Lessons Learned From Implementing Non-Standard Spacewire Cabling For Tacsat-4

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  – Long cables worked
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Our Configuration

• TacSat-4 was implemented in accordance with the ORS Phase III Bus Standards
  – Specified SpaceWire as high speed data interface
• The SpaceWire link on TacSat-4
  – From the Payload Data Handler (PDH) module to the Universal Interface Electronics (UIE)
  – PDH is on the bus side
  – UIE is on payload side
  – Operates at 25Mbs
• CCSDS space packets are used for the higher level protocol
  – Per ORS Standard Data Interfaces: Bus to Payload, Bus to Ground
TacSat-4 vs. ECSS-ST-50-12C

### TacSat-4 Deviations from ECSS-ST-50-12C

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<th>TacSat-4 test</th>
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<td>cable based on 26AWG (7x34) GORE-TEX-tape jacketed wire</td>
<td>cable based on 26AWG (7x34) GORE-TEX-tape jacketed wire</td>
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<td>only 9 position micro-D</td>
<td>38999 Series IV connectors</td>
<td>38999 Series IV D38999/40FB35SN &amp; D38999/46FB35PN Deutsch DS07-37S-081 &amp; 13084-37S-5020</td>
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<td>1 segment, 2 identical plug connectors</td>
<td>3 segments, 2 different types of connectors, 6 total connectors</td>
<td>3 segments, 3 different types of connectors, 6 total connectors</td>
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**ECSS-ST-50-12C defines max data rate via skew and jitter budget; however, 200Mbs and 400Mbs are accepted norms**

- ORS standards require that an ORS bus and payload are capable of
  - Being mated in a depot facility
    - Thus the three segments
  - By minimally trained personnel without specialized tools.
    - Thus the circular connectors
- To test the bus, additional cables were fabricated
  - The three segment 10m cable used for I&T testing with two breaks
  - One for passing thermal vacuum chamber wall
  - Another for the turn on panel of the bus.
- Comm-X payload testing required a longer test cable (18.5m)
- TacSat-4 chose 26 AWG SpaceWire cable manufactured by W.L. Gore & Associates GmbH
  - Less loss
  - Easier to work with: crimp & solder
  - More robust and less breakage
Current status of design

• Qualification of the TacSat-4 SpaceWire link is complete
  – in a previous study [Schierlmann]
  – Cabling, connector was qualified separate from bus

• Box level and system level testing w/ a commercial card
  – PMC SpaceWire card from Dynamic Engineering

• ORS bus and payload teams successfully tested SpaceWire
  – GSE to Bus, GSE to Payload, Bus to Payload
  – Bus I&T (10m cables)
  – Payload I&T (18.5m cables)
    • Still waiting on TVAC

• ORS Phase III bus is in storage awaiting the payload to complete environmental testing

• Upon completion of the Comm-X payload they will be integrated to form the TacSat-4 space vehicle.
  – Full SV level testing will be performed across the SpaceWire link at that point

• Launch in Fall 2009
I&T team comments (1 of 2)

- **EAGE**
  - PMC SpaceWire card
    - Simulated the Comm-X payload interface
    - Simulated a test port interface
    - Accommodated testing both channels of the PDH card.
  - Interfaced directly on Power 7E card
    - Located in our SES (space environment simulator) VME chassis.
    - This location seemed most beneficial for saving space in the SES chassis.
    - However, it proved to make interfacing the cables to the PMC card more difficult.
      - The small work area made it difficult to physically connect the cables to the card itself.
      - Resulted in a few cable wire to pin connections separating and having to rework the cable.

