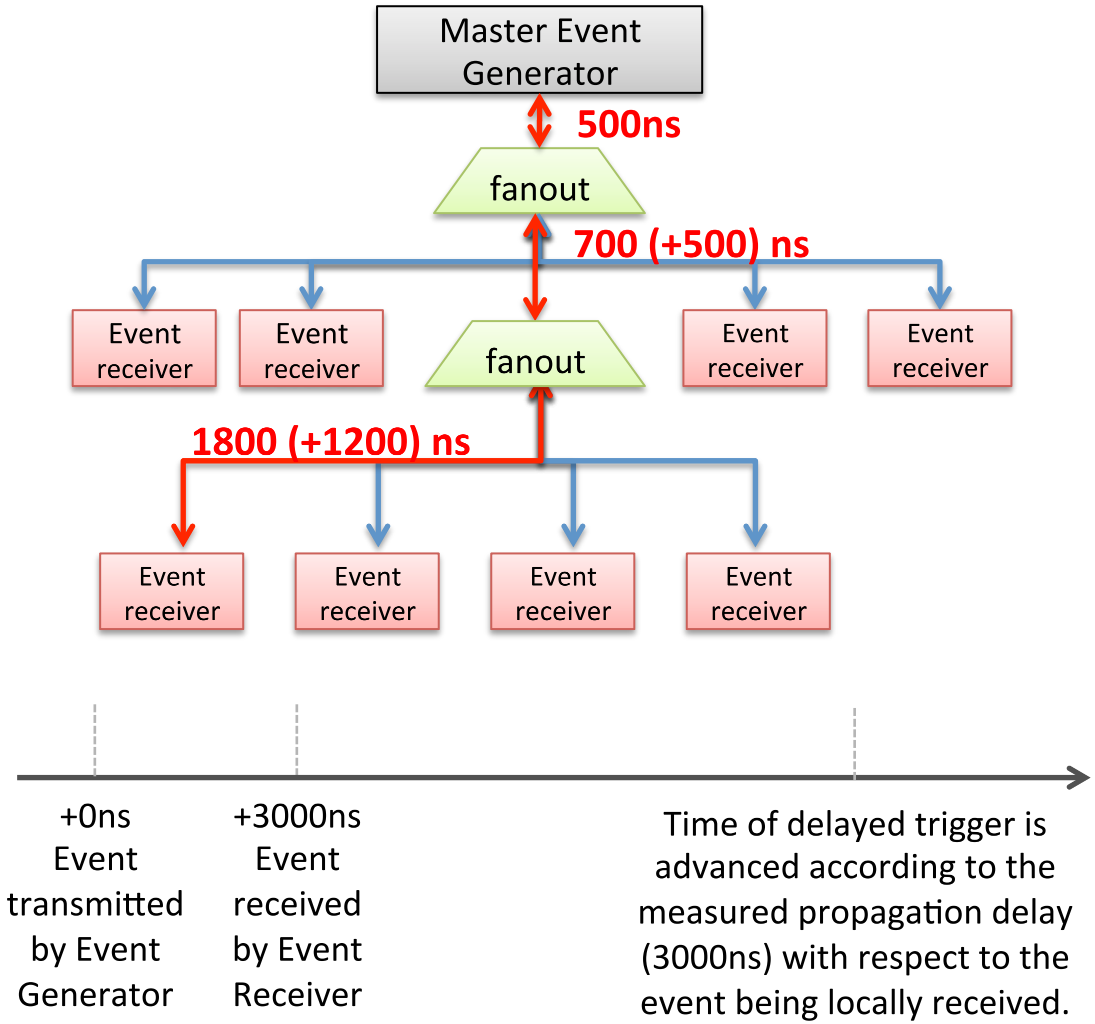
Receivers Can Trigger Upstream Events

- Communication between the Event Generator and Receiver is bi-directional.
- Receiver front panel input signals can be sent to the Generator and then rebroadcast to all as DBus signals.
- Software on a receiver can trigger events across the entire timing network.
  – e.g. LINAC systems can immediately flag a ‘bad pulse’ to instruments if a problem is detected.

