Dataflow System

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Level 4 Requirement (1)

Item	Description	Origin	Verification	Test Type	Metric
6.3.8 ACD Not Zero-Suppressed Readout Dead-Time	The DFS shall be able to read out the instrument average, not zero-suppressed PHA data at 50 Hz (TBR) without adding to the average instrument dead-time, assumed to be 20 µsec after a trigger.	DAQlevel4_14	T	P	Ti
6.4.1 CAL Readout Path	The DFS shall read out event data from 4 Analog Front-End Electronics (AFEE) Boards for each CAL module.	DAQlevel4_14	T	F	P/F
6.4.2 CAL Readout Data	The DFS shall read out data patterns as defined in the CAL Electronics Interface Document.	DAQlevel4_14	T	F	P/F
6.4.3 CAL Data Merging	The DFS shall correlate and merge the measurements from each end of all CsI logs.	DAQlevel4_14	T	F	P/F
6.4.4 Single Range and Four Range Readout	The DFS shall read out the data from a single gain range or four gain ranges per log-end determined by the trigger type received from the trigger system.	DAQlevel4_14	T	F	P/F
6.4.5.1 Zero Suppression Mode	The DFS shall zero-suppress the event data depending on the state of the log-accept bit and the trigger type.	DAQlevel4_14	T	F	P/F
6.4.5.2 Zero Suppression Criteria	The DFS shall keep the data of both sides of a log when at least one of the log-end log-accept bits is set or when the trigger type disables zero-suppression.	DAQlevel4_14	T	F	P/F
6.4.5.3 Zero Suppression Log-End Disable	The DFS shall zero-suppress the data based on the state of only one of the two log-accept bits.	DAQlevel4_14	T	F	P/F
6.4.7 CAL Zero-Suppressed Single-Range Readout Dead-Time	The DFS shall be able to read out the instrument average, zero-suppressed single-gain range data at 10 kHz without adding to the average instrument dead-time, assumed to be 20 µsec after a trigger.	DAQlevel4_14	T	P	Ti

Level 4 Requirement (2)

Item	Description	Origin	Verification	Test Type	Metric
6.4.8 CAL Zero-Suppressed Four-Range Readout Dead-Time	The DFS shall be able to read out the instrument average, zero-suppressed four-gain range data at 50 Hz (TBR) without adding to the average instrument dead-time, assumed to be 20 µsec after a trigger.	DAQlevel4_14	T	P	Ti
6.4.9 CAL Not Zero-Suppressed Single-Range or Four-Range Readout Dead-Time	The DFS shall be able to read out the instrument average, not zero-suppressed single or four-gain range data at 1 Hz (TBR) without adding to the average instrument dead-time, assumed to be 20 µsec per trigger.	DAQlevel4_14	T	P	Ti
6.5.1 TKR Dual Readout	The DFS shall read out each layer of the TKR from a dual cable interface with the split between GLAST TKR Front End (GTFE) ASICs within any layer determined by command.	DAQlevel4_14	T	F	P/F
6.5.2 TKR Single Cable Readout	Upon command, the DFS shall be able to read out an entire layer through either one of the dual readout cables.	DAQlevel4_14	T	F	P/F
6.5.3 TKR Readout Event Data Content for Each Layer	The DFS shall read out TKR event data as defined in the TKR Electronics Interface Document.	DAQlevel4_14	T	F	P/F
6.5.4 TKR Readout Event Data Content for Each TKR Module	The DFS shall read out a total number of 64 hits (32 hits per layer controller) for 30 (TBR) layers and 128 hits (64 per layer controller) for 6 (TBR) layers for a total of 2,688 hits for each TKR module.	DAQlevel4_14	T	F	P/F
6.5.5 TKR Readout Calibration Data Content	The DFS shall read out a total number of 128 hits (64 hits per controller) for a maximum of 10 (TBR) layers for a total of 2,652 hits for each TKR module.	DAQlevel4_14	T	F	P/F
6.5.6 TKR Dead-Time	The DFS readout of the TKR shall have sufficient event buffering that dead-time due to readout becomes significant (>1%) only when the readout bandwidth is saturated. This implies that it must be possible to keep the TKR trigger live during readout.	DAQlevel4_14	T	F	P/F

Level 4 Requirement (3)