- **GSW**
  - Significant learning curve developing GSW (ground software)
  - Knowing the SpaceWire protocol was helpful
  - Difficult to predict how the PMC card would behave until data was actually flowing across the interface
I&T team comments (2 of 2)

- **Useful tools**
  - A breakout box and logic analyzer proved to be critical tools to help understand and troubleshoot the interface
  - A DESWBO from Dynamic engineering provided an ‘active break-out box’ by buffering the SpaceWire Differential signals for display on a Logic Analyzer
  - Loopback connectors also proved very useful for stand alone testing of both the PDH and PMC cards

- **Cable problems**
  - DVI heritage SpaceWire cables were prone to breaking
    - Happened on previous programs (SECCHI)
    - Occurred during initial TacSat-4 studies
  - 26 AWG Gore cable used on TacSat-4 was robust and easy to work with
    - Some problems with breakage at PMC card connector
      - Always with solder cup connectors, never flying lead (i.e. potted)

- **Shield and twisting confusion**
  - Preliminary designs dedicated a pin to carry the outer shield
    - Since the outer shield is chassis ground, this was unnecessary and ill-advised
  - Twisting Confusion
    - With the addition of the TVAC chamber wall, ambiguity arose as to where the out-to-in twisting was to be done
    - The TacSat-4 bus team suggested to twist once in each cable, so that an odd number of cables resulted in proper in-to-out assignment
Left over from previous study (1 of 2)

• Eye diagrams
  – Eye diagrams were taken using a DSA70604
  – Scope was unavailable for flight qualification
    • Images were useful for validation of the I&T cable
  – The DSA also helped diagnose another problem with the SpaceWire test board

• Probe bandwidth
  – Previously used 400MHz differential probes
    • Rules of thumb suggest that $\geq$ 1GHz probes should be used
  – Testing was performed with 1GHz probes
    • No difference was found between results of the 400MHz and 1GHz probes

• Corrections
  – Not speed limited
    • The previous paper states max speed was 167Mb/s
    • This was from a misunderstanding of the results returned by the SpaceWire driver
    • Scope traces confirm that the tests were indeed run at full 200Mb/s
  – Series IV vs. Series II
    • Previous paper referred to a 38999 Series II with a 10-35 insert arrangement
    • Actually used a 38999 Series IV with an 11-35 insert arrangement
Left over from previous study (2 of 2)

- Crosstalk from Allen
  - TacSat-4 relied on the crosstalk, jitter and skew analysis performed in previous studies
    - JWST Connector Choice study [Allen]
  - Looking at [Allen]
    - Simplify the result to be constant loss (over all f)
    - Fit the configuration to a simple model (right) [Paul, Johnson 1993]
    - Cross talk noise shows a strong correlation to D/h
  - Given this we expect the TacSat-4 connector to perform like a High density D connector
    - Cross-talk performance is as good –or better than- the SpaceWire micro-D
  - Results should not be overstated
    - This is a significant simplification of a complex test
    - However, lacking the time or equipment to perform the test, it provides a baseline
      - A quick answer with some basis in fact
    - This baseline agrees with expectations from visual comparison of connectors
    - DB9 was an outlier from the trend; don’t know why
Conclusions (1 of 3)

• Long cables worked
  – The 10m and 18.5m cables fabricated for environmental test performed well
    • 126ft cable was attempted as well, but failed
  – The extra length increased loss
    • Helped to dampen ringing induced by the discontinuities of two inline connectors (bus and chamber wall)

[Image: COMM-x 60ft (18.5m) test cable scope trace (din @ 200Mbs)]
Conclusions (2 of 3)

- O’Scope board issues
  - After qualifying SpaceWire cables on two occasions, we still see opportunities for improvement with the test board
  - Our attempts resulted in noticeable reflection in the signal
  - Eye diagrams made this reflection obvious
  - Soldered to the internals of the SpaceWire brick from Dundee
    - Risky given the features and cost of the brick
  - In the future we will try to use a modified DESWBO for examining waveforms
Conclusions (3 of 3)

- **TDR board issues**
  - TDR bandwidth of a TDR is 20-30GHz
    - Geometry of the padstack, stack-up, and foot prints are all critically important
  - The TDR test board had excessive discontinuity
    - Large enough to prevent Iconnect from converging to an impedance solution
    - Caused by the antipad around the SMA + conductor being too large [Bakel]
  - When commissioning test boards
    - Know your frequency of interest
      - For this its related to TDR bandwidth (30GHz)
      - Not SpaceWire (<<1GHz)
    - Ensure that your layout engineer is familiar with designing to the frequency of interest
  - For future TDR testing, we will try to use the Gore test board described in [Allen]