MRF Active Delay Compensation (I)

- Bi-directional communication enables the round-trip delay measurement for each segment of the distribution network.
  - The data buffer bytes can transport this information.
- Quantify the cumulative delay at any point of the network.
- Each Event Receiver is aware of the delay between itself and the Event Generator.
- Programmed delayed triggers are adjusted in firmware according to the measured propagation delay.

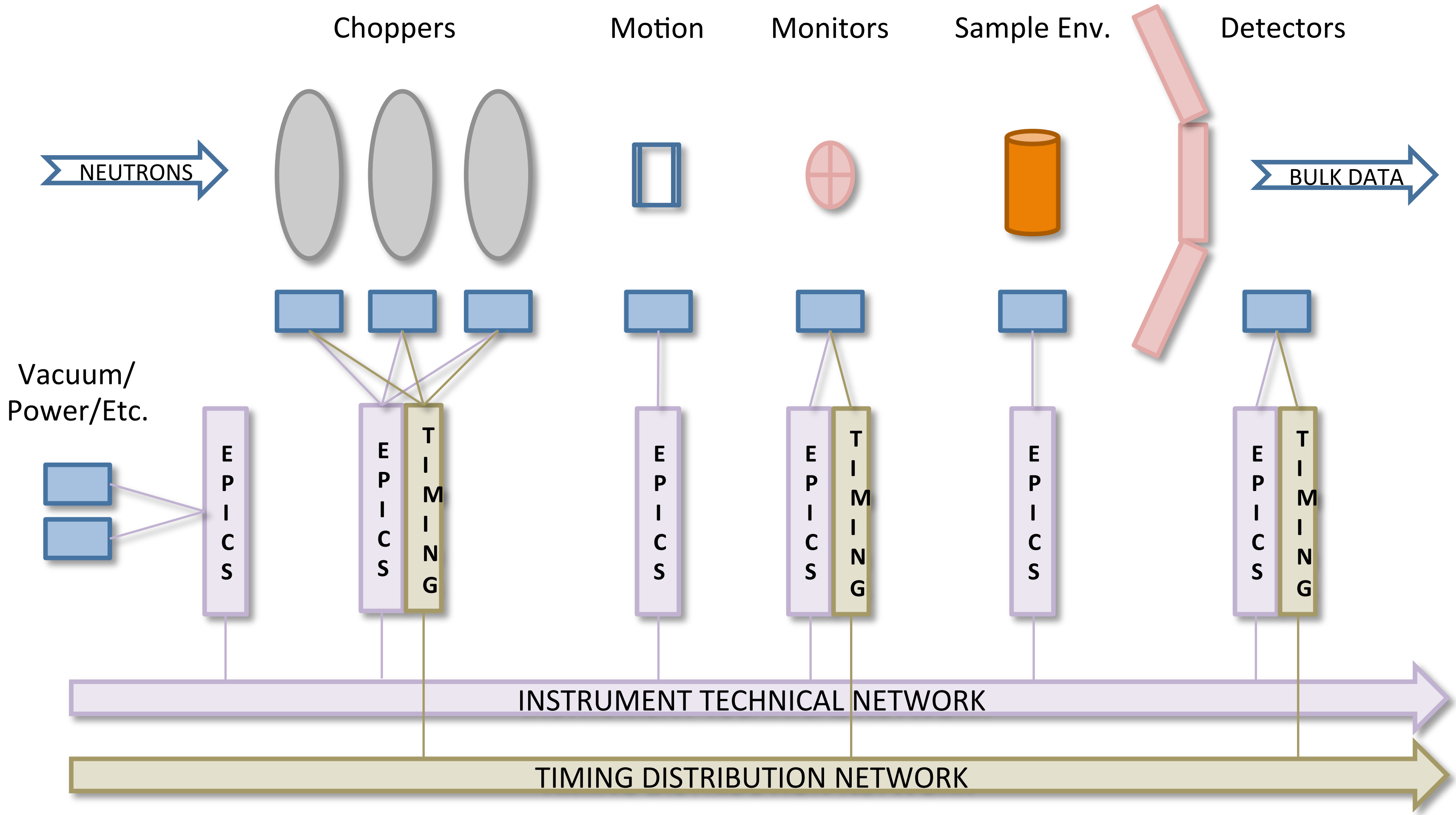
MRF Active Delay Compensation (II)



