SPACE PROPULSION CONFERENCE 2020+1

SERIAL PRODUCTION OF SPACE COMPONENTS FOR MEGACONSTELLATIONS

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ABSTRACT:

Space engineering is currently experiencing dynamic development. The market is facing increased demand for small satellites with a high number of identical spacecrafts and its components optimized for low-cost and serial production.
AST Advanced Space Technologies GmbH as a German SME translates the “New-Space” idea to its own production line capable to produce 600 flight units per year. Concepts of manufacturing and process development are presented, questioning common methods in space engineering. With a design for manufacturing and building block technology, a high grade of scalability and flexibility can be achieved. With this approach, AST produces the fluidic management system for OneWeb, currently one of the world's largest megaconstellation for broadband internet services open for suppliers.

INTRODUCTION:

New companies are currently entering the market, bringing new technologies and a breath of fresh air to the industry. New ways are gone in extraordinary short timescales.

Under the phrase, “New-Space” concepts of the industrial and digital world for ground applications are used and translated to space applications. These new capabilities result in radical price reductions on each product aspect like administration, development, production and test.

The “Traditional Space” market can profit from the extensive flight heritage of “New-Space” missions due to high spacecraft numbers. In this line, this market could also be influenced by a customer-adapted mix of concepts of the traditional and “new” way.

AST has grown from a start-up to a midsize company and works on innovative technologies to redesign propellant supplies for electrical propulsion and is world-leading in the production of xenon flow control units.

On the product side, AST serves this market with a fluidic assembly technology that is analogous to the printed circuit board with surface-mounted components in electronics. It has developed a flow management system based on building blocks optimized for high volume production at low costs. This building block approach creates synergies and allows rapid adaptation to customer’s requirements. The product line applies a design for manufacturing that takes advantage of simplification and scalability through internal standardization. To reduce costs of the entire production chain, AST has simplified and reduced processes and has introduced a high level of automation especially of the internally performed acceptance tests. Furthermore, AST uses commercially available components and adapt them to space requirements. In this manner, AST co-engineered technologies together with subcontractors in a robust component supply chain.

CONTENT AND DISCUSSION:

1. PRICE TARGET

An increasing number of players on the customer and producer side in the space marked causes a shift in the price target determination from an intrinsic to an extrinsic pricing process. In a marked driven by agencies and governments an intrinsic process in which the price tag is calculated by cost calculations of the product expenses. It is now an extrinsic process in which the market sets a price and formulates a Go / No-Go criterion during the design and process development phase.

In this line, the production process development is subject to the question of cost optimization in each subprocess to meet the price target.

At AST, a significant effort is applied for a “design for manufacturing”. Units of the AST product line are consistently made of standardized building blocks and processes, allowing modularity of the product and high rate production at high quality.

It is left to a constant trade-off which grade of automation is suitable for the high unit numbers produced for space (like megaconstellations) but tiny amounts compared to ground industrial processes in which automation is indispensable as mentioned in detail in chapter 4.

2. Using Modified Commercials of the Shelf Components (COTS)

Space grade key components can be purchased in three ways. (1) Purchase expensively and as long-lead items from few highly specialized producers due to low volumes and high-quality assurances. (2) Developed from scratch with own capabilities and broadly available service providers. (3) From ground application commercials of the shelf with adaptations to reach space grade.

For the most key components, AST uses the third approach. It means the usage of excellent proven and qualified products for higher industrial applications like medical or automotive and their adaptation to space applications in co-engineering between AST and the experts of the supplier company. In the majority of cases, this leads to a two-way evolution of the product for both ground and space applications.

Industrial compounds are produced in high quantities and collect a huge number of operating hours in widely spread ground applications.

Since high quantities are the bases of these industrial components, a high number of samples are available for delta qualifications for the transition to space-grade. This results in better statistics of the tests compared to few prototypes available in case (1).

In this way, quality can be assured by the fundamental advantage of high sample quantities for tests, qualification and the final application. Furthermore, a large amount of field test data provides insight of potential weaknesses and failure channels.