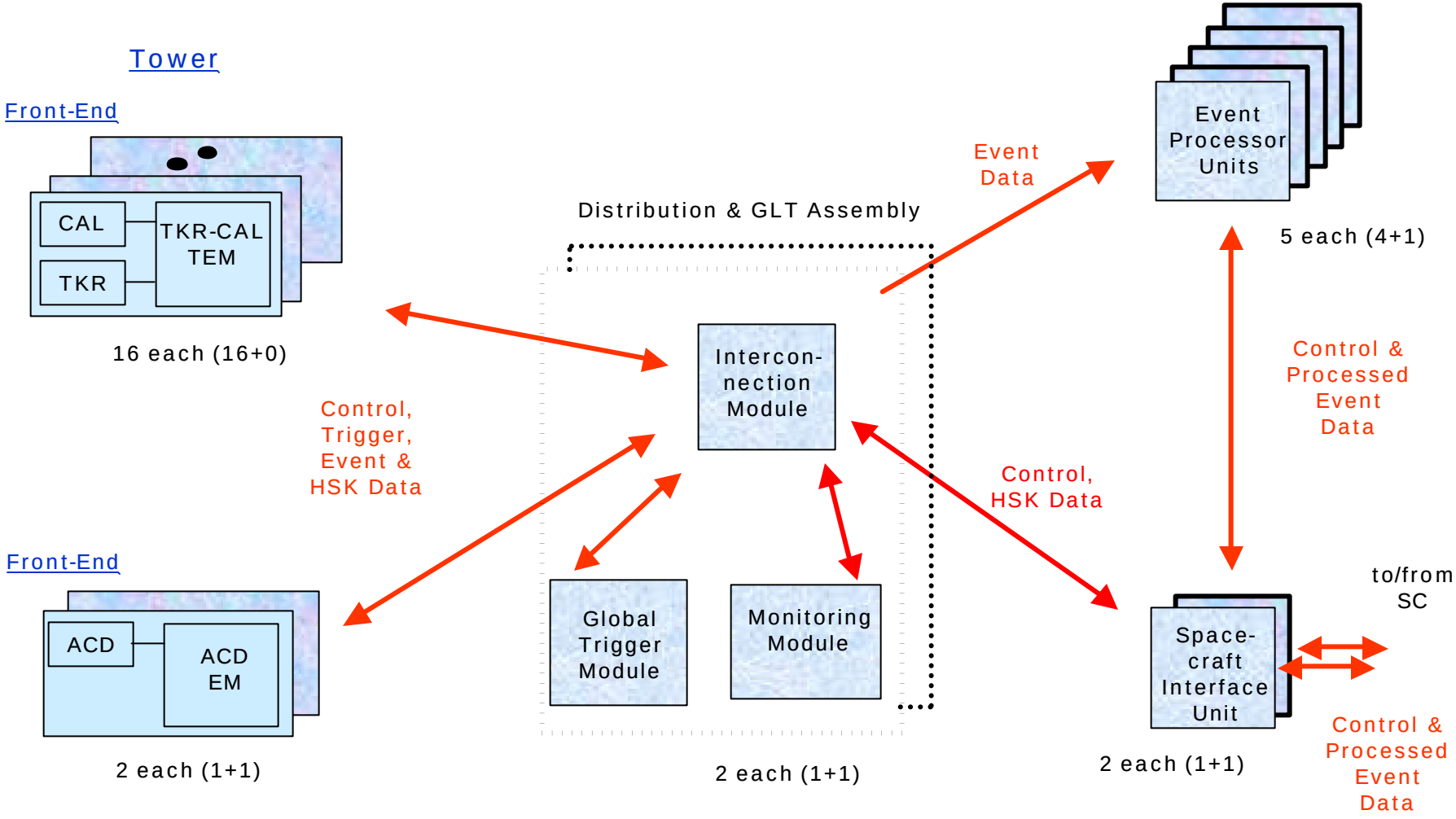
Item	Description	Origin	Verification	Test Type	Metric
6.5.7 TKR Hit Number	The DFS shall read out the TKR assuming 196 hits orbit average and 226 hits orbit maximum.	DAQlevel4_14	T	F	P/F
6.5.8 TKR Readout Dead-Time	The DFS shall be able to read out the instrument average TKR data at 10 kHz without adding to the average instrument dead-time, assumed to be 20 µsec after a trigger.	DAQlevel4_14	T	P	Ti
6.6.1 Time and Number Event Data	The DFS shall read out the trigger time and trigger number for each event.	DAQlevel4_14	T	F	P/F
6.6.2 ACD Trigger Event Data	There shall be no contribution from the ACD to the tower trigger event data.	DAQlevel4_14	T	F	P/F
6.6.3 CAL Trigger Event Data	The DFS shall read out trigger event data generated by the trigger CAL primitive logic.	DAQlevel4_14	T	F	P/F
6.6.4 TKR Trigger Event Data	The DFS shall read out trigger event data generated by the trigger TKR primitive logic. The data consists of the trigger inputs from the TKR layers, consisting of 36 Layer-Or signals (each generated by a logical OR operation of the two redundant cable signals).	DAQlevel4_14	T	F	P/F
6.6.5 Global Trigger Event Data	The DFS shall read out trigger event data generated by the Global trigger logic.	DAQlevel4_14	T	F	P/F
6.6.6 Trigger Event Readout Dead-Time	The DFS shall be able to read out the instrument trigger data at 10 kHz without adding to the average instrument dead-time, assumed to be 20 µsec after a trigger.	DAQlevel4_14	T	P	Ti
6.7 Event Data Bit Rates	The DFS shall read out events at a rate determined by the average and maximum trigger rates and the readout mode of each element.	DAQlevel4_14	T	P	Ti, DR

Level 4 Requirement (4)

Item	Description	Origin	Verification	Test Type	Metric
6.1 Event Flow Rate	The Dataflow System (DFS) shall read out the event data at a rate determined by the Trigger Acknowledge (TACK)	DAQlevel4_14	T	P	Ti
6.2 DFS Contribution to Dead Time	The DFS readout shall not increase the dead time of the instrument more than 5% when the TACK rate is at maximum TACK rate and nor more than 1% when the TACK rate is 60% of maximum.	DAQlevel4_14	T	P	Ti
6.3 Anti-Coincidence Detector (ACD) Event Data	The DFS shall read out the ACD event data.	DAQlevel4_14	T	F	P/F
6.3.1 ACD Readout Data	The DFS shall read out event data from 6 primary and 6 secondary 18-channel front-end boards.	DAQlevel4_14	T	F	P/F
6.3.2 ACD Veto Word Readout	The DFS shall read out 105 primary and 105 secondary 105 ACD Low (Veto) bits for a total of 210 bits for each event.	DAQlevel4_14	T	F	P/F
6.3.3 ACD Carbon-Nitrogen-Oxygen (CNO) Word Readout	The DFS shall read out 6 primary and 6 secondary ACD High (CNO) bits for a total of 12 bits for each event. (One bit from each front-end board).	DAQlevel4_14	T	F	P/F
6.3.4 ACD Pulse Height Analysis (PHA) Readout	The DFS shall be able to read out an instrument total of 105 primary and 105 secondary 12-bit PHA values (with a 5-bit address from each front-end board).	DAQlevel4_14	T	F	P/F
6.3.5 ACD Readout Data Content	The DFS shall read out ACD event data as defined in the ACD Electronics Interface Document.	DAQlevel4_14	T	F	P/F
6.3.6 ACD Average LAT Event Size	The DFS shall assume an average of 10 (TBR) tiles of PHA information per event.	DAQlevel4_14	T	F	P/F
6.3.7 ACD Zero-Suppressed Readout Dead-Time	The DFS shall be able to read out the instrument average, zero-suppressed PHA data at 10 kHz without adding to the average instrument dead-time, assumed to be 20 µsec after a trigger.	DAQlevel4_14	T	P	Ti