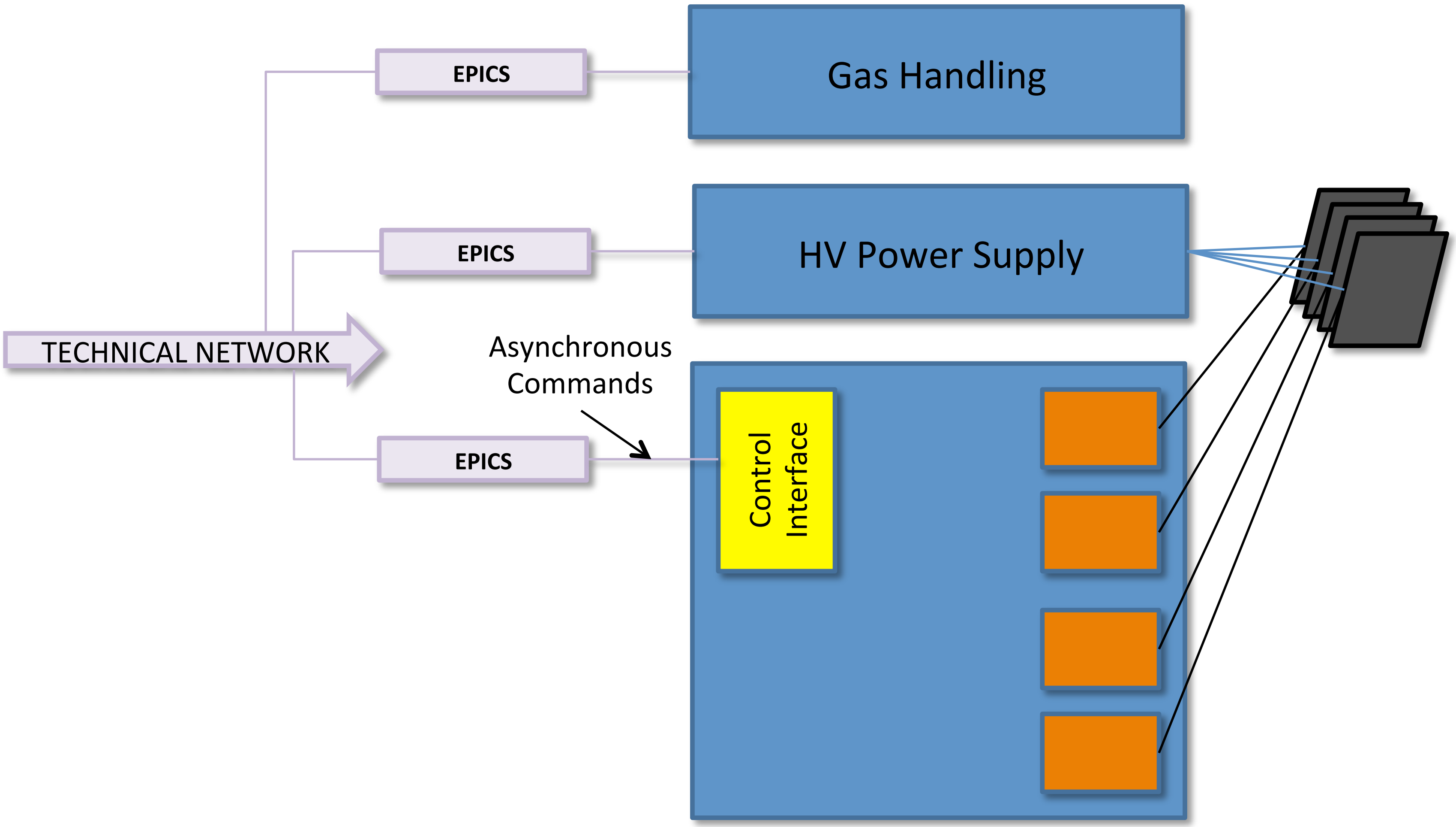
MRF EPICS Integration

- ‘mrfioc2’ by Michael Davidsaver (BNL) et al..
- Configure pulse generator modules to respond to events.
- Capture the arrival time of events.
- Query the current time.
- Register a callback function to receive notification when synchronous data buffers update.
- Respond to transitions on front panel inputs.
  - DBus, local event or trigger an upstream event.

