Trigger System

16 August 2001

Stanford Linear Accelerator Center
Stanford CA

Trigger Functions

- What does it do?
  - Accepts and conditions low level logic signals.
    - Alignment
    - Stretching
  - Combines low level logic signals.
    - Combinations are more useful.
  - Produces trigger decisions (Trigger Requests/Acknowledge).
  - Imposes dead time constraints.
    - Can't trigger the instrument if it is not prepared.
      - Involuntary.
  - Imposes prescales.
      - Voluntary.
  - Monitors live time and the performance of itself.

Relevant Documents

LAT-SS-284	Trigger Level 4 Subsystem Specification
LAT-SS-285	Dataflow Level 4 Subsystem Specification
LAT-SS-286	Global Trigger Conceptual Design

Trigger System Requirements (1)

Trigger Inputs	The TS shall accept trigger inputs from the ACD, CAL, TKR and Dataflow system
TKR Trigger Inputs	The TS shall accept 72 layer-OR inputs from the 36 TKR layers for each tower with a 2-bit location ID
CAL Trigger Inputs	The TS shall accept 16 CAL-LO and 16 CAL-HI layer-OR inputs from each tower.
ACD Trigger Inputs	The TS shall accept 18 ACD-LO (VETO) and 1 ACD-HI (CNO) inputs from each tower.
Dataflow Trigger Inputs	The TS shall accept trigger request inputs from the dataflow system.
Processing of Trigger Inputs	
Stretching	The TS shall stretch the trigger inputs to yield pulses between 200 nsecs and 1000nsecs in 50 nsec increments.
Alignment	The TS shall align the trigger inputs to within 50 nsecs (TBR).
Enable/Disable	The TS shall disable or enable each trigger input individually by configuration.

Trigger System Requirements (2)

Trigger Primitives	
ACD Trigger Primitives	
Tower Veto	The TS shall generate 16 tower-specific trigger primitives form subsets of the ACD-LO signals
One or more ACD-LO	The TS shall generate 5 trigger primitives defined as 1 or more ACD-LO active in each of the 5 (4 and 1 top) ACD planes.
Two or more ACD-LO	The TS shall generate 5 trigger primitives defined as 2 or more ACD-LO active in each of the 5 (4 and 1 top) ACD planes.
Three or more ACD-LO	The TS shall generate 5 trigger primitives defined as 3 or more ACD-LO active in each of the 5 (4 and 1 top) ACD planes.
Top ACD-HI	The TS shall generate 1 trigger primitive defined as 1 or more ACD-HI acitve in the top tiles.
Side ACD-HI	The TS shall generate 1 trigger primitive defined as 1 or more ACD-HI active in the side tiles
Coincidence ACD-LO	The TS shall generate 2 trigger primitives, one for the x and one for the y orientation, defined as 1 or more ACD-LO active in one plane and 2 or more ACD-LO active in the opposite plane.

Trigger System Requirements (3)

CAL Trigger Primitives	
CAL-LO	The TS shall generate 1 trigger primitive defined as 1 or more CAL-LO active.
CAL-3-in-a-row	The TS shall generate 1 trigger primitive defined as 1 CAL-HI layer-OR active in each of three consecutive layers in any tower.
TKR Trigger Primitives	
TKR-3-in-a-row	The TS shall generate 1 trigger primitive defined as 1 TKR layer-OR active in each of three consecutive tower x and y layers (total of 6 layers) with 2 bits of location ID indicating the start of the track.
Combinations of Sub-system Trigger Primitives	
TKR-ACD Primitives	The TS shall generate 1 primitive defined as one tower or more having a TKR-3-in-a-row signal being vetoed by the shadowing ACD tiles (tower specific veto).