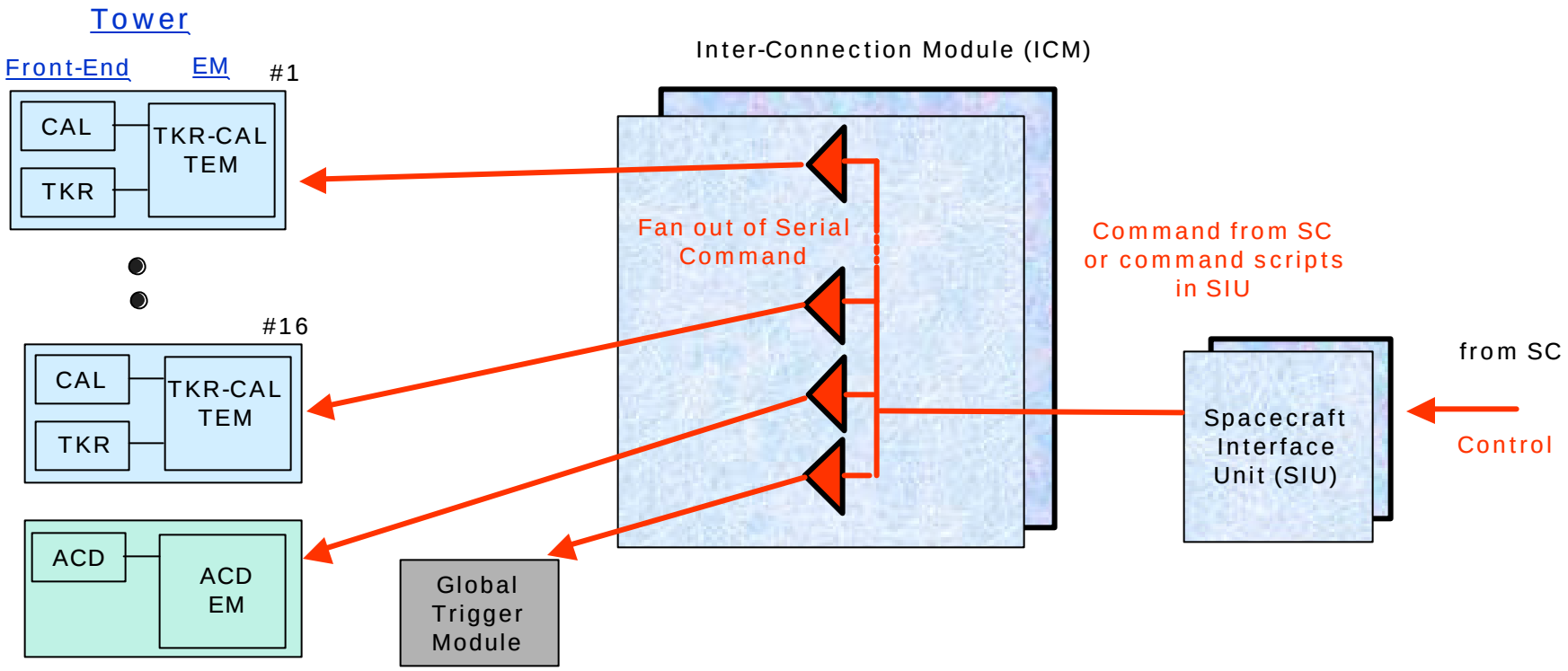
7 more pages, not shown here. See document for more

T&DF Architecture



* (1+1) = (1 Primary + 1 Secondary)

Commanding & Configuration



- **Serial Command is transmitted from SIU to ICM where it is fanned out (broadcast) to all electronics component, no logic to be configured on ICM for fan out**
- **Connecting via ICM saves cables –> see later**
- **Target decodes address in serial command to decide whether it should accept command**
- **Global Trigger looks just like an additional TEM**
- **No flow-control needed since configuration data cannot backup**