Timing For ESS Instruments



Neutron Detector Controls



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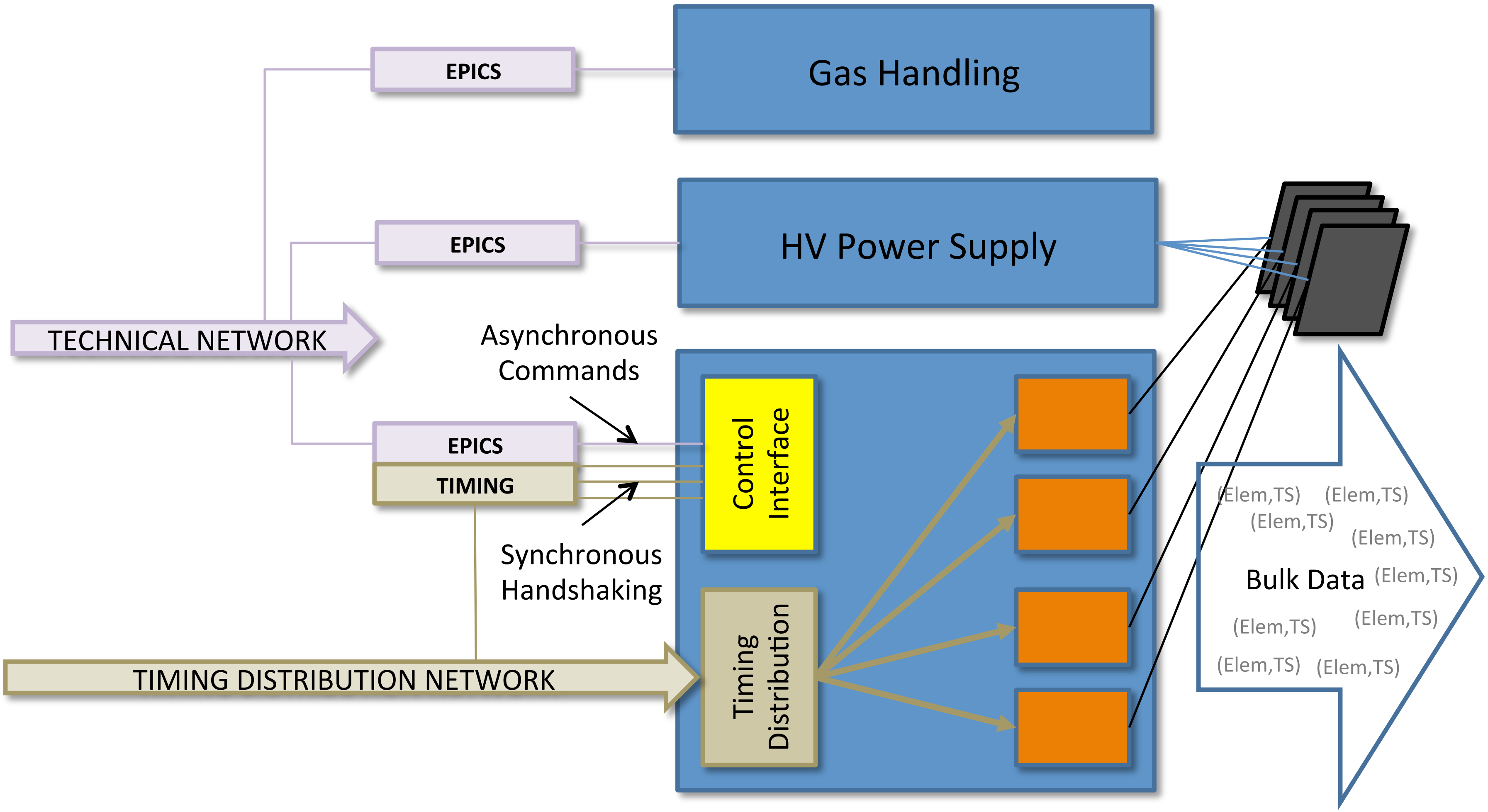
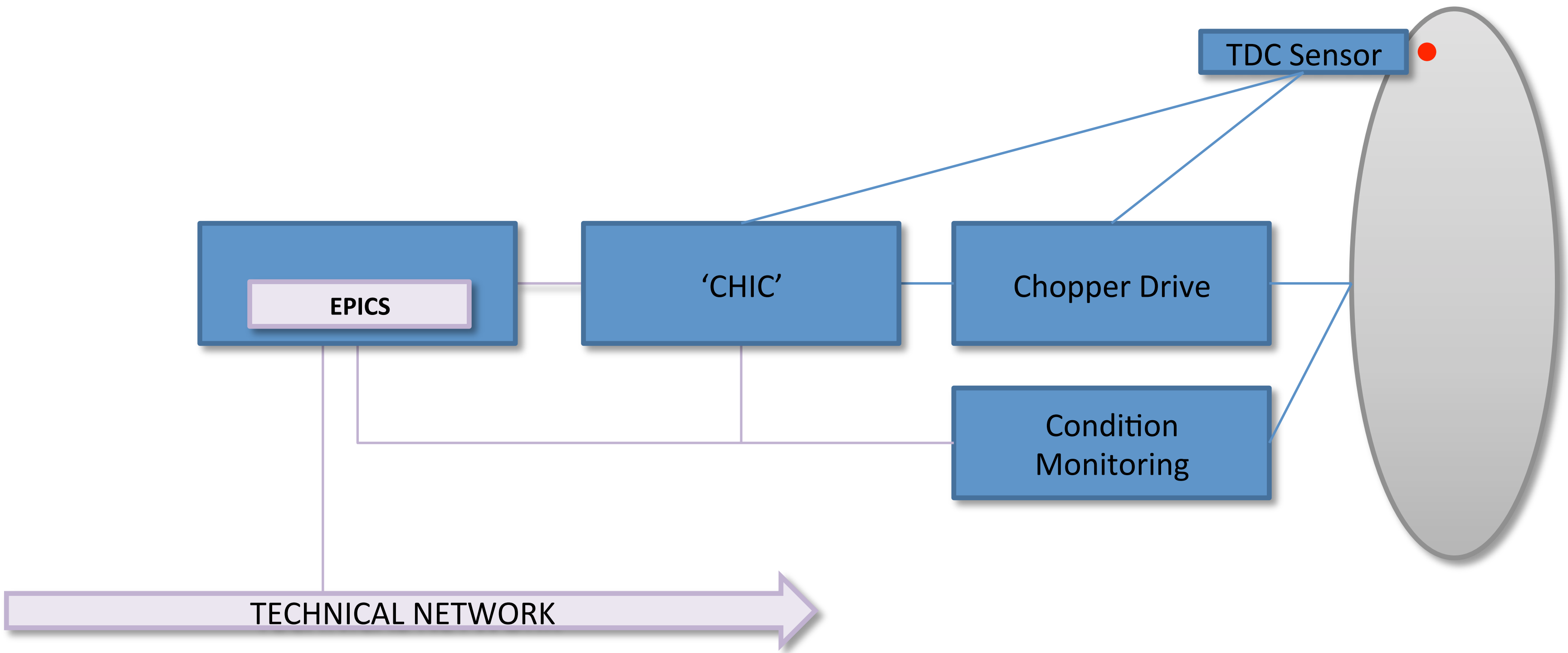