Trigger System Requirements (4)

Triggers	
Periodic Trigger	The TS shall generate 4 (TBR) periodic trigger inputs with a frequency between 0.1Hz (TBR) and 50KHz (TBR) with a resolution of 50 nsecs (TBR).
Generation of Named Triggers	The TS shall produce named triggers by combinatorial logic (configurable, TBR) or the trigger primitives and the periodic and dataflow trigger inputs.
Prescaling, Occurrence Based	The TS shall be able to prescale up to 1 in 64,000 each named trigger. (Prescaler decrements with each trigger.)
Prescaling, Time-Based (TBR)	The TS shall be able to prescale by time-out each named trigger in the range of 0.1 Hz to 50KHz (Prescaler decrements by clock.)

Trigger System Requirements (5)

Trigger Acknowledge	
Notification	
ACD Notification	**The TS shall distribute a trigger acknowledge signal to the ACD with two bits, one indicating whether to zero-suppress or not the PHA readout and one whether to readout both the PHA ranges or not.**
CAL Notification	**The TS shall distribute a trigger acknowledge signal to the CAL sub-system with two bits, one indicating whether to readout all or only one ADC ranges and one whether to zero-suppress the data or not.**
TKR Notification	**The TS shall distribute a trigger acknowledge signal to the TKR system.**
Dataflow Notification	**The TS shall distribute a trigger acknowledge signal to the Dataflow sub-system indicating all the bits usedd for sub-system notification plus: a start-run type bit, a stop-run bit, additional CPU-initiated trigger type bits (TBR), the destination event-processor for the event (TBR), calibration-trigger indicator bit, and possibly event ID bits (TBR).**

Trigger System Requirements (6)

Latency Delay	The TS shall be able to deliver the Trigger Acknowledge signal to each sub-system within 1.3 usec (TBR) from the time the trigger inputs are received.
Latency Adjustment	The TS shall be able to adjust the Trigger Acknowledge signal to each sub-system independently from 0 nsec to 10 usec in steps of 50 nsec.
Jitter	The TS shall add no more than 100 nsec to the trigger jitter.
Live-Dead Time	
L1 Trigger Dead-time Contribution	The TS shall be able to generate Trigger Acknowledge signals with a minimum spacing down to the larger of: minimum dead-time imposed by the calorimeter system, or minimum dead-time imposed by the tracker system or 5 usec.
Inhibit	The TS shall inhibit the issuance of a trigger acknowledge if a name triggered requested and the trigger throttel input from dataflow is asserted.
Trigger Live Time Measurement	The trigger system shall measure the livetime between each event candidate sent to the ground to a precision of better than 500 nsec (TBR).
Trigger Event Dead Time Cause	The trigger system shall provide output data to monitor contributions to the dead-time.
Trigger Event Deadtime Reporting	The trigger system shall report dead-time associated with an event to better than 500 nsec.

Trigger System Requirements (7)

Calibration Trigger	
Generation of TACK	The TS shall issue a trigger acknowledge with trigger message in respons to a calibration strobe command issued to any sub-system.
Delay Of TACK	The TS shall be able to delay the TACK with respect to the calibration strobe command from 0 nsec to 15 usec (TBR) in steps of 50 nsec.
Dataflow Configuration and Event Data	
Configuration by Dataflow	The TS shall be configurable by the dataflow system.
Readback by Dataflow	The configuration of the TS shall be non-destructively readable by dataflow.
Event Data	The TS shall provide, for each trigger acknowledge dispensed, a contribution to the event data.
Trigger Inputs	The TS shall include the state of all trigger inputs in the event data.
Trigger Primitives	The TS shall include the state of all sub-system trigger primitives in the event data