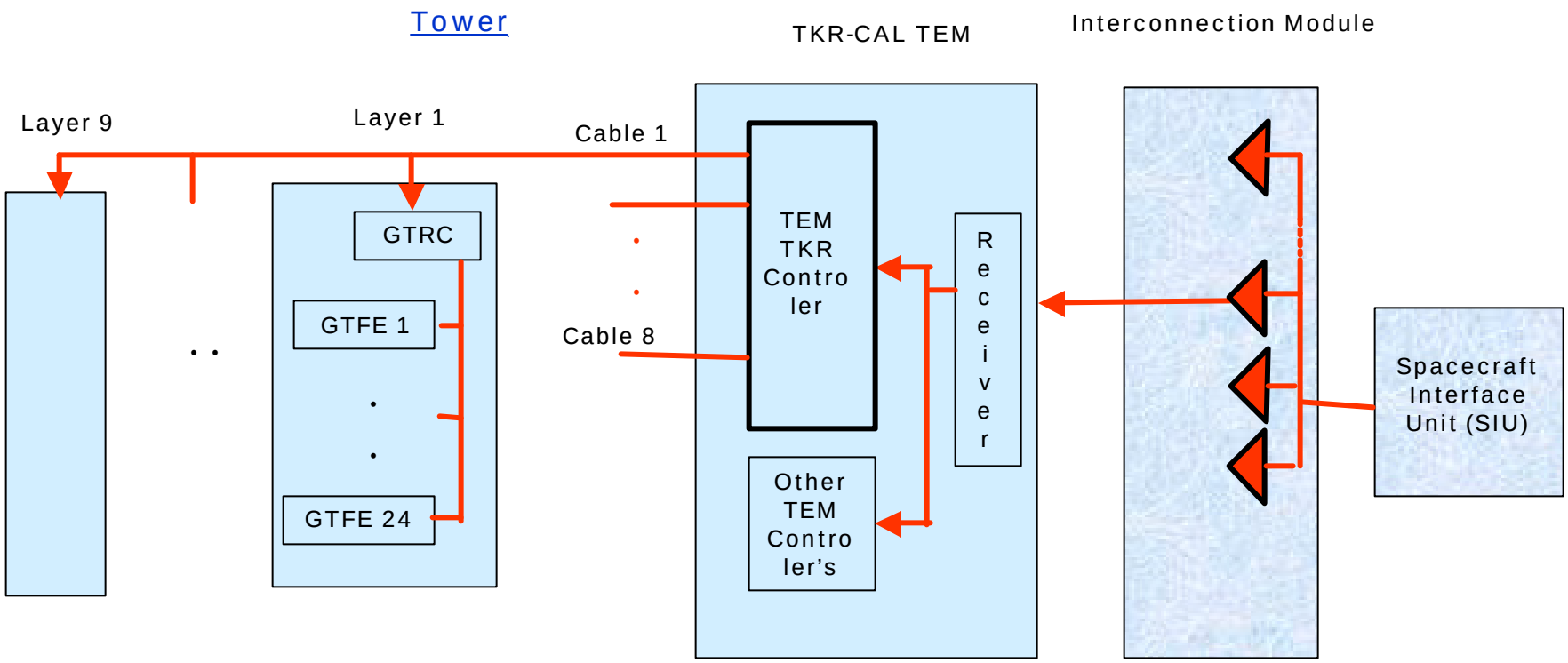
Serial Command Protocol

- Simple serial command protocol
  - Startbit
  - Address, each section with broadcast capability
    - Module Address, followed by
    - Sub-System Controller Address on Module, followed by
    - Cable Address of Sub-System followed by,
    - Address of layer on cable, followed by
    - Address of Front-end ASIC on layer
  - Function Code
  - Data Field
  - Parity bits after address/function and each 16-bit data-field
- Leading address bits are stripped in each decoding stage, command is either consumed or rest of command is forwarded to target

Serial Command

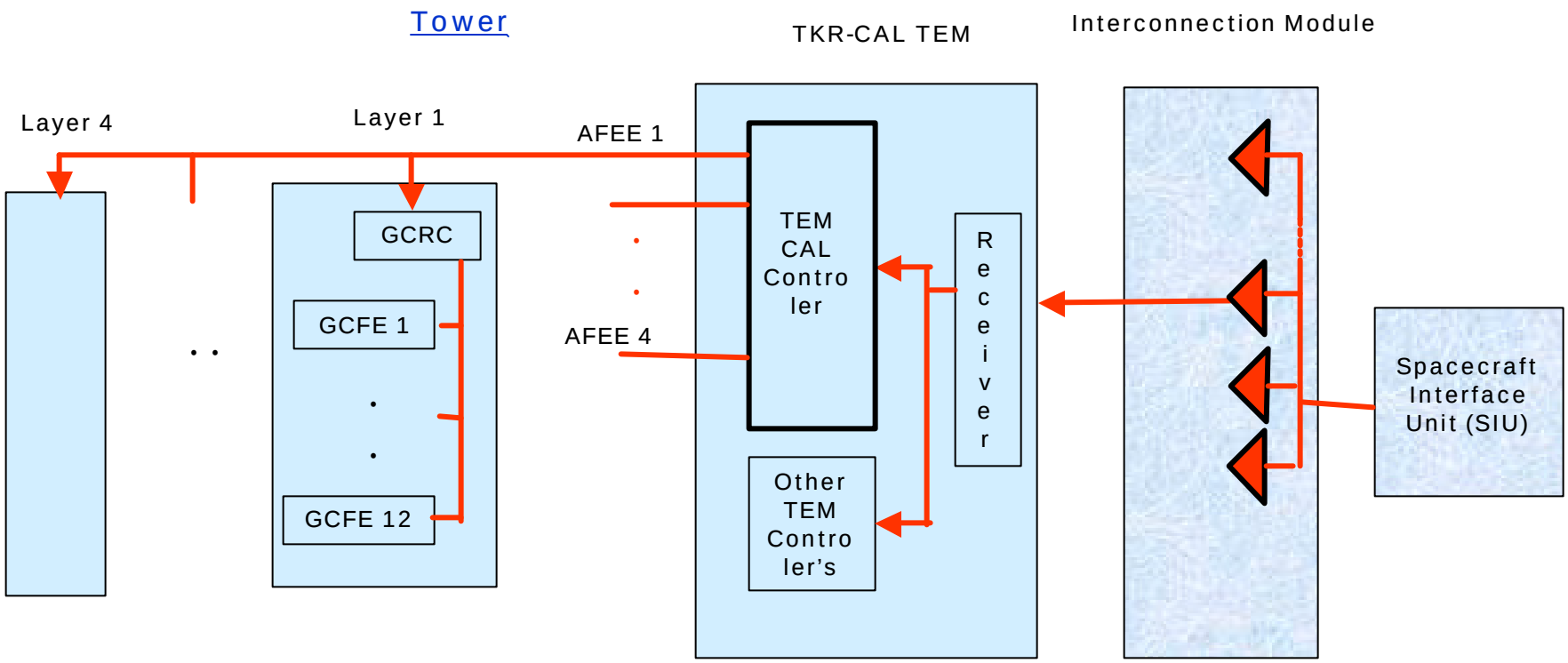
- Commands used to
  - write configuration/mode registers & DAC's
  - Reset/sync commands
  - Readback register content
  - Reset/latch/read low-rate science counters
  - Readback environmental data (T/V/I)
- Broadcast of commands used for
  - Common configuration
  - Event time stamp synchronization
  - Low-rate science (rate-counter) synchronization
- Effort to make all sub-systems uniform (see following slides), simplification of system hardware and software