Neutron Chopper Timing



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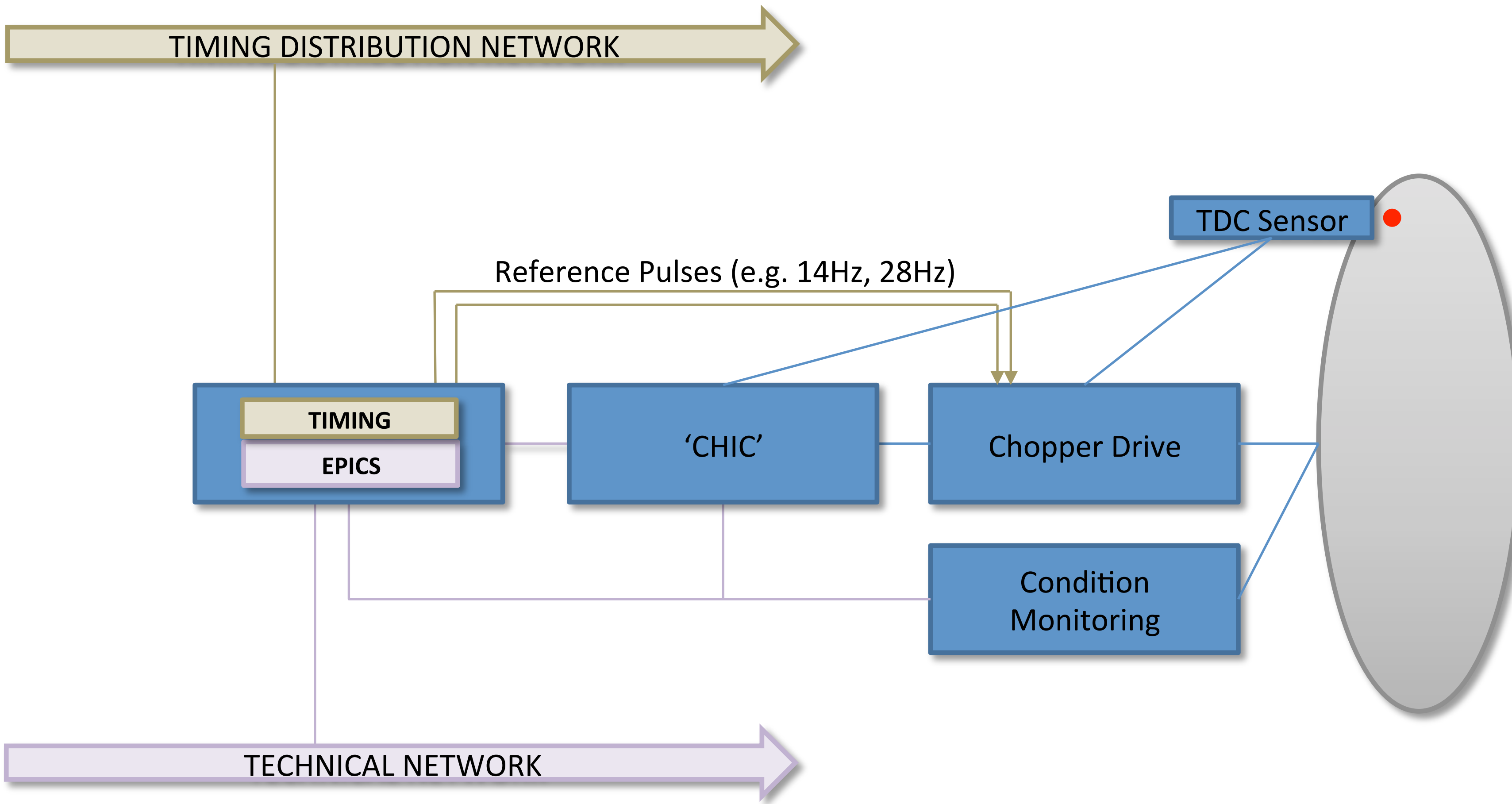

