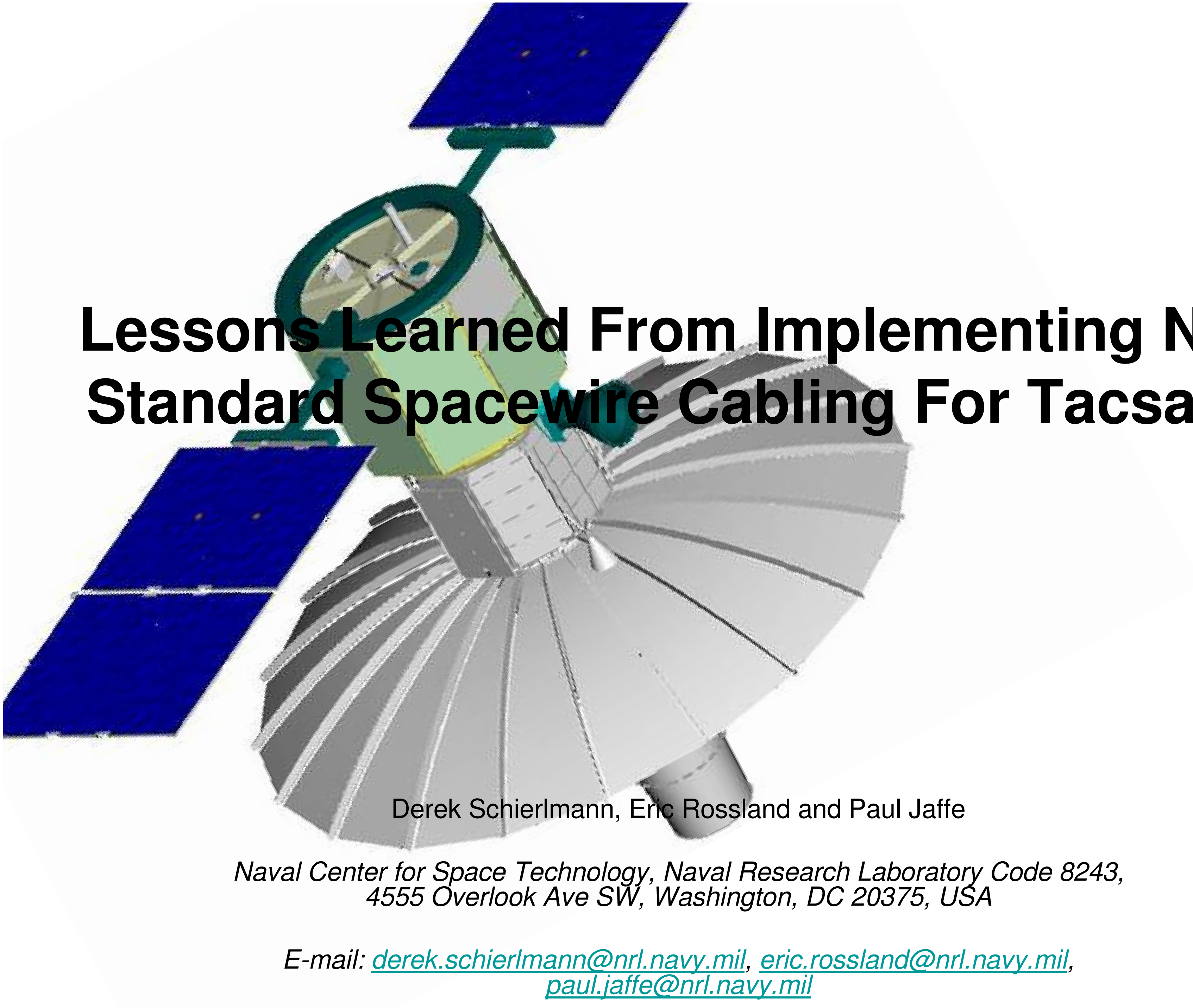


Lessons Learned From Implementing Non Standard Spacewire Cabling For Tacsat-4

Derek Schierlmann, Eric Rossland and Paul Jaffe

Naval Center for Space Technology, Naval Research Laboratory Code 8243,
4555 Overlook Ave SW, Washington, DC 20375, USA