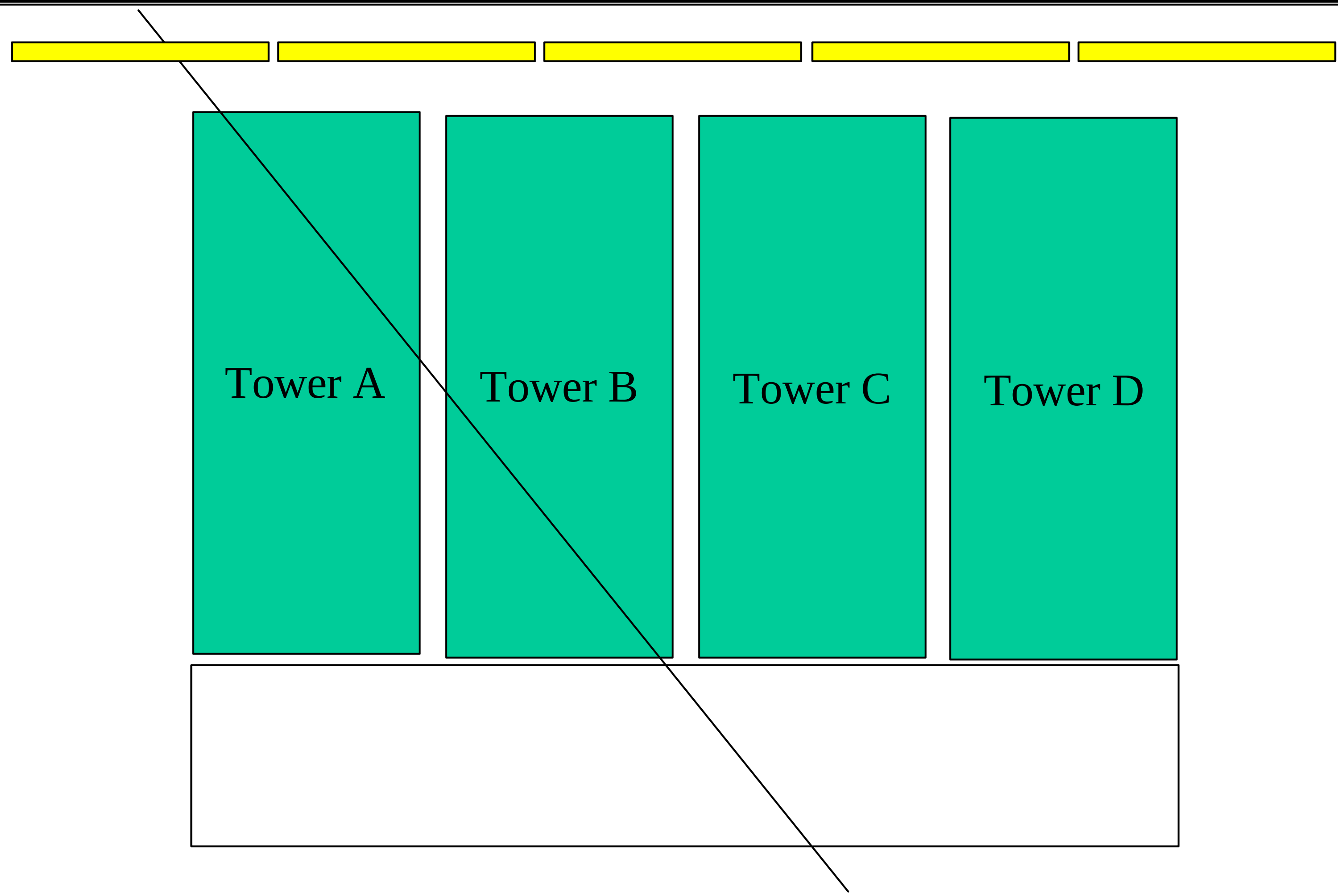
Trigger System Requirements (8)

Trigger Name	The TS shall include the names of all the triggers in the event data.
Trigger Outputs	The TS shall include the trigger message in the event data.
Live-Time Counter	The TS shall include the state of all live-time counters in the event data.

Why a Global Trigger?