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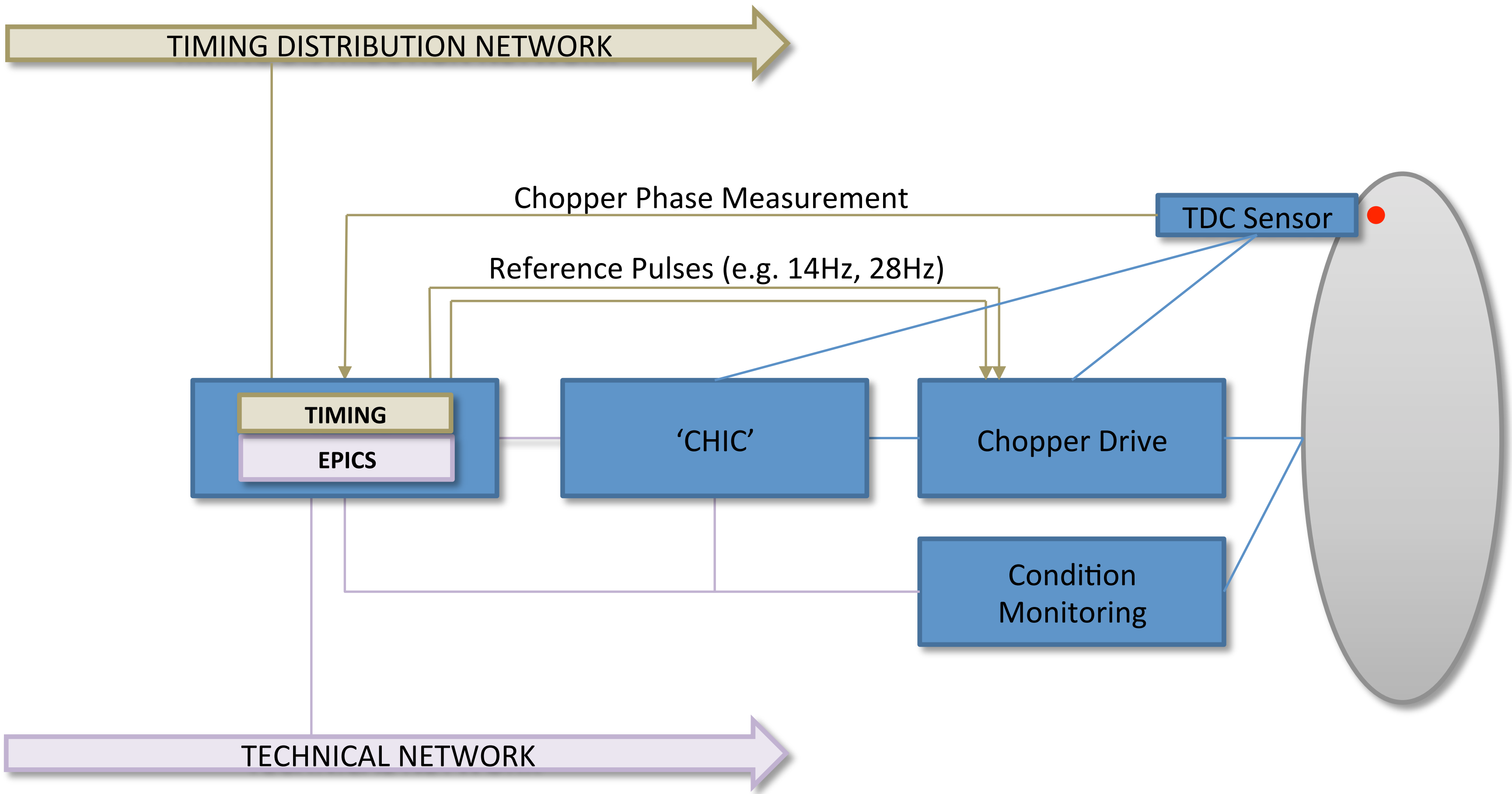