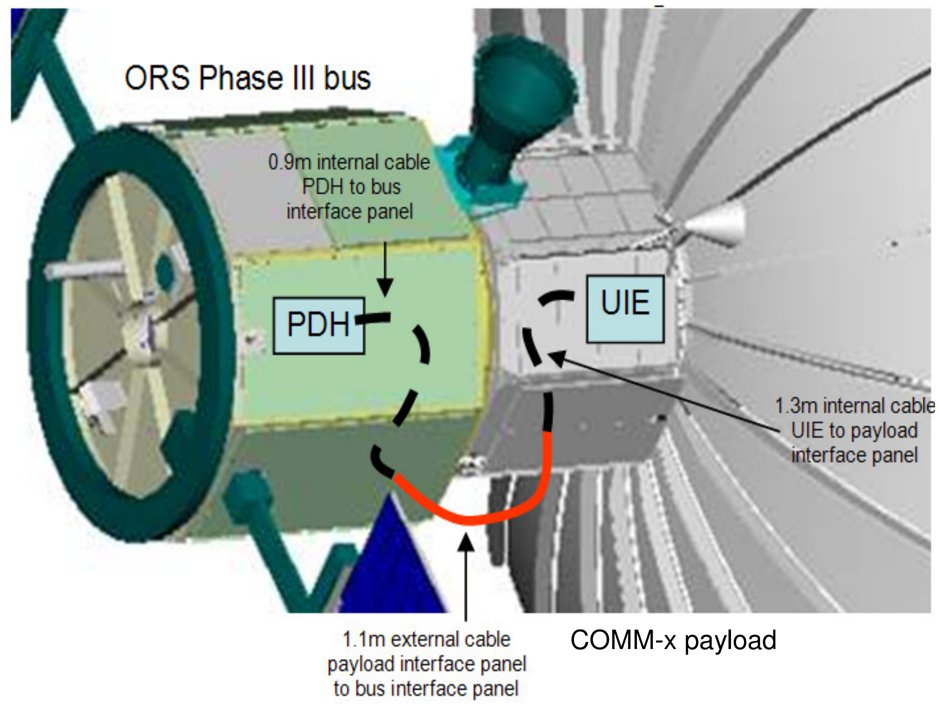
E-mail: derek.schierlmann@nrl.navy.mil, eric.rossland@nrl.navy.mil,
paul.jaffe@nrl.navy.mil

Outline

- Introduction
  - Our configuration
  - TacSat-4 vs. ECSS-ST-50-12C
- Data
  - Current status of design
  - I&T team comments
    - EAGE
    - GSW
    - Cable problems
    - Shield and Twisting confusion
  - Left over from previous study
    - Eye diagrams
    - Probe bandwidth
    - Crosstalk from Allen
    - Not speed limited
    - Series IV vs. Series II
- Conclusions
  - Long cables worked
  - Oscilloscope board issues
  - TDR board issues

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 SpaceWire cabling configuration

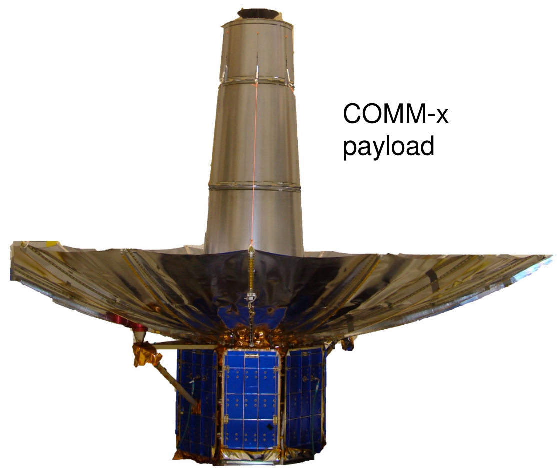
TacSat-4 vs. ECSS-ST-50-12C

TacSat-4 Deviations from ECSS-ST-50-12C				
Section	Topic	ECSS-ST-50-12C	TacSat-4 flight	TacSat-4 test
5.2	Cable	cable based on 28AWG (7x36) PFTE jacketed wire	cable based on 26AWG (7x34) GORE-TEX-tape jacketed wire	cable based on 26AWG (7x34) GORE-TEX-tape jacketed wire
5.3	Connectors	only 9 position micro-D	38999 Series IV connectors D38999/40FB35SN & D38999/46FB35PN	38999 Series IV D38999/40FB35SN & D38999/46FB35PN Deutsch DS07-37S-081 & 13084-37S-5020
5.4	Cable Assembly	1 segment, 2 identical plug connectors	3 segments, 2 different types of connectors, 6 total connectors	3 segments, 3 different types of connectors, 6 total connectors
5.4.2	Cable length	<10m	3.4m total	10m, 10m, and 18.5m
6.6	Data rate	2-400Mbs*	25Mbs	25Mbs and 200Mbs
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