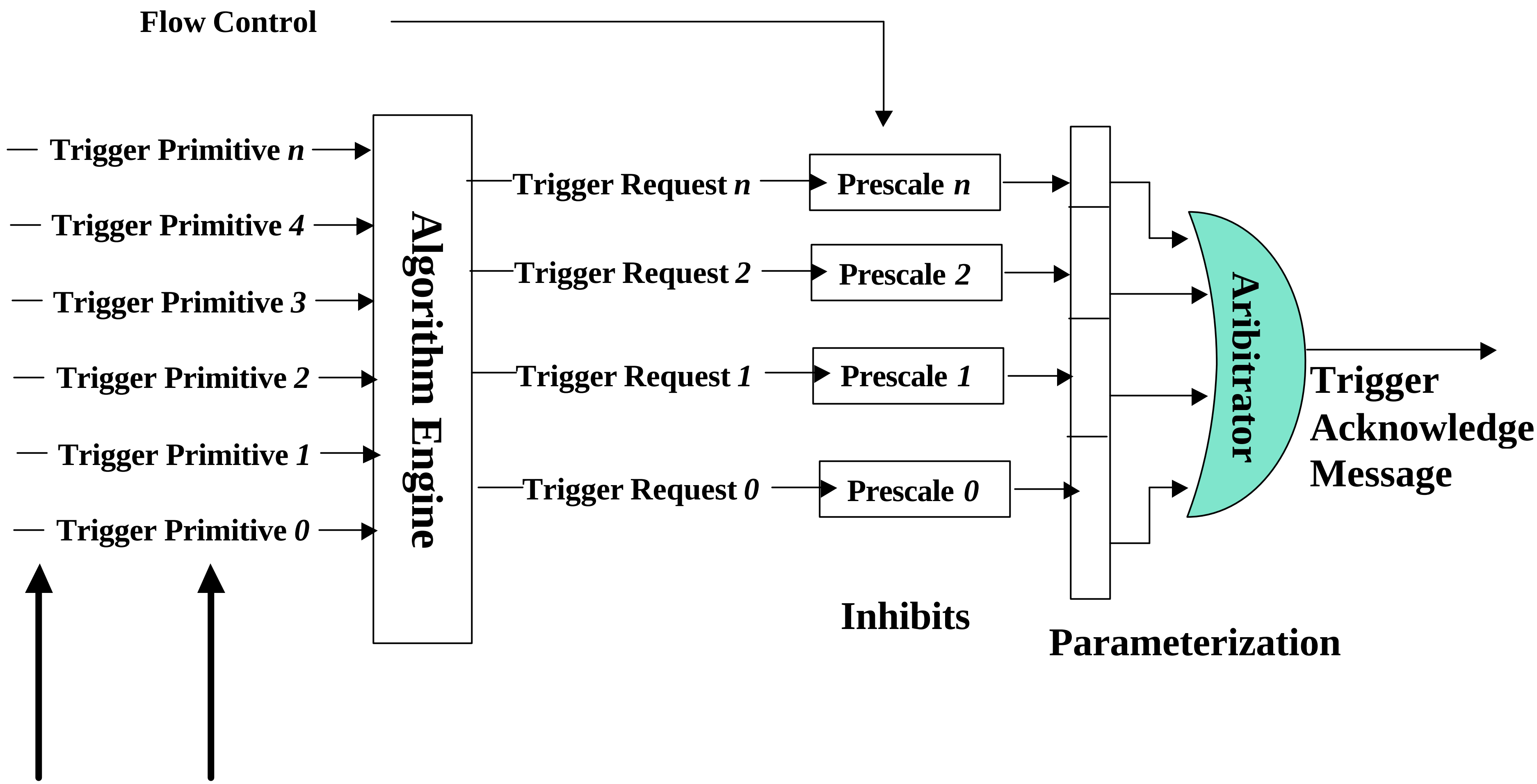
- **Physical Reason**
  - **These functions demand many signals be brought together.**
- **Logical Reason**
  - **Local Tower Trigger does not give the necessary rejection.**
    - **30% reduction with a local trigger.**
    - **85% reduction with a global trigger.**
- **Goal,**
  - **Provide flexibility.**
    - **Get the most out of the LAT in a variety of conditions.**

Why a Global Trigger ?



Local Trigger would not veto this track.
A says no, but B says yes, therefore trigger.

GLT Block Diagram



Front-End Trigger Signals

- Front-End provides the following low-level signals:
  - ACD, LO and HI discriminator signals.
    - LO is efficient for minimum ionizing particles.
    - HI selects CNO events.
  - CAL, LO and HI discriminator signals.
    - LO is used as monitor trigger for TKR.
    - HI is used for very high energy (>10GeV) events.
  - TKR, Layer OR.