TKR Commanding/Configuration



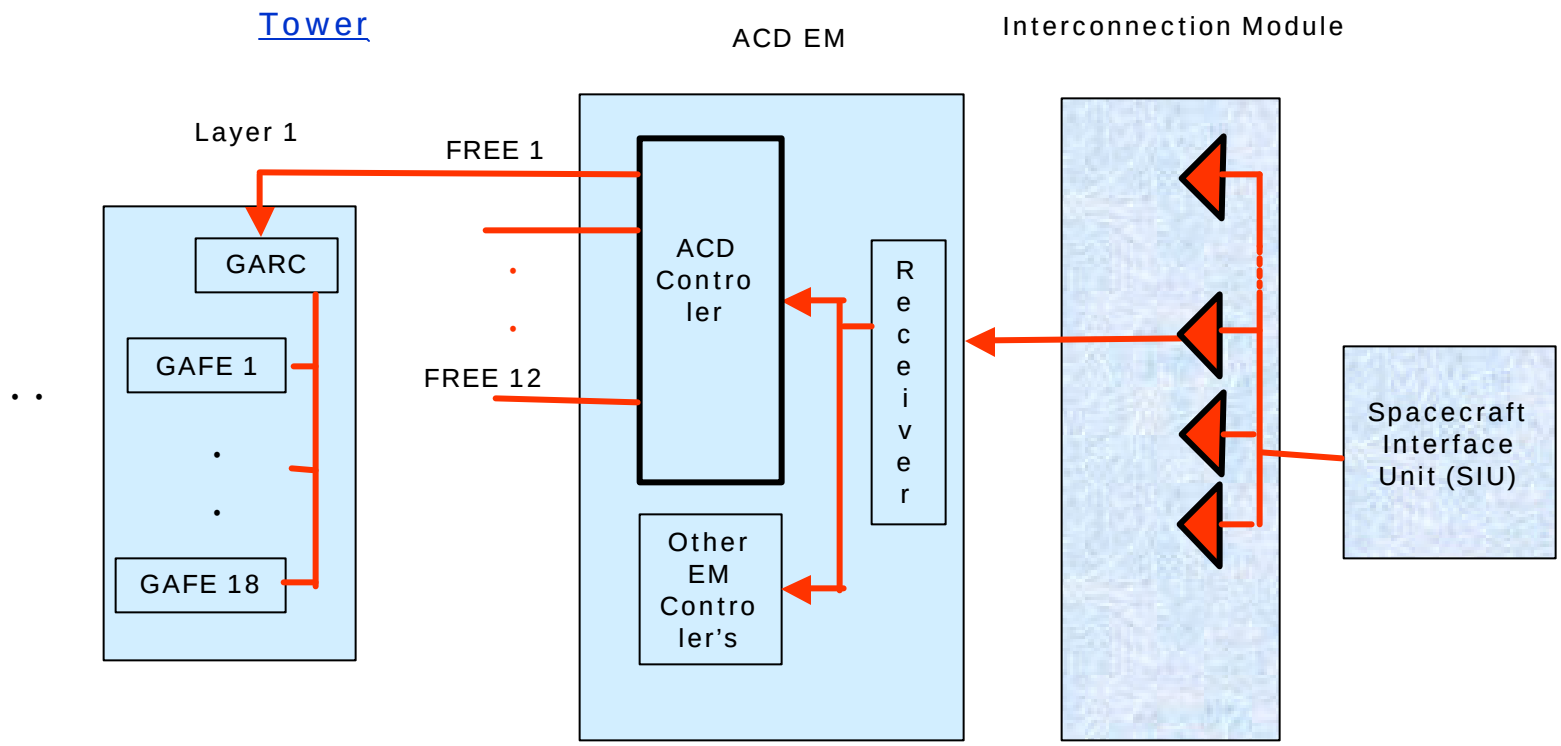
- **SIU-> ICM -> TEM Receiver (1 of 16 or all) -> TEM TKR Controller (or all controllers) -> Cable # (1 of 8 or all) -> Layer Readout Controller (GTRC) ASIC (1 of 9 or all) -> Front-End (GTFE) ASIC (1 of 24 or all)**