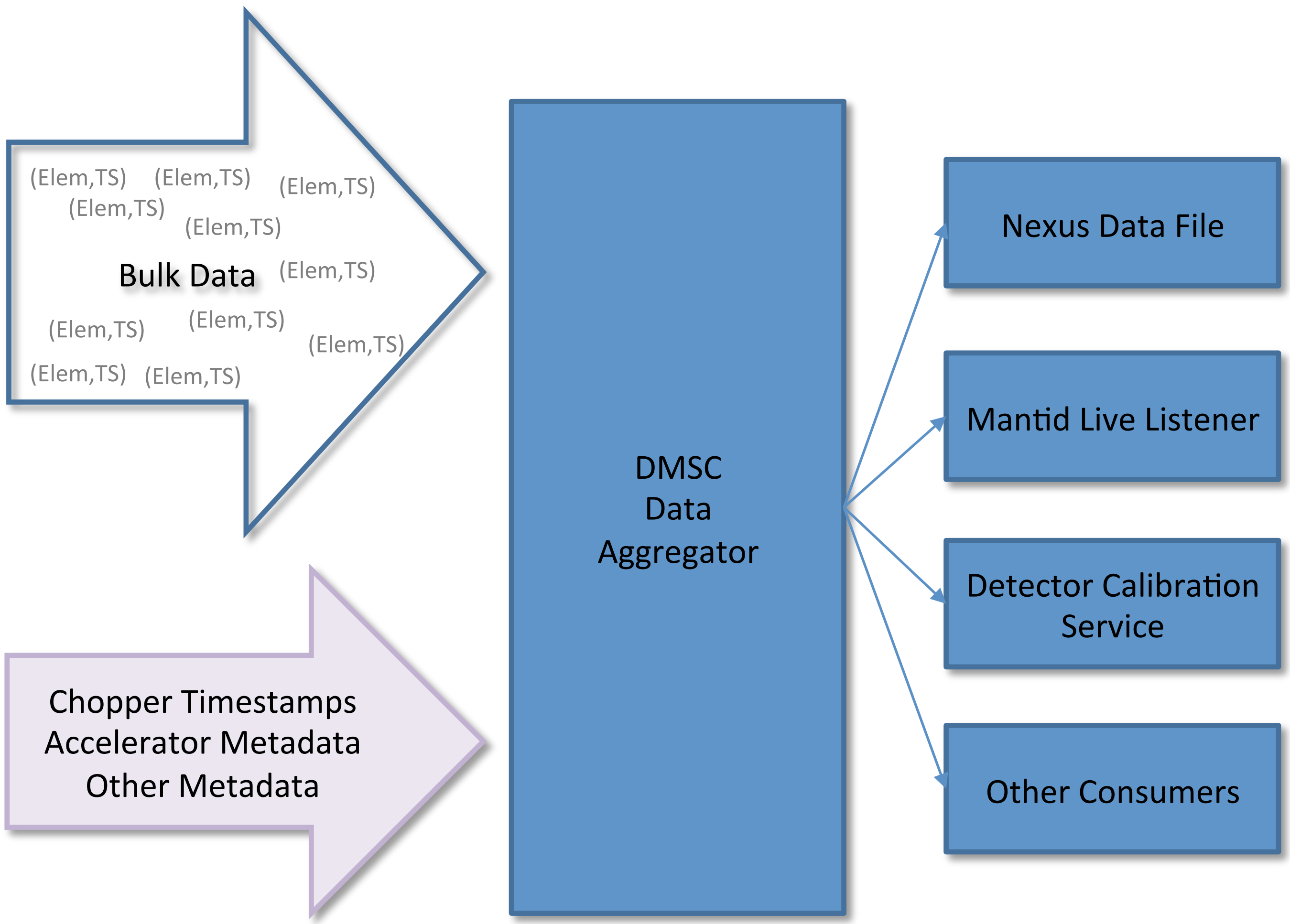


Data Aggregator



The End

Questions?