- Inputs can be disabled or by-passed.
- Signals are combined at the tower level to make primitives.
  - ACD has 33 primitives.
  - CAL has 2/tower.
  - TKR has 1 2-bit numbers/tower.

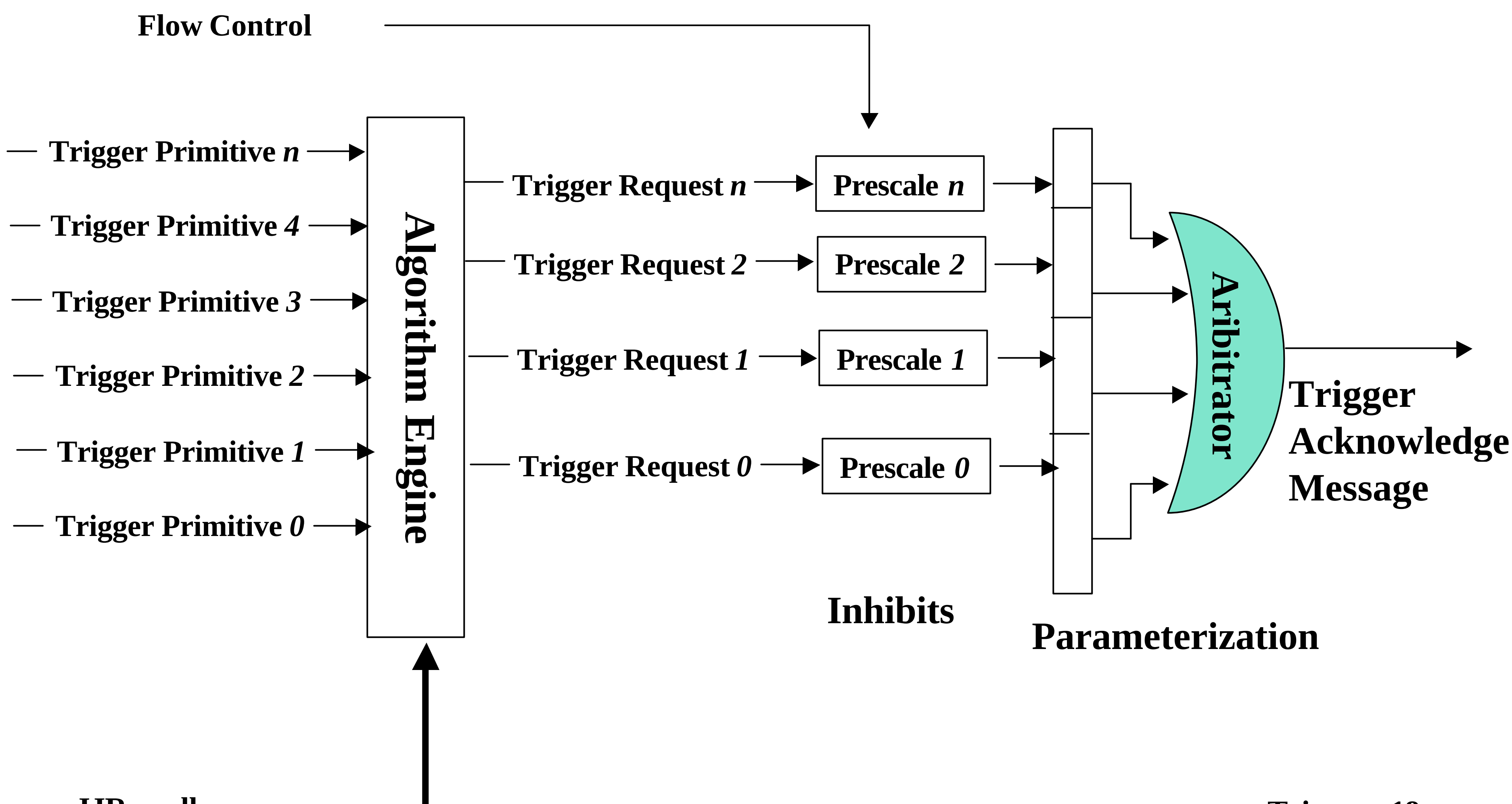
Trigger Primitives - Inventory

- ACD Primitives – 33:
  - 16 tower vetoes.
  - 1, OR of HI discriminators from top tiles.
  - 1, OR of HI discriminators from side tiles.
  - 15 signals:
    - OR of > 1 tile/face (5 faces, LO discriminator).
    - OR of > 2 tile/face (5 faces, LO discriminator).
    - OR of > 3 tile/face (5 faces, LO discriminator).
- CAL – 2 / tower:
  - OR of LO discriminator.
  - 3-in-a-row coincidence of HI discriminator layer ORs.
- TKR – 2 bits / tower:
  - 3-in-a-row coincidence of layer ORs.
  - 2 bits give the information on starting Z-position.

Trigger Primitives – Wires

- **The number of wires to carry the primitives is predicated on**
  - **4 wires for each signal:**
    - **x2, carried on LVDS differential pair.**
    - **x2, redundancy.**
- **The total count is 388 wires:**
  - **Towers: 4 signals * 4 wires/signal * 16 towers = 256 wires**
  - **ACD : 33 signals * 4 wires/signal = 132 wires**