3. DEVELOPMENT AND PRODUCTION CYCLES

Development of a product or process in the “New-Space” era is not necessary cheaper compared to a classical approach. The huge difference is the time period the development takes. Often and also at AST achieved by concurrent engineering, namely a high grade of parallelization of development subprocesses. This includes the consideration of a

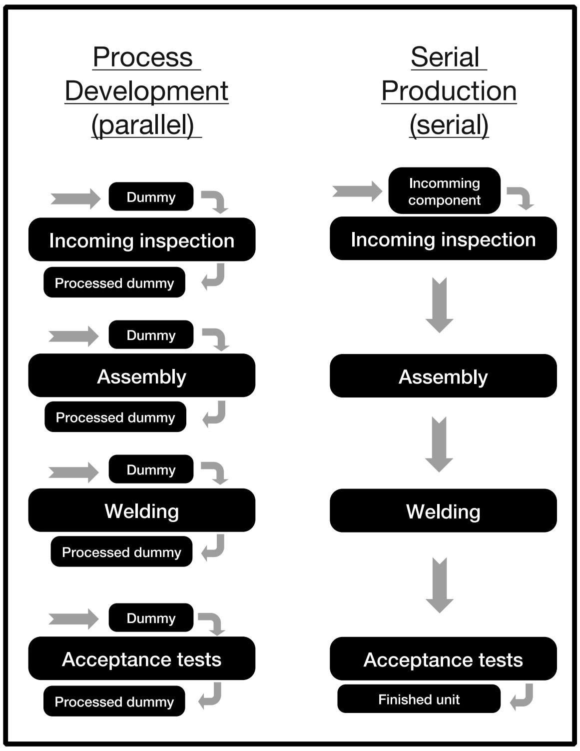

Figure 1 Difference between a parallel process (concurrent engineering) during development compared to the pure serial approach (sequential engineering) during production.

risk due to an uncertainty of the predecessor and successor process at this stage of development.

The main process is divided into subprocesses that are developed in parallel to introducing fast (and cheap) failures and an overall speedup (Figure 1 (left)). The number of sub-processes is kept as small as possible and each sub-process is checked for simplification.
To take track of the readiness of each subprocess and the identification of bottlenecks each subprocess is rated by a Readiness Level in analogy to the common product TRL in space engineering (Figure 2).

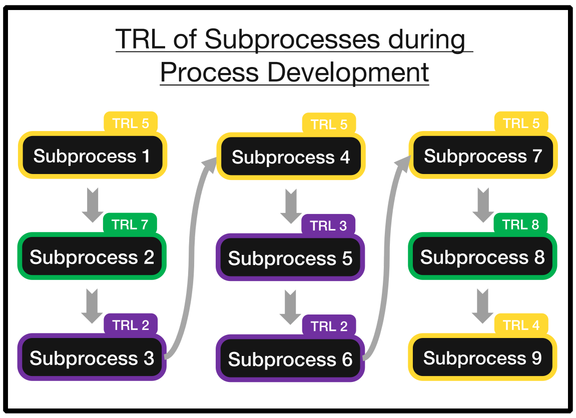

Figure 2 During process development, each process is divided into subprocesses rated by Readiness Levels (TRL) to identify bottlenecks and simplify focus.

Whereas the process development is intended to be performed to a maximal extend in parallel, the serial production on the other hand is done in pure series (Figure 1 (right)). During production, each process has a well-defined predecessor or successor. This allows a huge simplification and intrinsic self-fulfilling process with reduced supervision and management coupled with an empowering of the producing operator as further explained in the next chapter 4.

4. AST's PRODUCTION LINE

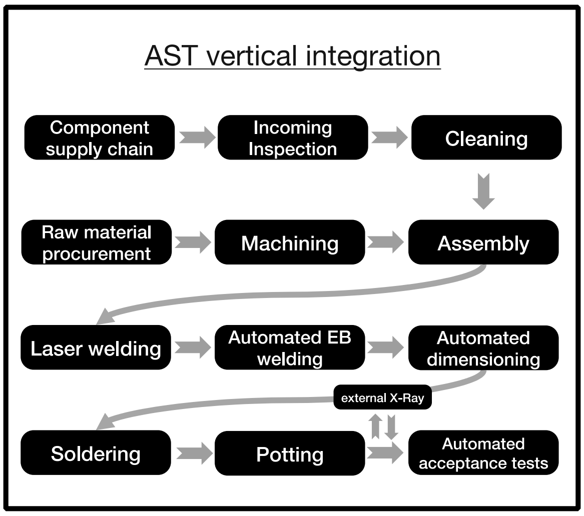

Figure 3 ASTs vertically integrated production line including all key manufacturing processes in-house combined with broadly available service providers.