CAL Commanding/Configuration



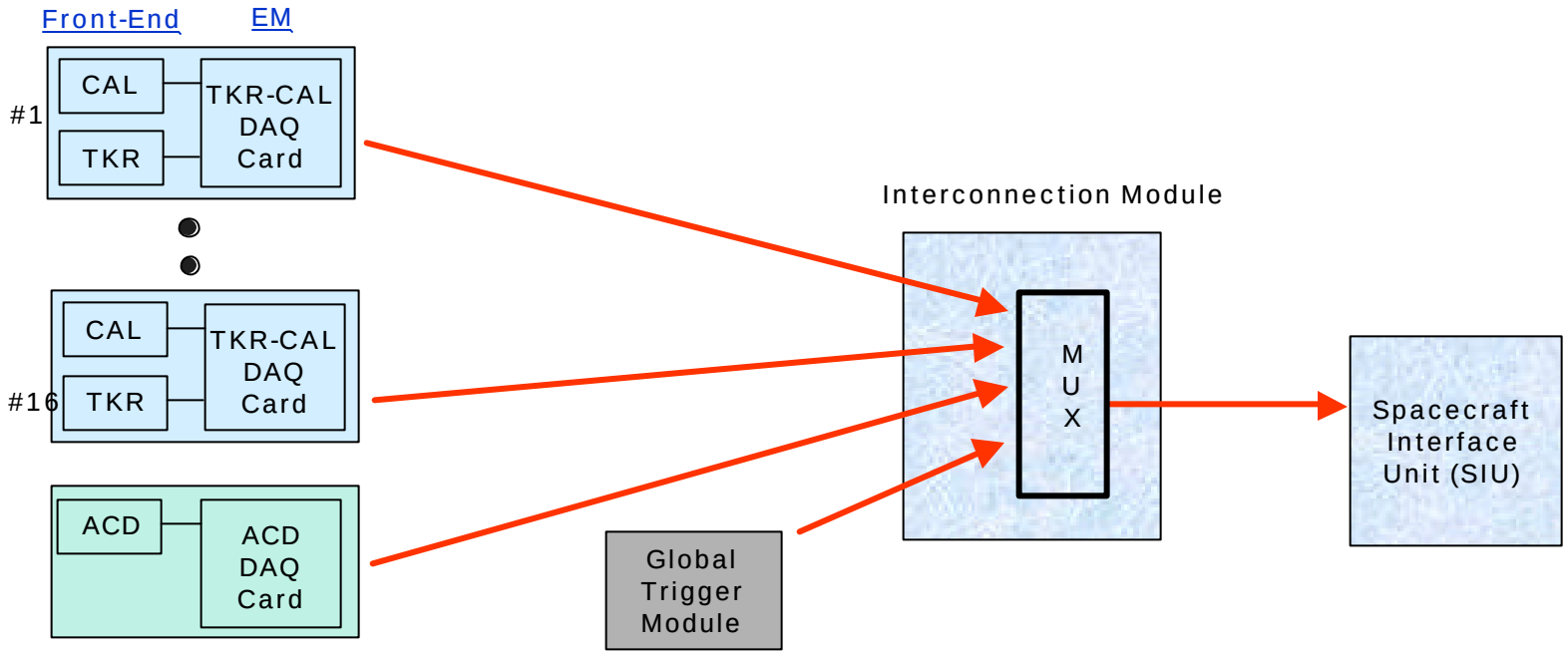
- **SIU-> ICM -> TEM Receiver (1 of 16 or all) -> TEM CAL Controller (or all controllers) -> AFEE-sideboard (1 of 4 or all) -> Layer Readout Controller (GCRC) ASIC (1 of 4 or all) -> Front-End (GCFE) ASIC (1 of 12 or all)**

ACD Commanding/Configuration



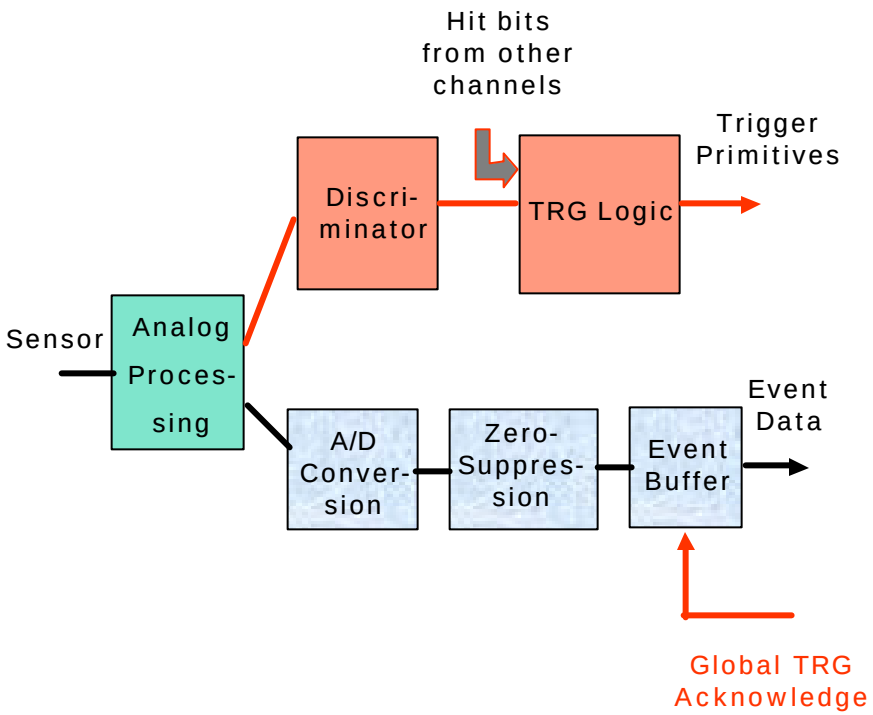
- **SIU-> ICM -> ACD EM Receiver (1 of 2 or all) -> EM ACD Controller (or all controllers) -> FREE (1 of 12 or all) -> FREE Readout Controller (GARC) ASIC -> Front-End (GAFE) ASIC (1 of 18 or all)**

Non-Event Data Readback

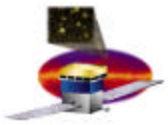


- **Non-Event Data is connected to ICM and sent to SIU via multiplexer (tbd) (configured by SIU)**
- **Saves cables/wires –> see later**
- **Only need one data receiver in SIU**
- **All registers must be capable of being read back non-destructively (no new write needed)**
- **Register read-back, low-rate science counter readback, environmental data readback via same wire**