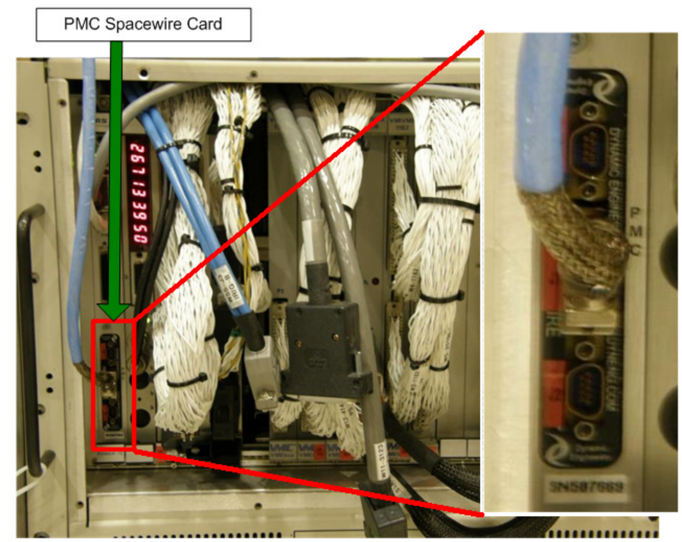


COMM-x payload

ORS phase III bus preparing for TVAC testing

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

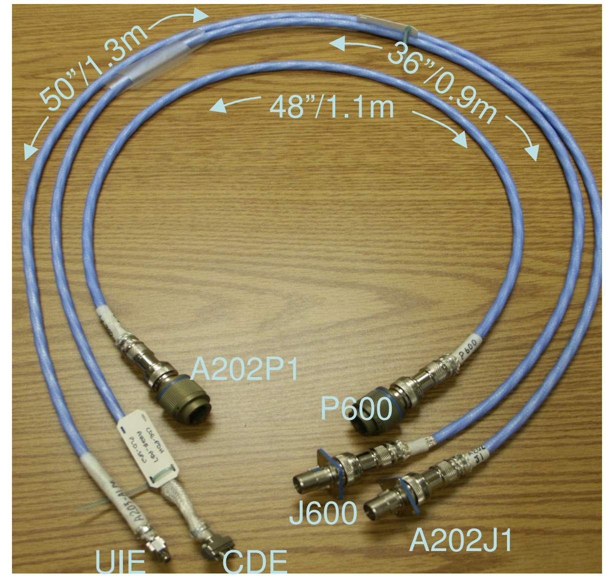


TacSat-4 SES chassis w/ PMC Spacewire Card

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
    - TheTacSat-4 bus team suggested to twist once in each cable, so that an odd number of cables resulted in proper in-to-out assignment

