Minutes of Meeting

Subject/objet: **The First ESA-NASA Working Meeting on Optoelectronics: Fiber Optic System Technologies in Space – Lessons Learned**

Record of the discussion session Thursday 6 October 2005, Einstein Hall, ESTEC/ESA, Noordwijk, The Netherlands

Seventy experts participated in the meeting and most of them were present in the discussion session that concluded the meeting. Roman Kruzelecky – MPB (Canada) and Darius Nikanpour – Canadian Space Agency, participated via Video Conference from the VC facility of CSA in Montreal, Canada.

Topic 1: In the trade-off between mechanical strength and weight, is mass saving a real advantage of optical fibres in satellites? Moreover, for which applications are they appropriate?

Martin Mosberger - Contraves Space (Switzerland):
The experience gained with SMOS shows that yes, mass was saved compared with an electrical harness. The mass saving was not quantified. However, the main driver for the use of a FO system for SMOS was the phase stability requirement, which could only be met by an optoelectronic system.
The other big advantage realised by use of FO in SMOS was in greatly simplifying the mechanical complexity for deployment of the arrays, by eliminating waveguide plumbing etc.

Denis Dilhan – CNES (France)
For the planned implementation of a pyro-optical system on the Ariane 5 launcher CNES did carry out a system analysis with Alacatel and EADS Astrium with the conclusion that a mass saving of 50% was possible when compared with the standard electrical-pyro harness. There is also a significant advantage for harness integration. The standard electrical and pyro-optical harnesses can be routed together. This is not currently feasible with the electrical-pyro harness for safety reasons.

Ulrich Hildebrand – TeSAT (Germany)
Thought it was unfair to directly compare optical and electrical harnesses in this way.

Melanie Ott – NASA Goddard (US)
Was asked to comment on the potential additional advantage of using FO ribbon cable and connectors (now widely used in the terrestrial telecoms industry).

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Explained that the use of single fiber lines and large connectors prevalent in NASA and the space industry was due to the heritage of this technology being derived from the historical and widespread application and use of Mil-Spec standards. Large multipole electrical connectors such as the "38-999" type were in fact previously used by NASA for FO applications by "simply" replacing the electrical pins with FO ferrules. With the gradual phasing out of use of Mil-Spec standards the push is on to use more appropriate technologies leveraged from the telecom industry.
The use of MTP type 12-channel FO ribbon cable and connectors is now being actively advocated within NASA. This type of technology can certainly bring very significant weight advantages. It is now possible to have ribbon connectors with up to 72 fibers.

Roman Cruzelecky – MPB (Canada)
The FO harness being built for the FO sensor system implemented on Proba-2 will have additional mass due to the sheathing and protection layers required to be added to the basic FO cabling. However, the goal is nevertheless to maintain a 1mm maximum outside diameter for each completed cable to ensure as small overall FO harness cross-section as possible.

Martin Seifert – Neufern (US)
Speculated about the use of a "cable-tray" type approach to the harnessing-routing problem of FO cables in spacecraft. [A similar approach is already used for aircraft systems?]

Lee Thienel – Jackson & Tull (US)
Commented that the cable tray approach is not a big problem in his experience with military aviation systems, if the people doing the integration are well trained and experienced in handling fiber optics.

Topic 2: Can we use fibers and related components when we have no access to the material composition of the devices? Manufacturer's credibility…vendors come and go…We are in the world of COTS …

Stefan Metzger – Fraunhofer Institute (Germany)
Considers that the question is not appropriate. They have found from experience that industry does respond well and is usually able to meet the specifications demanded of them. Confidence in the component vendors can generally be relied upon.

Melanie Ott – NASA Goddard (USA)
Now considers herself a "Failure Analyst" rather than a component development specialist, which was her original role in NASA. Because we are now in a "COTS world" one of the principal means of information gathering must be via efficient networking and knowledge sharing between experts.
Melanie reminded the meeting that it is essential to have components experts and engineers always involved from the start of any programme (i.e. pre phase A if possible).

In addition, failure analysts involved should be those who understand the physics of failure.

Martin Seifert – Neufern (USA)
The component vendor distribution and knowledge sharing needs to be managed. It would be very useful to have such working meetings for both this user community and the vendors.

Topic 3: Confidence building – what is the current feeling of main customers in using fiber optic technology? - RISK MANAGEMENT; FIBERS THE ENABLING TECHNOLOGY?

Ulrich Hildebrand – TeSAT (Germany)
TeSAT decided during the development phase of their optical inter-satellite terminal to eliminate the use of a fiber optic link between two modules of the system. It is now built and sold as a single stand-alone unit for ease of integration on any platform.

