How to build harnesses for a Mega Constellation of satellites?

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As this kind of a project is more likely to be done by many supplying international companies, the company for the harness supply should have international network as well:

Axon’ has this set-up, being an international company with subsidiaries and/or factories in France, Spain, UK, USA, Canada, Germany and other places.

Our 20-year space flight heritage and over 50 years working as experts in the field of interconnect solutions allow us to provide innovation as needed for such a big Mega constellation project.

Among those solutions are:
- DC Miniaturized interconnections,
- DC harnesses with fast assembling capabilities due to special designed connector technologies: fast locking solutions for signals and power,
- Power connections and bus bars,
- Different technology for bus networking (MIL 1553, CAN)
- High data Rate connectors and system solutions supporting digital signal requirements to achieve high bandwidth based on high quality (SpaceWire, Spacefiber, CML protocol, Ethernet - Etherspace).
- Microwave /RF harnesses with optimized attenuation behaviour.

Different families of ESCC wires and cables and customized cables for space needs developed, evaluated and brought into space programs.

All with designed profiles to specific satellite needs.
For the needs of fewer components in a small Internet satellite, weight saving solutions and easier manufacturing methods to assemble, AXON’ proposes components to build a harness for such satellites which are supporting all those expectations. Therefore a development of “ready to plug” connectors with a quick lock system have been developed for power (MMC connector) and RF (coaxial contact connectors). For DC harness the fast to connect “D-click MicroD connector” has been created and MicroStrips help to keep connection small. For high digital data bandwidth the MicroMach connector has been introduced to offer high performance for this kind of communication interfaces.

Products to build harnesses in efficient ways:

I. MICROSTRIP CONNECTORS

This single row plastic connector for space and weight saving applications is based on the success of AXON’ Twist Pin contacts, a 100% tested product for high quality and reliability of interconnects.

Guide pins or latches are available for secure mating process. This simple but reliable connector is used e.g. for heater and thermistor interconnection and harnesses. It’s range is available from 2 Pin’s to 21 Pin’s, all in single row and therefore a flat, space saving solution.

II. MICRO MODULAR CONNECTORS (MMC & MMCA)

a. MMC Micro Modular PCB Connector

This connector had been originally developed in a frame of an EMITS by ESA. The cavities are designed for size 12 and size 16 power contacts as
well as coaxial contacts. They are available basically in 2 sizes: 4 and 8 cavities. With these 2 sizes all known needs within the power interconnection of an Internet Satellite could be fulfilled. As they are easy to install, small by size (meeting similar dimensions as the well-known MicroD connectors) and offered with a fair price, they meet all requirements that Mega constellation manufacturers will be looking for.

![Fig. 2](image)

The power contacts used within these connectors are made for cable sizes AWG 12 to AWG 20. For coaxial applications the relevant contacts are available as well: for 50Ω, in size 12, they are tested until 18GHz signals.

![Fig. 3](image)

The MMC connectors are made with a fast locking system, allowing a quick connect with a save connecting position at the end of the connection. A schematic of this quick connection is shown in Figure 6 of the following chapter. All MMC product range follows the double insulation rule concept.

With this MMC connector as well as the following MMCA connector Axon has layed the way to integrate harnesses in a fast and efficient way during an assembly line manufacturing as it is realized within a Mega constellation project.

b. MMCA Micro Pigtail Connector with dismountable contact
The MMC connector is also available in a variant with removable contacts, then called MMCA. The concept to remove these contacts is made by the use of a spring in combination with a contact locking part. For this process there is no tool needed. The locked position can be checked by a visual mark around the contact locking part.

![Fig. 4](image1.png) ![Fig. 5](image2.png)

Figure 6 shows the mating concept of the MMC(A) connectors. This concept is based on the use of a spring on one of the mating connectors, which catches the guide pin of the other mating half of that interconnection. The development of these connectors had been achieved through extensive evaluation, e.g. vibrations, mating, shielding effectiveness, thermal cycling, current overload and voltage overload tests. ESCC specification writing and qualification are scheduled and in preparation. The connectors have been selected for a Mega constellation programme, already.

III. MICRO-D CONNECTORS – D-CLICK

Also the well-known MicroD connector have been modified and adapted to allow a quick installation during integration of a harness.
Today available from 9 ways to 37 ways. The mating concept is similar to the described MMC(A) connectors special hardware concept (made by a spring and a mating guide pin – jackpost).

![Fig. 7](image1)
![Fig. 8](image2)

Also this adapted Micro-D connectors with it’s unique “D-click” mechanism are a key driver for quick assemblies of harnesses inside an assembly line manufacturing!

IV. MICROMACH CONNECTORS

Developed under an ESA Technology research Project (TRP).

Following the new Connector Design

![Fig.10](image3)
![Fig.11](image4)
The shape of the proposed new connector was rapidly chosen in accordance with customers’ needs to be a rectangular design with 4 separate cavities. Each cavity is separated by a metallic wall to improve crosstalk performance. The 4 ways are designed to all be fully 100Ω adapted throughout the complete transmission line.

To secure the mating sequence, 2 special guide pins are used which, as well as securing the backshell to the connector, help accurately guide the male and female connectors together during mating.

The electrical contacts are assured by the very well-known and reliable Twist Pin technology used on Micro-D connectors, which produced decades of successful flight heritage. These contacts are inserted by first fitting them into dielectrics which are then press-fitted into the connector shell. This design prevents the contacts moving backwards or forwards within the connector.