Tacsat-4 flight SpaceWire cables



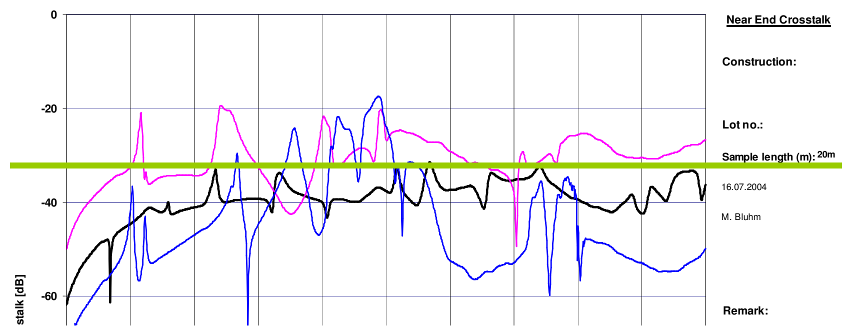
DVI SpaceWire cables

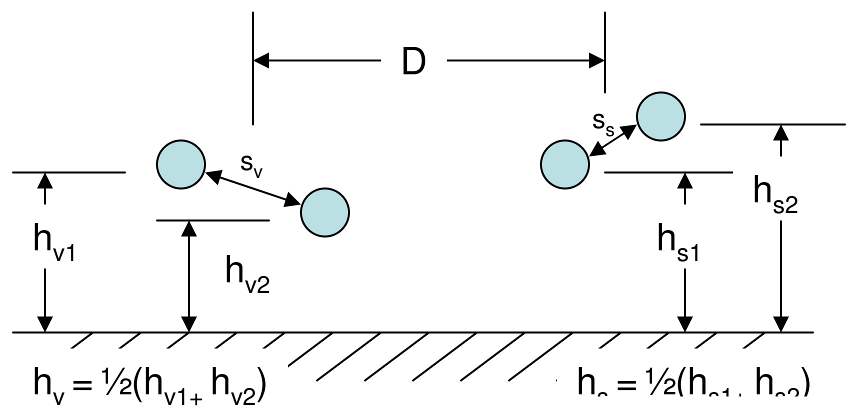
Left over from previous study (1 of 2)

- 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 >= 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



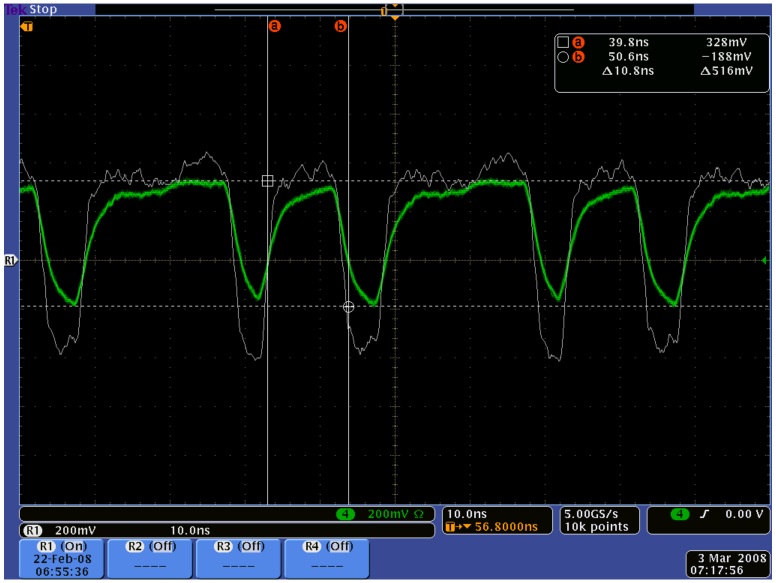


Xtalk ≈k/(D/ h_v)

Connector	Source->Victim	Pins	Victim h (mils)	Victim s (mils)	D (mils)	D/s	D/h	dB	Test group
uD9	Dout->Sout	9/5->8/4	70	50	50	1.00	0.71	-24	2
uD9	Dout->Sout	9/5->8/4	70	50	50	1.00	0.71	-24	2
uD9	Sout->Sin	8/4->2/7	70	50	75	1.50	1.07	-24	2
uD9	Dout->Din	9/5->1/6	70	50	175	3.50	2.49	-40	1
uD9	Dout->Din	9/5->1/6	70	50	175	3.50	2.49	-40	2
11_35P	Dout->Din	10/9->2/3	74	90	223	2.47	3.00		N/A
DB9	Dout->Din	9/5->1/6	98	124	378	3.04	3.86	-30	1
HDD15	Dout->Din	1/2->14/15	76	90	312	3.46	4.10	-47	1

Conclusions (1 of 3)

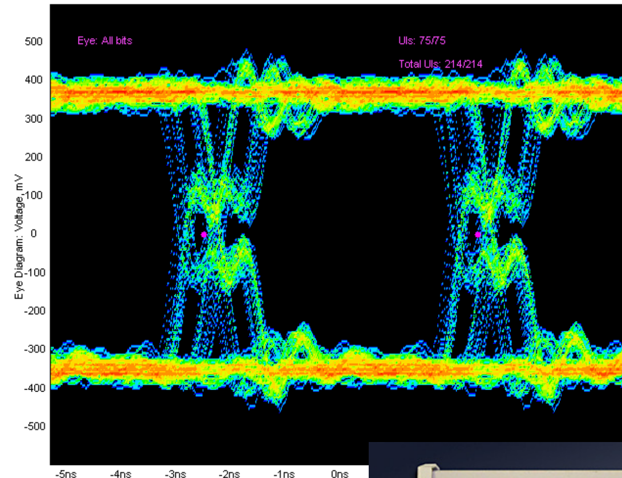
- Long cables worked
  - The 10m and 18.5m cables fabricated for environmental test performed well
    - 126ft cable was attempted as well, but failed
  - The extra length increased loss
    - Helped to dampen ringing induced by the discontinuities of two inline connectors (bus and chamber wall)