Roman Cruzelecky – MPB (Canada)
The initial implementation of the FO sensor system on Proba-2 is deliberately being done in parallel to the routine deployment of a primary electrical sensor system carrying out the same functions. The FO system is therefore not yet relied upon to perform a mission critical function. It will clearly take some time to build confidence for such applications.

Doug Hardy – W.L.Gore Inc (USA)
There is a huge change perceived in the space business because of the transfer of skills and knowledge from the (FO) telecom sector following the downturn.

David Gill – Boeing Corp, ISS programme @ NASA Johnson (US)
In building FO systems for space all we are doing in fact is managing risk. Technical, schedule and management issues need to be handled in a systematic way.
In the ISS programme, (because of its scale and duration) knowledge transfer is a critical issue. This has not always been done efficiently to date. This type of working meeting is seen as a very good way to improve the situation.
In response to a comment/question on the phasing out of FO systems on the ISS Mr Gill stated that this was not really the case and that FO systems will certainly be used in the new generation of crewed vehicles.

Arnd Reutlinger – Kayser-Threde GmbH (D)
The best confidence building exercise is to actually use the new FO technologies in applications where conventional systems do not work. For example FO sensors in the 64 m diameter Cargo Lifter balloon. Conventional electrical systems were precluded due to critical safety issues with discharges inside the envelope.

A good idea is always to take a two-step approach; 1) Implement the system in a testing application (e.g. Proba-2) and following success then 2) Use in an operational application with confidence.

Darius Nikanpour – Canadian Space Agency
Agrees that, yes, we need to be careful how we introduce and deploy FO sensing systems. Proba-2 is in fact a very good example of the correct approach.
The transfer of technology from ground to space is not necessarily easy or straightforward however. It is very important that the applications chosen are appropriate and prudently chosen. If perceptions about the performance of FO systems in space are incorrectly formed, it is very difficult to change them later!

Nikos Karafolas – ESA-ESTEC (Netherlands)
Addressing CSA & MPB: Does it make you nervous to be the first to deploy a complete FO sensing system in space?

Roman Cruzelecky – MPB (Canada)
NO! We are confident because of our very careful and systematic approach.

Melanie Ott – NASA Goddard (US)
At GSFC for the application of fiber and optoelectronic systems in LIDAR systems, in general the approach is to just go ahead and do it! Experience is gained as they go along. Engineering trade-offs are done carefully by including all players as early as possible in the process. Failures are not precluded and do occur. These are dealt with in a business like manner and, most importantly, valuable lessons are learned in the process. Unfortunately, the most significant feedback to upper management occurs following a failure.

Barry Coyle – NASA Goddard (US)
There is a continuing and growing need for both solid state (diode pumped) and fiber lasers. This remains a difficult and technically challenging area. However, the experience gained to date with diode pumped lasers is now being used positively to provide valuable feedback into the development of fiber laser systems.

Nikos Karafolas – ESA-ESTEC (Netherlands)
My personal experience in trying to build confidence with the users of FO technology is to outline all the missions that have successfully used FO, and address thoroughly the new approaches adopted in response to cases of failures. I believe that this Working Meeting has provided us with many examples of such missions and I think that following the meeting we should try to compile a database of information concerning the successes and failures of all space flown FO (and laser) systems to date.

Topic 4: ITAR restrictions; what impact does this have on our (small) community and which technologies are affected?

Martin Seifert – Neufern (USA)
For the most part low power (laser) systems are not restricted. These are up to 2 W above 1.5 micron wavelength and above 50 W up to 1 micron. In general it is much more difficult for American suppliers than for foreign based companies and agencies.

Darius Nikanpour (Canadian Space Agency), speculated that Canada could play a brokering role for ESA in dealing with ITAR restrictions and negotiations.
However, *Martin Seifert* stated that in fact Canada is also a signatory to ITAR. Exceptions can be applied for and are often granted for specific space application of restricted technologies.

Errico Armandillo – ESA-ESTEC (Netherlands)
It is essential to sort out ITAR issues well in advance of the Phase C/D of a project. ESA's experience to date is that we have not had major problems in this area.

Darius Nikanpour (Canadian Space Agency)
FO technologies are extensively marketed from Canada worldwide and they wish to transfer their technologies as widely as possible.

Topic 5: *Dominic Doyle (ESA):* FO cable routing and harnessing are issues that arose a number of times as lessons learned during the last two days. What is the best way to learn from both terrestrial and other aerospace (i.e. aviation) systems where these issues are dealt with on a routine basis?