GLT Block Diagram



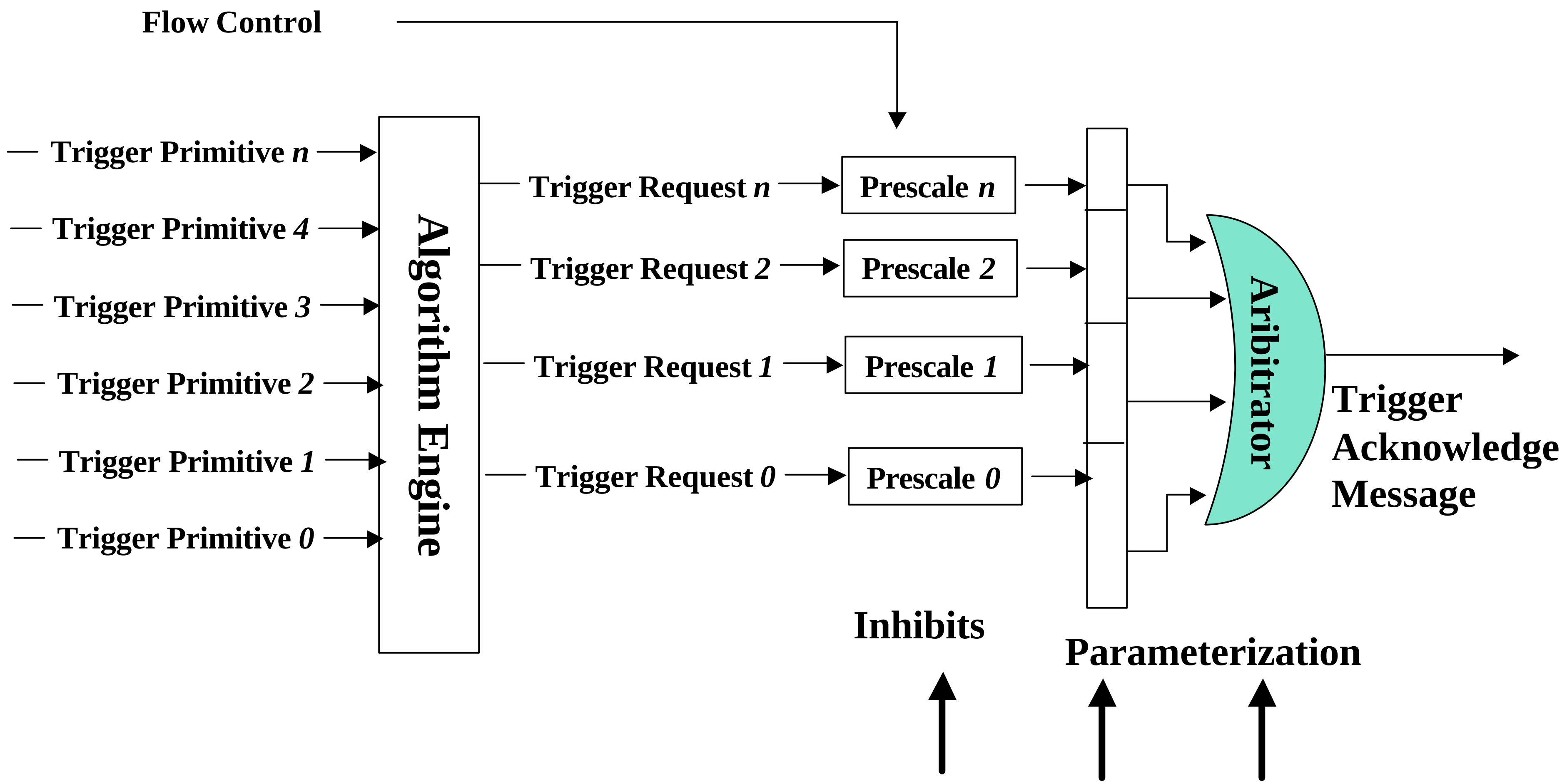
Algorithm Engine

- **Algorithm Engines maps Trigger Primitives to Trigger Requests.**
- **Trigger will first reduce the number of Trigger Primitives.**
  - **Makes a more manageable number of Trigger Primitives**
    - **Combine each TKR 3-in-a-row with the OR of the LO discriminator from a shadowing collection of ACD tiles.**
      - **Apply a prescale to each of these 16 signals (TBD), then**
      - **OR together.**
    - **Same applies to the bare 3-in-a-row (1 signal).**
    - **Reduces the 32 primitives to 2.**

Algorithm Engine – Inputs/Outputs

- Refined Trigger Primitives:
  - TKR 3-in-a-row
  - TKR 3-in-a-row, not vetoed
  - CAL LO
  - CAL HI
  - ACD HI (CNO)
  - ACD Splash Veto
  - CPU Request (supports calibration and random triggering)
  - External Trigger (supports testing)
- Small number of primitives admits to a lookup table implementation.
  - Address is formed from the state of the primitives.
  - Contents is a list of the active Trigger Requests.

GLT Block Diagram



Trigger Request -> Trigger Acknowledge

- Trigger Request becomes an Acknowledge, if not inhibited by
  - The global flow-control signal.
  - Its prescaler.
    - Occurrence based, decremented by Trigger Request.
    - Time based, decremented by clock.

- Trigger Acknowledge Message carries the following information.
  - How to read out the front-end.