COMM-x 60ft (18.5m) test cable scope trace (din @ 200Mbs)

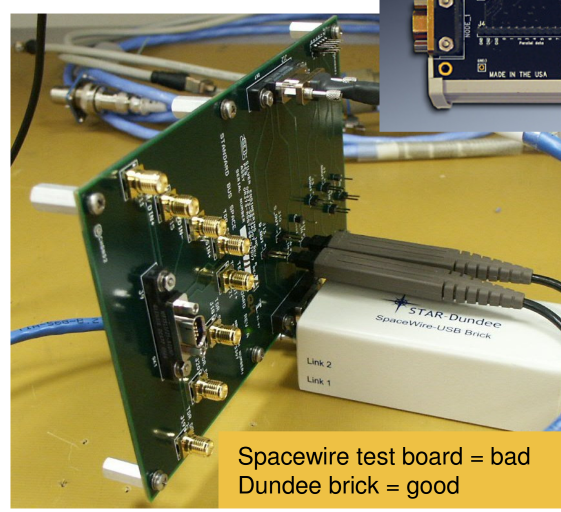
Conclusions (2 of 3)

- 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



Eye diagram with test board: can you say reflection?

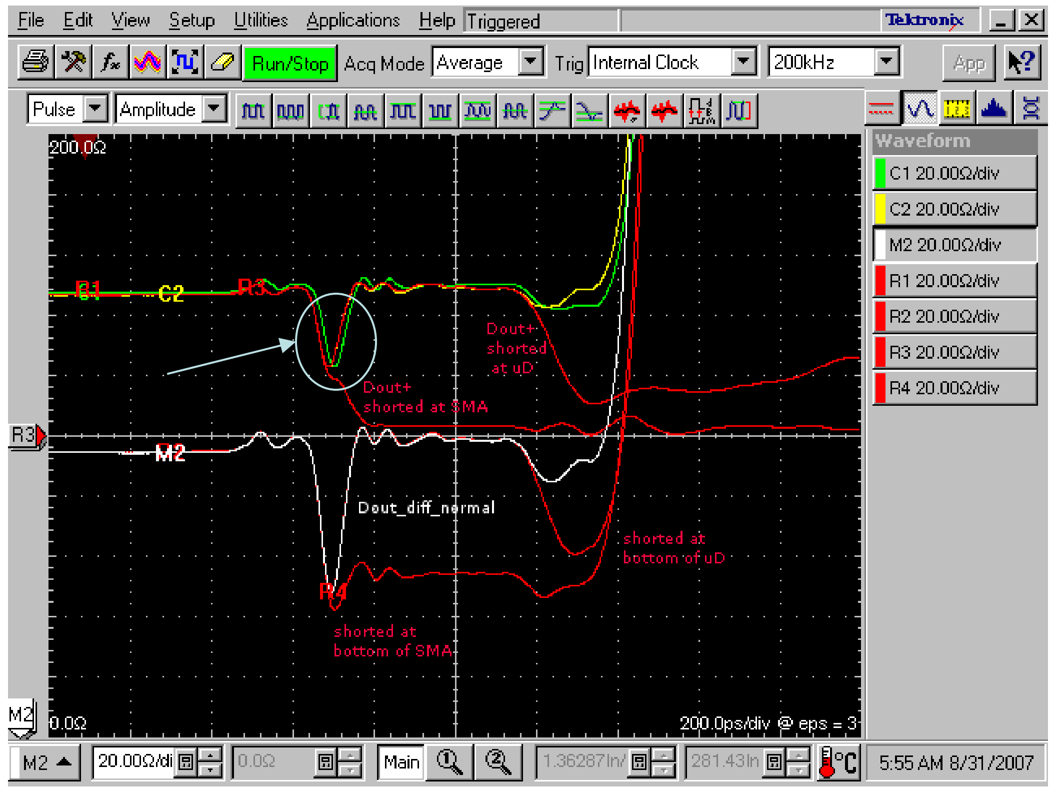
Dynamic Engineering DESWBO: useful for debug



Spacewire test board = bad
Dundee brick = good

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]



TDR image of SpaceWire test board. Comments and previous traces point out various features on the board. Note the large discontinuity at the SMA connector