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LASER COMMUNICATIONS FOR SATELLITE MEGA-CONSTELLATIONS – NEWSPACE-STYLE

Kevin Shortt
ViaLight Communications GmbH, kevin.shortt@vialight.de

Dr. Markus Knapek
ViaLight Communications GmbH, knapek@vialight.de

ABSTRACT

As today's society becomes increasingly connected, vast amounts of data are being transferred around the world and the idea of "big data" is becoming a hot topic. In the context of avionics and aeronautical payloads, sensor systems are generating a deluge of information for a variety of applications, all of which must find its way down to the ground efficiently and effectively. Furthermore, projects such as Google's *Loon* and Facebook's droned-based "internet in the sky" stand as a testament to the upcoming paradigm shift in high speed communications and will change the face of how we stay connected. Wireless laser communication systems are now finding their way out of the laboratory and into the mainstream commercial market. This paper highlights some of the technology to target the needs of the growing number of so-called LEO mega-constellations.

INTRODUCTION

A number of successful wireless laser communication demonstrations have been carried out over the past 15 years. In 2001, the European Space Agency (ESA) established the world's first inter-satellite link using lasers[1]. This demonstration has been followed over the years by demonstrations of a variety of different scenarios from the Japanese Space Exploration Agency (JAXA), the German Aerospace Center (DLR) and NASA[2345]. In 2013, ViaLight Communications GmbH accomplished a world-first by establishing an optical link between a fast-moving Tornado jet aircraft and the ground with a data rate of 1.25 Gbps[6].

Vialight Communications proposes to develop a space laser communications terminal (LCT) based on its world leading series of aeronautic and stratospheric MLTs. By leveraging this pre-existing technology, ViaLight will expedite the development process, focus on the truly critical elements often overlooked by others in industry, and ensure completion in tight schedules.

The primary motives behind the development of the miniature laser terminal (MLT) series has been the mass production of terminals to support the growing interest in what are becoming known as pseudo-satellite broadband networks (i.e. communication networks deployed on high altitude platforms such as in the case of Google's Loon project). Extending the MLT's capabilities to a micro-satellite platform will strategically position ViaLight as a leading commercial provider for satellite networks such as those planned by OneWeb and SpaceX. With satellite fleets numbering in the thousands, the reduction in recurring costs will be significant through the use of mass-production processes as well as the use of existing stratospheric MLT concepts.