Front-End Electronics



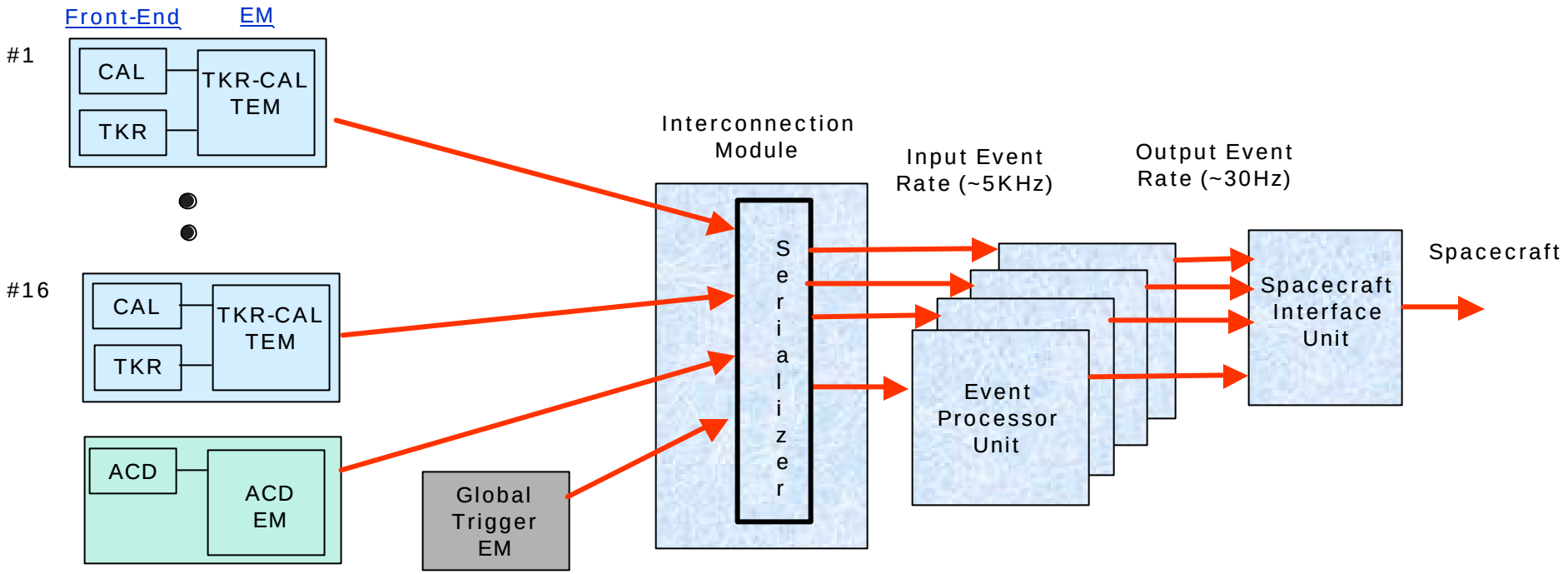
- CAL, TKR & ACD are front-end sub-systems, similar in architecture
- Signals from sensors are amplified & shaped
- Trigger: analog signals are discriminated and combined in front-end logic
- Global Trigger returns trigger acknowledge signal
- Data: analog signals are digitized, zero-suppressed , and buffered
- Each sub-system has one analog and one digital full-custom ASIC



Taking Data

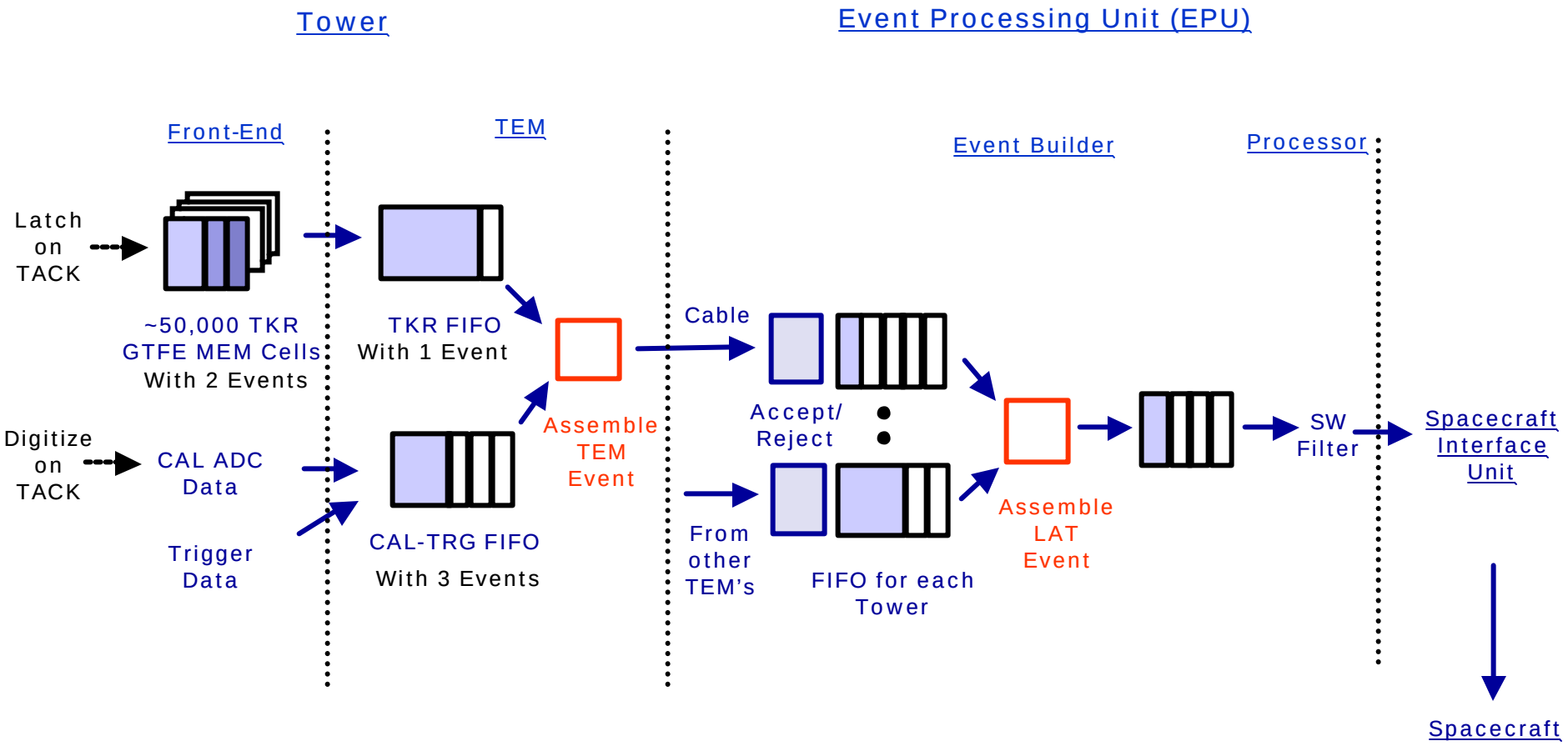
- Trigger signals (discriminator outputs) from each front-end systems are logically combined on TEM's/ACD EM to form trigger primitives
- Trigger primitives are logically combined on Global Trigger to generate Trigger Acknowledge Signal (TACK)
- TACK is sent back to front-end and event data is latched
- TACK has EPU destination bitmap in message
- Sub-system event data is sent to all Event Processor Units (EPU's) but only stored in EPU's with matching destination address (distribution of events among processors)
- Event filters in processors reduce rate and keep "interesting" events
- "Interesting" events are sent to processor in Spacecraft Interface Unit (SIU) and forwarded to solid-state recorder in spacecraft