    - Disable zero-suppress/auto-ranging for CAL/ACD (4 bits).

- A Trigger Acknowledge Message may carry:
  - Event Identification.
  - Dispatch Information.
    - Directs event to a processing CPU.

Trigger Acknowledge Path

- Trigger Accept Message is transported to the front-ends by a dedicated wire.
  - Avoids arbitration problems.
- FE saves/latches its current data upon receipt of Trigger Accept.
  - Message arrives < 2 usec after event T0.
  - Message arrives with low jitter, ~ ± 250 nsecs.
  - The CAL and ACD have no internal buffering, so data moves directly output FIFOs.
  - TKR has buffering, so after latching the data, some form of the trigger message must be queued to control the readout.

Dead Time Monitoring

- Global Trigger monitors dead-time.
  - Two non-resetting counters are maintained:
    - A clock.
    - A clock gated by the flow-control signal.
  - Recorded with every event.
    - Differences give the dead-time between the events.
  - The monitoring of dead-time must include
    - Contribution due to the flow-control signal
    - Contribution due to the trigger itself.

Trigger Data

- GLT contributes a data block to the event.
- Two basic purposes
  - Dead time monitoring
    - Aforementioned counters.
    - Dead time cause
  - Integrity and performance monitoring
    - Includes
      - State of trigger inputs
      - State of trigger primitives
      - Trigger Requests
      - Trigger Message
      - Counters (TBD)