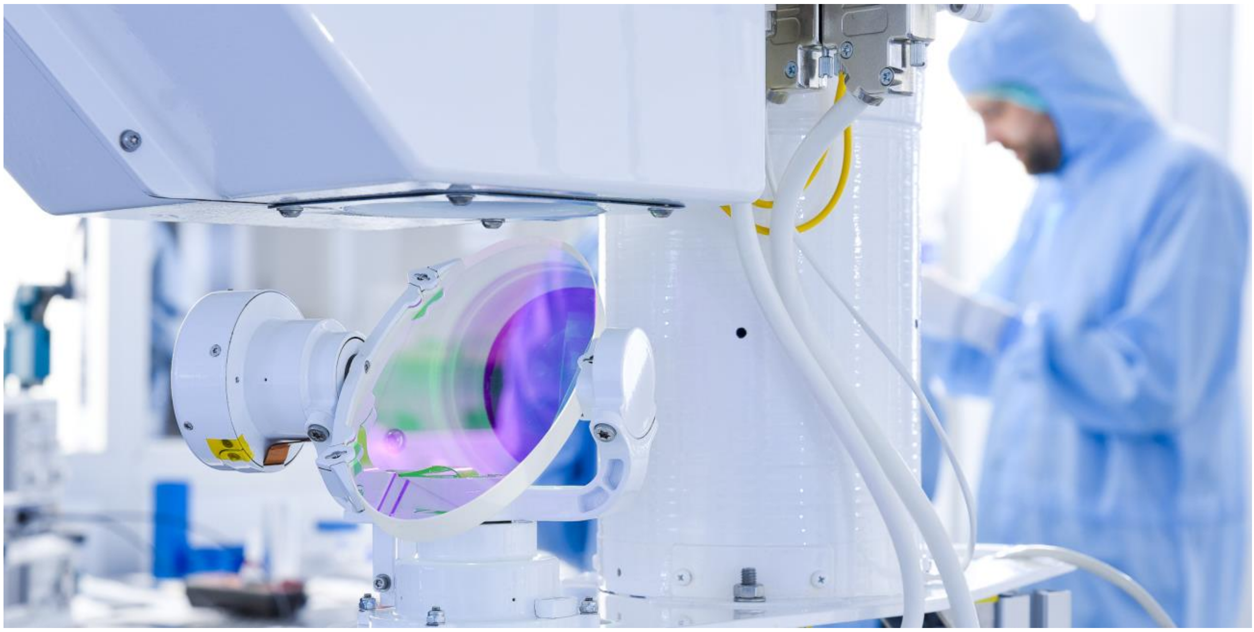

Exhibit 1: Stratospheric inter-platform LCT. Left: Coarse pointing assembly with entry aperture during integration in the clean room.

ViaLight Communications is taking the necessary steps to establishing a true mass-production process for the manufacturing of sophisticated laser communication terminals for a variety of aerospace applications. This paper will highlight some of the key features of that process and the design principles underlying the technology to make it suitable for serial production for space applications.

SERIAL PRODUCTION OF LASER COMMUNICATIONS HARDWARE

At the heart of any serial production process is an organisation's supply chain, a sophisticated mechanism founded in fundamental precepts of industrial manufacturing. It comprises of a series of checks and balances which, when taken as a whole, provide a robust and reliable means by which a laser communication terminal can be manufactured to exacting standards. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the overall structure of a typical supply chain, which consists of three fundamental elements: i) Product and Process Development; ii) "Make or Buy" Strategy; iii) Operations.

Product & Process Development	**Product Design**	**Manufacturing & Test Processes**
Make or Buy Strategy	**Supplier Base**	**Assembly & Test**
Operations	**Personnel**	**Business Processes**

Exhibit 2: The overall organization of a manufacturing supply chain.

In the initial step, the product is designed and manufacturing and test processes are elaborated. During this stage of the manufacturing process, thought is already given to how the product will be absorbed into the assembly line production.

In the *"Make or Buy"* phase, decisions are made regarding which elements of the final product will be sent to the supplier base for manufacturing and test (i.e. "buy"). Those that are not delegated to the organisation's supplier network, will be assembled and tested in-house (i.e. "make").

In the *Operations* phase, task-specific personnel and business processes carry out the physical manufacturing of the laser terminal. Throughout the course of this phase, processes and testing are continuously optimized to make the manufacturing process more efficient, reduce cost, and bring added value to customer product.

Product and Process Development

Product development proceeds in the same way as for any engineering project: requirements are defined, specifications are elaborated, and designs are implemented. However, in addition to these traditional technology design steps, processes for assembly line-style production are taken into consideration. By taking into account the specific processes necessary for the physical construction of a given unit, design issues are taken into consideration that will streamline the manufacturing process while ensuring that each unit coming off of the assembly line adheres to the same stringent system and quality requirements.

Value engineering and design is defined as the well-defined and measured process by which a product is continuously improved upon. The establishment of so-called system "building blocks" allow for the ongoing optimization of the product design using these principles for manufacturing in order to keep things such as weight and cost of each terminal to a minimum and maximize the reliability/repeatability of the manufacturing process.


Exhibit 3: Sample sub-systems that serve as building blocks for a laser communications terminal – coarse pointing system (left), receiver front-end electronics (right).

"Make or Buy" Strategy

This strategy allows an organisation to decompose its products into those elements that will be made in-house and those that will be purchased from its supply chain.

Supplier Base: The "Buy" Side of the Equation

ViaLight organizes and controls all aspects of the components used in its products (**Fehler! Verweisquelle konnte nicht gefunden werden.**). They are 100% checked and documented as per ISO 9001 standards. Furthermore, each sub-assembly is subjected to the same ISO 9001 standards for traceability, verification and documentation.