Vertical integration:

Having most of the key processes in-house (vertical integrated) implies increased development flexibility, scalability and quality control at reduced costs. The company AST has grown from a start-up to a medium-size company. At small company size, the existence of a widespread supply and subcontractor network is necessary. AST has undergone a shift from purchasing customized components in low volume towards in-house manufacturing of the main processes combined with few standard processes from external service providers as shown in Figure 3.
As an example, the units are sequentially cleaned, laser tack welded and EB welded few meters next to each other with only small temporary buffer storage in-between to optimize production flow as shown in Figure 4. The units do not leave the cleanroom and no extra processes like packing or logistics are applied.

Manual and automated serial production

Currently, serial production for one megaconstellations includes the production of units for around 100 - 1000 satellites per year. Manufacturing of this amount in a production line enters a tipping point from optimized manual production to part automation.

Figure 4 EB welding (left), laser welding (right) and cleaning (back), are located right next to each other in the cleanroom to reduce transition ways.

Optimization of manual serial production:

Easily underestimated is the optimization of the manual serial process. This includes creative use of auxiliary tools, short ways, availability of tools, task coordination, reduced lead time, or the introduction of lead time filling tasks.
It is attempted that the success of each task is available locally at the workspace as well as in time to allow the operator, first, to evolve on its task and, second, to have an early removal of poor parts.
By increasing production load, it may be useful to increase the lot size of each operator or its team. This introduces a certain in-process buffer of the production line which can also buffer production fluctuations of subprocesses. Lot size per operator as well as the distribution of task variance per operator should also be adjusted to the individual preferences of the operator to ensure motivation and work satisfaction.

Production automation:

At this unit quantity, not all subprocesses are immediately suitable for automation due to e.g. automation complexity or rarity in the process. Simple, monotonic or straightforward tasks on the other hand are well qualified for full or partial automation.
An implementation can be introduced among others for two reasons (1) quality assurance and (2) labor cost reduction.
An example of the current production line at AST for the first case (1) is the automated EB and Laser welding process. A process that would require a high operator skillset and would still be error-prone compared to automation.
An example of the second case (2) is the automation of acceptance tests including data logging. A time consuming and straight forward task which is replaced by the inserting and removing of the unit by the operator who saves capacity to take over other tasks in the meantime of the test duration.
Both the manual and automated processes in the production lines benefit significantly from the support of in-house manufacturing of electronics, mechanical equipment and additive manufacturing.

Closely linked to automation is the digitalization of production monitoring. The company seeks a steady increase in interconnection, digitalization of procedures and process monitorization to simplify comprehensibility of production and identify anomalies and correlations.

AST Product Portfolio:

The AST product line is designed for the manufacturing of scalable high quantities. It is based on a modular system in which highly reliable components are surface mounted by EB welding in one operation. This concept is inspired by electronics with the printed circuit board (PCB) replaces by a flow path board (FPB) containing fluidic connections and fluidic functional groups.

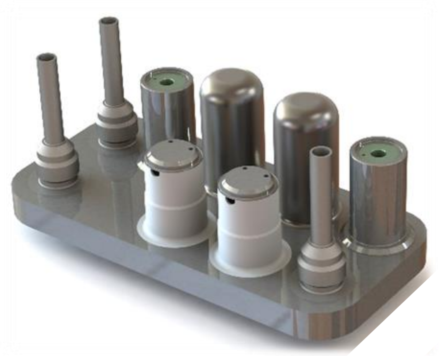

Figure 5 High-pressure flow control unit ("RADICAL") of the AST product line, a TRL9 high-pressure flow control unit that can be directly connected to the tank and thruster in an electrical propulsion subsystem.

The AST high-pressure flow control unit, called RADICAL (Figure 5), combines electric pressure regulation and flow control unit in a single device.

The unit relies on building blocks that can be adapted to the customer's needs. With this approach, costs, time and effort can be reduced due to synergies and heritage. Development effort can be measured by the deviation from the design baseline. Therefore, non-recurring costs can be kept low.

CONCLUSION

Based on the presented methods it is postulated that a manufacturing line for high quantities is a very stable process. This stability can exceed the product quality compared to prototype manufacturing even with extensive efforts for quality assurance ("Traditional Space"). As a result, the product might not only be more cost-effective but also might be of higher quality.

110 units of AST's baseline product are in orbit without failures and an accumulation of 670 000 in-orbit hours (Jan 2021).

New players and concepts in the market force a mindset change in the manufacturing of space components. Due to the mentioned advantages, these components start to enter also space markets with small quantities and high reliabilities like exploration. It is expected that industrial concepts including digitalization and automation of terrestrial manufacturing are just beginning to enter the space sector.

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