Euan Livingston – XLoom Communications Ltd (Israel)
There is a large experience on harnessing issues to be exploited by examining terrestrial "Central Office Switch" installations. System installers such as Nortel Networks, Alcatel, Lucent and Cisco systems could be contacted.
FO ribbon cable is now used widely within terrestrial switch installations. Experience has shown that the asymmetric cross-section of the cable has a direct consequence on it's routing through a harness. Bending is no longer symmetrical in all directions. Ribbon fiber cable is very stiff in the plane of the fibers. This will be of concern for the design and implementation of harnesses with this type of cable on spacecraft.
VCEL technology will need also to be addressed.

Added information from an off-line discussion following the meeting -
Sub-Sea FO cabling is a well-established technology, with similarly demanding requirements for reliability as space systems. It may be possible to leverage some knowledge from this sector of the industry. A couple of very experienced companies are; Tyco Subsea Systems and KDD, the Japanese long haul carrier.

The use of laser diode pumps at 980 and 1480 nm is widespread in the sub-sea repeaters, and there is consequently a large volume of lifetime test data available.

Veli Heikkinen– VTT Finland
VTT are actively researching high-speed FO intra-satellite networks. Results to date are very encouraging.

Melanie Ott – NASA Goddard (USA)
On the question of integration of FO systems on spacecraft, our experience has shown that unless dedicated and experienced and FO specialized engineers are used problems will arise. Of particular note and a real lesson learned is that harnessing and integration of FO systems cannot be adequately assured by documentation alone! In other words, developing and delivering a procedure is not sufficient. It must be executed in a controlled way by qualified and experienced personnel.

NASA's experience to date with VCELs is very good and these devices certainly look promising for space application. There are a number of companies already supplying the technology (to NASA?).

Topic 6: *Iain McKenzie (ESA):* How is it best accomplished to set up (encourage) companies to develop and supply FO hardware for the space market?

Barry Coyle – NASA Goddard (USA)
NASA's experience is that a significant number of companies they deal with do space work because they need to! In general the smaller companies are more motivated. Larger companies can be quite reluctant because of the small margins and specialized nature of the business.

Martin Seifert – Neufern (USA)
Big companies can have very high financial thresholds for conducting business, e.g. 5M$. In dealing with small companies beware to deal only with those that have a sound business model, which covers both their core (revenue generating) activities and the more specialized space stuff!
Smaller companies also have the advantage of being able to learn quickly and apply the knowledge gained directly and efficiently.

Darius Nikanpour (Canadian Space Agency)
Agree that in their experience knowledge gained by (small) companies on space work is in general filtered down and applied throughout the company. They have found a very good synergy between space and other activities, and see that in fact business achieved in the space sector is often used by companies as a positive marketing and selling point. Invariably, successfully developed space technologies are integrated into terrestrial activities.

Topic 7: ***Dominic Doyle (ESA):*** **Fiber lifetime was questioned and discussed recently as part of a fiber failure investigation. Given the statistical nature of this quantity (as used in the terrestrial telecom industry), is it valid to address this parameter for space application? If so how should it be quantified?**

No real discussion on this topic apart from a general "nodding of heads" in agreement with the statement that it's probably not an appropriate parameter to quantify based on small sample sizes and short lengths of fiber typically embarked on most space missions.

Wrap-up and Summary

Nikos Karafolas – ESA-ESTEC

Let's remember what this Working Meeting was about: It was to share hands-on experience from of spaceflight and qualification process of fiber optic technology. It was not to discuss the R&D projects and ideas pursued in this field. From this point of view I think that the meeting accomplished its task. We should continue in this way and I suggest that in the next meeting we should include experience form the various R&D activities in this field. In addition there should be new information available on the lessons learned from missions flown in the interim using FO technology. This meeting creates by default a forum for exchanging information and experiences. All the presentations delivered at this meeting along with the list of names and emails of the participants will be available on the following ESA and NASA web sites:
https://escies.org
http://misspiggy.gsfc.nasa.gov/

Errico Armandillo – ESA-ESTEC (Netherlands)

The meeting has been extremely successful and it should be continued possibly by holding the meetings alternately in the US and Europe.

Melanie Ott – NASA Goddard (USA)

Expressed her thanks to all participants for participating in the meeting. Such a meeting has been long awaited and it is important that we all gathered here and shared our experiences.

Acknowledgements

Melanie Ott – NASA Goddard (USA) & Nikos Karafolas – ESA-ESTEC

A very big and heartfelt thanks to all the contributors who made presentations, in particular those from the all over the US and from Japan. Particular recognition goes to Nikos who took the initiative to propose such a forum to Melanie as a joint inter-agency activity (*on a snowy day in Washinton DC early 2005!!*)

Finally a very sincere thank-you to the technical support team here at ESTEC for ensuring the smooth operation of all the conference room facilities and in particular for the videoconference link with our colleagues in Canada.