Small quantities of sub-assemblies are partly tested and certified at ViaLight's facilities and, where necessary, are dispersed to facilities available through ViaLight's supply chain in order to meet schedule and conformity requirements. As production quantities increase (e.g. >100 units), additional investments for in-house testing facilities are made.

Assembly and Test: The "Make" Side of the Equation

The following activities take place within ViaLight's manufacturing facilities:

- Assemble and calibrate optical bench
- Final assembly of the laser terminals
- Calibration (Selecting/developing the equipment for calibration and testing)
- Level of automation in assembly and testing (cycle times for assembly and testing)
- Test (spot check of sub-assemblies, system build-up testing, integrated system testing)
- Documentation – test reports, manuals, shipping & handling processes
- Export & logistics

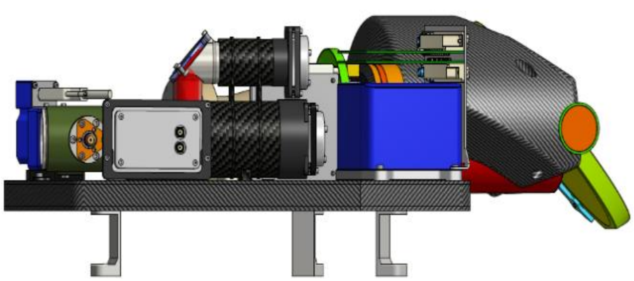

Exhibit 4: Laser communication terminal after final assembly and testing in ViaLight's facilities.

Manufacturing and Test Processes

Central to the manufacture and testing of any product are the processes that are followed in order to realize the end product. For these reasons, ViaLight puts into practice the following ISO 9001 standardized process control methodology:

- Control specification/parameters for sub-assemblies at the suppliers (Design-FMEA)
- Measurement system analysis (MSA) for the final test equipment (internal), to ensure stability and conformance of measurement processes
- Continuous improvement based upon lean manufacturing principles

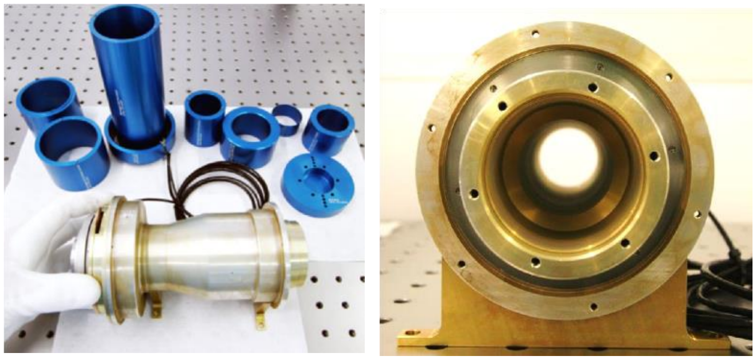

Exhibit 5: Test equipment at ViaLight's manufacturing facilities.

Manufacturing Process Adaptation for New or Customer-specific Products

One of the significant advantages that a supply chain and assembly line methodology brings to a company's operations is that as new products are introduced, the way in which they are produced is essentially already in place, save for minor adjustments to account for unique product- or customer-specific changes. The following process describes the way in which new/custom products are incorporated into the assembly line process:

- decision regarding priority ranking of product specification → streamlines process of incorporating new products into assembly
- organization of service & maintenance plan for products exiting assembly line – for space systems, this means support and maintenance during all phases of integration into the satellite leading up to launch as well as during on-orbit commissioning

CONCLUSION

With the growing number of large scale network constellations that are entering the commercial market, there is a growing demand to provide high-capacity communication options for a price that the market can bear. Laser communication systems have always been the obvious option for meeting large bandwidth requirements but have been cost prohibitive. Only by embracing new methods of manufacturing, can wireless laser communication technologies truly enter the mainstream commercial market for a price that is attractive to industry stakeholders. ViaLight's strategy to apply these serial-production concepts to its laser communication terminals has resulted in the production of two terminals, the MLT-20 and the MLT-70, which serve as an excellent foundation for a space qualified terminal.

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