Event Data Path



- Event Data is connected to ICM, fanned out, and sent to Event Processor Units (EPU)
- ICM saves cables/wires, possible use of UTMC Serializers –> see later
- All data is sent to all EPU's, EPU decides whether to accept/reject the event
- EPU has event-builder card and processor card
- Processed (filtered) events are forwarded to SIU and then to SC
- Event Data path is separate from non-event data path
- Global Trigger also generates event-data

Datapath & Building Events (1)



Datapath & Building Events (2)

- Trigger -> TKR Data latched in FE ASIC (4 buffers) -> Transferred to TEM FIFO
- Trigger -> CAL Data digitized and transferred to TEM CAL-TRG FIFO
- When a complete event from each sub-system (CAL, TRG, and TKR) is in TEM FIFO's:
  - TEM event is assembled and transferred to Event Builders (EB) of all Event Processor Units
- Event fragments from each Tower/ACD/GLT are put in EB FIFO's
- When a complete event from each Tower, ACD, GLT is in EB FIFO's:
  - LAT event is assembled and transferred to processor for filtering
  - Filtered events are transferred to SIU and then to spacecraft
- Transfer of data into TEM FIFO's and EB FIFO's is asynchronous
- All TEM and LAT event-fragments are time-ordered throughout the system by design (very important feature)
  - Event-builder is really only state-machine reading the oldest event-fragment from each FIFO and appending those fragments
- Full flow-control to prevent buffer overflow at all stages: back-pressure model

Electronics Calibration

- All electronics is tested and calibrated via injection of signals at front-end input and data readout via regular data path
  - Amplitude of signal is configured by programming front-end DAC's
  - Repetition rate of calibration strobe is programmable
  - Strobe command originates in processor and is distributed via regular command path
  - Global Trigger generates TACK to initiate readout of data
- Typical calibration loops over
  - DAC levels (software major loop) to get linearity, with
  - Number of strobes (software minor loop) to get noise
- No hardware loops needed in front-end systems

Environmental Monitoring

- Requirements in Level IV Dataflow Specifications document
- T's/V's/I's from sub-systems, local power-supply, and TEM are digitized on TEM and put in a data buffer together with digital status bits
- SIU commands TEM to read out data buffer on regular command line, readout frequency is programmed in SIU
- Data-buffer is transmitted to SIU via read-back data line
- Additional environmental sensors are read out via monitoring board to SIU
- There are T's,V's,I's which are connected directly to spacecraft to monitor LAT when LAT is powered off

Low-Rate Science

- Requirements in Level IV Dataflow Specifications document
- Rate-counters for diagnostics and science (tbr) on each TKR-CAL TEM, ACD EM, and GLT
- SIU commands rate-counters to reset
- SIU commands rate-counters to be latched
- SIU commands rate-counters to be read back to SIU
- Time-counter can be added to report time
- Rate-counters can be reset & latched synchronously across LAT, if desired, via regular command path
- Frequency programmed in SIU

Error Monitoring for Electrical Transmission and Event Building

- Transmission errors are detected via parity-bits in command and data protocol
- All registers written are read back non-destructively to verify content (~ 3 million configuration bits in front-ends alone)
- Acquisition of event fragments on TEM are checked via event number sent to e.g. TKR front-end and included as part of event data packets
- Both TEM FIFO's contain time-stamp and event number for each event fragment, all part of TEM-built event
- LAT event-builder compares all TEM/ACD-EM/GLT-event fragments, time-stamp, event number
- Error Handling -> Flight Software Presentation

Issues

- Required bandwidth between modules -> flight software presentation
- Cabling between modules -> mechanical presentation
- Number of connections -> mechanical presentation
- Possible reductions of wires through use of UTMC 54LVDS217/218 serializer/deserializer, 7-to-1 wire reduction
  - Transmitter
    - Input: 21 serial 20-Mbps CMOS signals
    - Output: 3 ~140-Mbps lvds signals + lvds clock
  - Receiver
    - Input: 3 ~140-Mbps lvds signals + ~140-MHz lvds clock
    - Output: 21 serial 20-Mbps CMOS signals + PLL recovered 20 MHz clock
  - Qualified parts available 11/2001 ($1200 each), pin-compatible with commercial National Semi part