A SpaceWire cable consists of 4 inner shields (around the twisted pairs) and one overall shield. One of the main challenges of this new development, therefore, was to design a connector with 4 effective inner shield terminations in an overall size as close as possible to that of a 9 way Micro-D. The choice, made jointly with ESA and STAR-Dundee, was to work on a connector with “good-but-not-360°” inner shield termination (as illustrated in Fig. 3) in order to make it more compact. The purpose of this design was to guarantee sufficient electrical contact between the braided shield of each pair and the metallic shell of the connector whilst saving space and significantly reducing crosstalk.

Fig. 12. 3D Cross-section of the in-line male MicroMach SpW connector
For the contact of all 4 inner shields using a metallic “nano” band tightened around a special feedthrough insert with the 4 shielded inner pairs in situ (Fig. 4). The cruciform shape at the rear of this inner shield insert ensures a solid electrical contact by maintaining a degree of pressure over the 4 cable braids. This Axon-designed insert has been dubbed internally “aXiform”.

The overall (outer) shield of the cable is then crimped over the backshell funnel with an axoclamp® (or equivalent) banding adaptor.

Fig. 13. Twisted pair shield connection demonstration with “aXiform” inner shield feedthrough insert

The MicroMach SpW connector is currently designed for both AWG 26 and AWG 28 SpaceWire cable variants with a specific “aXiform” insert for each size. Other cable constructions could be achieved simply by adapting the insert as required.

Finite Element Simulation

To identify the best compromise between the hardware design and the resulting electrical performance, AXON’ carried out Finite Element simulation on 3D models using CST software. These analyses were principally focused on characteristic impedance in order to determine the optimum size of all the inner connector elements. As can be seen in Fig. 5, the main mismatching is where the cable is terminated to the contacts. At the crimped contact interface the Zc variation may be around 20Ω for AWG 28 and 15Ω for AWG 26 cable.
Fig. 5. CST simulation with Finite Element Model

**Key Mechanical Specifications of the MicroMach SpW Connector**

Dimensions: **21.4 x 9.3 mm** → Fairly close to a 9 way Micro-D (19.7 x 7.6 – comparative photograph in Fig 6.).
Female weight: **6 g**
Male weight: **7.5 g**

Fig. 14. 9 way Micro D next to New MicroMach SpW connector

**Preliminary Electrical Results**

1. Ground contact between Male & Female bodies < **5mΩ**
2. Next/Fext < **-50dB up to 1GHz**
3. Return loss < **-20dB up to 1GHz**
4. Characteristic Impedance:

The following characteristic Impedance plots (Fig. 7) were measured on a Micro-D mated pair terminated with AWG28 Low Mass SpaceWire (ESCC 3902.004.01) versus the MicroMach SpW connector mated pair terminated with classic AWG26 Space Wire (ESCC 3902.003.02). The differing cable types are not particularly relevant – they were simply the available test samples to hand at time of writing – but the results show
clearly that the new MicroMach SpW connector is highly adapted even in full band (around 20GHz).

Eye pattern / SpaceWire mask compliancy

The Eye Pattern in Fig. 8 is a 1 metre link using Low Mass SpW cable (ESCC 3902.004.01) terminated to 2 MicroMach SpW mated pairs and run successfully at 4Gb/s with respect to the SpaceWire mask.
Presentation of a Possible MicroMach SpW Range

AXON’ has also worked on a number of different possible connector variants as presented briefly below (Table.1). Some additional PCB connectors will be developed according to the need.

<table>
<thead>
<tr>
<th>PCB Female Board Straight</th>
<th>PCB Female Flex</th>
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<tr>
<td>Basic PCB version to connect to a board with limited mismatching and crosstalk.</td>
<td>Allows a good mechanical decoupling between PCB and equipment panel while maintaining impedance matching and crosstalk reduction. The skew is also very low.</td>
</tr>
<tr>
<td>PCB Female SMT Edge</td>
<td>PCB Female SMT Edge</td>
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<tr>
<td>This variant saves a lot of space on the PCB and allows a significant crosstalk reduction between the two connection sides.</td>
<td>Adds the possibility of mounting the connector on a panel (rear mount).</td>
</tr>
<tr>
<td>PCB Female CBR</td>
<td>Saver</td>
</tr>
<tr>
<td>This variant allows a right angle mount while maintaining impedance matching. Offering limited crosstalk and skew.</td>
<td>Savers are often needed during the AIT phase.</td>
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Table.1. Illustration of likely members of the MicroMach SpW range

CONCLUSION
AXON’ continues to develop high performance HDR links by working on both cable and connectors in parallel, as well as on the overall termination methods. The new MicroMach SpW connector range, which will be available by end 2017 offers, in a size only slightly larger than the current 9 way Micro-D, significantly improved performances in data rate, EMC and crosstalk compared to any of the current market solutions.

An important outcome of this project will be the update of the generic specification No. 201 (2263xxx) for the harness plus a new ESCC detail specification characterizing these new SpaceWire in-line and PCB connectors. At the same time the latest revision of the SpaceWire standard, ECSS-Q-ST-50-12 has been issued incorporating the possibility to use this new “MicroMach SpW” connector as a type B.

The components offered by Axon’ cable meet the standard and special requirements of the Mega Constellation: LEO environment suitable, cost efficient, supply chain oriented (“just in time”), similar to MILAERO volume capabilities production lots, and mass saving oriented product features.